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ScienceDirect

Transportation Research Procedia 29 (2018) 146–156

Transportation Research Procedia

www.elsevier.com/locate/procedia

6th CEAS AIR & SPACE CONFERENCE AEROSPACE EUROPE 2017, CEAS 2017, 16-20 October 2017, Bucharest, Romania

A modelling framework to support power architecture trade-off studies for More-Electric Aircraft

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Abstract

This work presents a modelling framework to enable comparison and trade-off study of different aircraft system architectures. The framework integrates a computational module to select feasible architectures with a modelling platform that simulates the power generation, distribution and fuel consumption of the aircraft as well as system-level models for the system being evaluated. Its capabilities are demonstrated for the case of the electrification of the primary flight control system (PFCS) using different electric technologies (EHA, EMA) and different levels of electrification ranging from the conventional hydraulic to the all-electric. The performances of different architectures are analysed with respect to the change in the mechanical power extracted from the engine, the weight and the fuel burn of the aircraft. The framework demonstrates the capability of evaluating multiple, different, system architectures in a way that is scalable for different systems or different aircraft. It supports a designer evaluating the aircraft-level impact of their design choice at system-level, and it can aid in assessing technology options early in the design process.

Keywords: *More-Electric Aircraft; Architecture Evaluation; Trade-off Analysis; Modelling and Simulation*

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10.1016/j.trpro.2018.02.013

1. Introduction

The number of passengers transported by commercial aircraft is expected to double by 2035 [IATA (2016)] and as the aviation industry rises to meet those market needs, some considerations need to be taken. The increase in passenger numbers means an increase in the environmental impacts of aircraft, and an increase in the number of aircraft being designed and built in a short period of time. To outline clear goals that take these and other factors into account, the Advisory Council for Aeronautics Research in Europe (ACARE) set clear goals for the aviation industry to reach by the year 2050 [ACARE (2017)]: A reduction in perceived noise to one half of current average levels, a 50% cut in carbon dioxide (CO2) emissions per passenger kilometre and an 80% cut in nitrogen oxide (NOx) emissions. In addition to the environmental goals, ACARE proposes to establish ways in which different companies are able to work together more effectively. This enhanced collaboration in conjunction with advanced tools, methods and processes would allow the time to market of new products to be reduced.

In this context, the European Commission launched the Clean Sky 2 Joint Technology Initiative [European Commission (2014)], a public-private partnership which provides funding for research and development of the processes, tools and technologies that will enable the aviation industry to reach the goals set out by ACARE. The studies presented in this paper are conducted within the ModellIng and Simulation tools for Systems IntegratiON on Aircraft (MISSION) project [Valdivia – Guerrero *et al.* (2016)] which is funded by Clean Sky 2. The MISSION project aims to develop an integrated framework capable of supporting aircraft design, development, and validation processes. The development of such a framework presents many challenges [Cimmino *et al.* (2017), Burgio *et al.* (2017)]. Specifically, this paper focuses on the trade-off comparison of different aircraft power architectures. To enable this comparison, several modules are integrated: a modelling platform to simulate power generation, transformation and distribution at aircraft-level; a computational module to filter sets of feasible architectures; and system-level models. The framework is demonstrated for the case study of the electrification of the aircraft's flight control system using different technologies and different levels of electrification ranging from the conventional hydraulic to the completely electric.

The challenge is that the conceptual phase of the design process of aircraft involves the largest amount of design freedom, and while this allows the designer the opportunity to explore numerous solutions, the effective exploration of the vastness of the potential overall trade space is difficult. The overall trade space comprises of a set of feasible architectures that can provide the necessary functions and the design space for the individual systems and components of each architecture. Effective exploration and evaluation of the overall trade space is becoming increasingly important in the aerospace domain due to the emergence of several technologies that can be used as drivers of systems within the aircraft. This allows for the possibility of unearthing innovative architecture and design solutions that may not conform to conventional architectures and designs of the past generations of aircraft via a systematic exploration of this design space. Because of the combinatorial explosion of the number of candidate architectures, an automated architecture exploration and filtering process is essential to narrow down the design space to a list of feasible candidate solutions.

This work follows on the steps taken within previous European Union (EU) research frameworks. Several other projects have undertaken efforts to improve aircraft design, development, validation and verification processes. For example, within the sixth framework program (FP6), Vivace (2011) developed a collaborative enterprise to support the aeronautic product engineering life cycle, Moet (2011) developed a framework for the integrated design of validated electrical technologies for More-Electric Aircraft (MEA); in the seventh framework programme (FP7), Toica (2017) created an integrated platform for the aircraft thermal system, Across (2017) created an integrated framework for cockpit design and Crescendo (2012) laid the foundations for the Behavioural Digital Aircraft up to MISSION in the current Horizon 2020 Clean Sky 2 Initiative.

In the same vein as the Moet project mentioned above, one of the key design evolutions the MISSION project will support is the progressive electrification of aircraft towards MEA and All-Electric Aircraft (AEA). There are numerous efforts reported in current literature [Cao *et al.* (2012) to Sarlioglu *et al.* (2015)] that give an overview of the key technology enablers for MEA. One such enabler is the electrification of the actuation system of the aircraft and subsequent removal of the hydraulic power system, which motivates the choice of this case study to demonstrate the MISSION framework. Previous work in this topic is extensive and a selection of the most relevant efforts in the context of this paper is presented below. In Jackson (2013), the author compares a conventional hydraulic actuation and a hybrid architecture featuring both Electro-Hydrostatic Actuators (EHAs) and hydraulic actuators this approach didn't address Electro-Mechanical Actuators (EMA). To be able to study a complete electric architecture, a deeper