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Model-Based Systems Engineering for an Aircraft Design Process driven by Digital Twinning

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Declaration

I hereby declare that, the contents and organization of this Dissertation constitute my own original work and does not compromise in any way the rights of third parties, including those relating to the security of personal data. This dissertation has been carried out in collaboration with Leonardo SpA, funder of the relative Ph.D. scholarship. All data and results reported in the manuscript are updated to the submission date. The data used in the present dissertation has been obtained from the available literature.

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Model-Based Systems Engineering for an Aircraft Design Process driven by Digital Twinning

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The current industrial landscape, probably more now than ever, is experiencing a drastic and continuous change. Such change can be seen in various areas and aspects, from change in modus operandi, in tools employed, in resources spent, in technologies discovered and exploited and many others. Among these, the most noticeable is the transition to purely digital technologies, especially in the field of design of complex products, including automotive, naval, manufacturing, energy and, most relevantly for the present dissertation, aerospace.

Even though the digital exploitation during design has reached quite a high degree in the aerospace industry, there is still a lot to be done in order to achieve a truly cohesive digital design environment and process. This is especially true when considering some disciplines, like requirements engineering, preliminary design, V&V or data management, in many industrial realities, are still carried out with documents or legacy tools that do not allow for the interconnection, traceability and management of the ever-growing number of digital models and artefacts. To this end, two concepts are currently being explored by the industry: the methodologies of Model-Based Systems Engineering and the Digital Twin. The former allows formalising the design process, guaranteeing complete traceability and compatibility of every aspect of a product, while the latter represents the culmination of the digital design models, consisting of an entirely interconnected network of models for the high-fidelity reproduction of the product-to-be.

In this context, the present work intends to explore both technologies, starting with the evaluation and understanding of their respective characteristics. Then, an MBSE methodology will be proposed, aimed at defining a modelling process that allows for the complete identification and characterisation of requirements, systems and, most relevantly, design models, both for the development and the verification stages. The methodology aims at enabling a robust management of the digital models that are used during the development stages of a product and acts as the foundation of a high-fidelity and multidisciplinary digital representation of the product-to-be, i.e. its digital twin. Thus, it is structured as a mean to achieve a single source of truth and process for all digital artefacts related to the product. An aspect particularly

relevant in an industrial context, where the number of digital artefacts exponentially increases as the product life cycle progresses.

Such methodology will later be used as the foundation for the creation of a platform for the management of the digital design process, acting as a bridge between the formal aspects defined with MBSE models, like requirements and architectures, and the analysis and simulations carried out through digital design models. Such a platform aims at being the starting point for the creation of a complete design digital twin, intended as a highly advanced interconnection of models that can act as the fully functioning prototype of the product. Finally, a test case will be presented, on which the entire methodology and the platform has been applied: starting from the definition of requirements, the identification and characterisation of systems/subsystems/components, the formalisation of necessary design models and the creation and execution of said models, with the parallel digital verification of product requirements.

The final goal of this work is to provide a completely digital design environment, capable of encompassing every stage in the design process and capable of managing and tracing all the data, information and knowledge that is generated and/or used during such a complex life cycle stage of a product, and applicable to any industrial field where design and development are of primary importance.