ROTORCRAFT FLIGHT SIMULATION TO SUPPORT AIRCRAFT CERTIFICATION: A REVIEW OF THE STATE OF THE ART WITH AN EYE TO FUTURE APPLICATIONS[1]

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SPECIAL SESSION ON ROTORCRAFT CERTIFICATION BY SIMULATION

Extended abstract

To certify an aircraft means to issue, by the competent regulatory authority (e.g., EASA in Europe), a document that states that the aircraft conforms to its approved design and complies with the relevant certification standards. This, in turn, means that the aircraft has been verified to meet the necessary requirement to fly safely within the allowable limits. It is the applicant's responsibility to develop processes to show 'means of compliance' that typically rely on a combination of physical testing and computations through virtual models [1,2]. As an example in the field of rotorcraft, the standards state that proof of compliance with EASA CS-27/29 Subpart B [3, 4] (or the equivalent Federal Aviation Administration standards) must be obtained by "tests upon a rotorcraft of the type for which certification is requested, or by calculations based on, and equal in accuracy to, the results of testing". For the Federal Aviation Administration (FAA) Advisory Circular AC-29.21(a) [5], the term "calculation" includes flight simulation.

Historically, the certification evidence provided by the applicant has relied heavily on physical tests, because the level of confidence on their reliability has been always considered high. This prevalence of physical tests is certainly rooted in the fact that acceptable means of compliance, i.e. methodologies to show compliance to a certification requirement Ref. [1], were developed in periods where simulation approaches lacked the necessary fidelity and robustness. However, paraphrasing a famous quote attributed to Albert Einstein, it is also true that "A *simulation model* is something nobody believes, except the person who made it; an experiment is something everybody believes, except the person who made it", expressing the general lack of credibility that is often associated with simulation.

However, there are several reasons that may push in the direction of certification by simulation in place of performing physical tests for some requirements. Defining a test set-up and performing the tests may be expensive and extremely time consuming. Physical testing, and in particular flight testing, has several limitations. Some flight test conditions for rotorcraft, or those related to engine or control systems failure, may carry significant risks. Additionally, the lack of repeatability and the limited capability to control the environmental conditions and the scenarios make flight testing somehow a suboptimal approach for certification.

FAA's AC 25-7D §3.1.2.6 defines the general principles under which flight simulation may be proposed as an acceptable alternative to flight testing for large aeroplanes [6]. With the increase in fidelity of physics-based rotorcraft flight simulation models, it is foreseeable that the usage of flight simulation to replace flight testing through a virtual-engineering process will become more dominant, as the industry pursues efficiency, low cost,

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increased safety, and low energy consumption [7]. The team of the European CleanSky2 funded project, Rotorcraft Certification by Simulation (RoCS), has the aim to explore the possibilities, limitations, and develop guidelines for best practices for the application of flight simulation to demonstrate compliance with the airworthiness regulations related to helicopters and tiltrotors [8,9].

Within the framework of the RoCS project, preliminary Guidance for the application of (rotorcraft) flight modelling and simulation has been developed in support of certification for compliance with standards CS-27/29, PART B (Flight) and other flight-related aspects (e.g. CS-29, Appendix B, Airworthiness Criteria for Helicopter Instrument Flight) [10]. The Guidance follows a requirements-based approach and is presented in the form of a structured process for Rotorcraft Certification by Simulation (RCbS). The process starts with the selection of 'applicable certification requirements' (ACRs) for the exercising of RCbS, with judgements on a matrix of factors of Influence (how the RCbS process will be applied), Predictability (extent of interpolation/extrapolation), and Credibility (confidence in results), in line with a comprehensive description of the assembly of flight simulation requirements.

In particular, the topic of Credibility of the modelling and simulation approach used, goes beyond the classical Verification and Validation (V&V) processes when a model is developed for certification purposes. Credibility represents what is necessary to reach the level of confidence in the evidence presented during simulation tests compared to that gained during a flight test. To build credibility it is, in fact, necessary to take into consideration a detailed assessment of errors and uncertainties, both in the areas of validation of the model and in the ranges where extrapolation is applied, as well as a certain degree of conservatism when the level of uncertainty is not so small. In fact, as well stated by Roy and Oberkampf, "without forthrightly estimating and clearly presenting the total uncertainty in a prediction, decision makers are ill advised, possibly resulting in inadequate safety, reliability and performance of the system" [11].

The need to develop methodologies to perform certification by simulation has been considered by a broad range of technical communities. AIAA developed a recommended practice to use flight modelling to reduce flight testing supporting aircraft certification [12]. EASA issued a Certification Memorandum dedicated to the use of Modelling and Simulation for CS-25 Structural certification [13]. NASA developed its own guide on simulation credibility that provides "an approved set of requirements, recommendations, and criteria with which models and simulations (M&S) may be developed, accepted, and used in support of NASA activities" [14]. ASME developed several standards for the V&V of numerical models [15]. Similar ideas are pursued for the certification of autonomous automotive vehicles [16]. The specification for the approval of driving system for fully automated vehicles adopted by the European Parliament contains, in part 4, the principles for credibility assessment of models for certification [17].

The paper will review and compare different approaches to better explain what it means to develop the credibility of M&S when used for certification purposes. The approach taken by the RoCS team for the uncertainty-quantification aspects of credibility assessment will be presented.

Then, the paper will address why, in the opinion of the authors, certification by simulation should be considered the preferred option for the certification of the future class of eVTOL aircraft in Europe, under the Special Condition VTOL standard (SC-VTOL) developed by EASA [18]. In fact, for these vehicles, the SC-VTOL proposes the use of approaches inspired by ADS-33E-PRF [19], as means of compliance to assess if the aircraft handling qualities are adequate for the mission task needs. While this is a very innovative approach, it may prove difficult to implement through physical flight tests, without requiring a significant effort, in terms of resources and time, with many challenges faced to ensure the necessary repeatability, e.g. in terms of control of the level of disturbances applied. Many of these aircraft are single pilot, or even un-crewed, making it difficult to perform training or have flight test engineers on-board that can support the safe execution of flight testing [20]. Additionally, these tests will probably require a very careful set-up and management, to avoid exciting hazardous phenomena that may damage the aircraft, while simulation allows verification of the limits of the aircraft capabilities, even beyond the safe boundaries, without the need to bear unnecessary risks.

The paper takes the form of a scene-setter for the series of RoCS papers submitted for presentation at the 49th European Rotorcraft Forum.

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