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RESEARCH AND TECHNOLOGY ORGANIZATION

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RTO AGARDograph 300

Flight Test Techniques Series – Volume 19

Simulation in Support of Flight Testing

(la Simulation pour le soutien des essais en vol)

This AGARDograph has been sponsored by the SCI-055 Task Group, the Flight Test Technology Team of the Systems Concepts and Integration Panel (SCI) of RTO.

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Edited by
Dennis O. Hines

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Simulation in Support of Flight Testing

(RTO AG-300 Volume 19)

Executive Summary

Flight testing continues to remain an essential step in the development or modification of an aircraft. Modern fixed wing aircraft are highly complex systems that push the edges of aerodynamic, propulsion, and control system technologies. Many of these technologies are integrated together and dependent upon each other. Certainly, modern military aircraft ranging from the F-22 to the EF2000 push the boundaries of capabilities that can be built into an aircraft. Commercial transportation such as Airbus's A310 and Boeing's 777 incorporate many aircraft advances that were first used in military airplanes. The ever-increasing complexity of the aircraft presents new challenges to those who are involved in the flight testing of those vehicles. For over 40 years simulation has played a key role in flight testing. As the aircraft continue to evolve in complexity, the role of simulation continues to grow. Every major aircraft developer, whether they are commercial or military, depends on the use of simulation to some degree. The application of these simulations to flight testing is an important aspect of the aircraft's development. Each year, dozens of symposium and conferences are held around the world to discuss simulation and its uses. As computer technology continues to evolve at an accelerating pace, the field of simulation continues to expand with it. Unfortunately, very little has been written to document how simulation can be effectively used to support flight testing.

The purpose of this AGARDograph is to provide an introduction to simulation and how it can be used to support flight testing of fixed-wing aircraft. Simulation of rotary wing aircraft is a similar but different subject and should be covered in a separate report. This AGARDograph has been written from the perspective of trying to provide a flight test engineer the basic information in how to effectively use simulation to support flight testing and what must be considered when developing a simulation that is to be used for flight test support. The first chapter introduces the reader to simulation and its role in supporting flight testing. Chapter two provides a history and overview of simulation and the benefits of using it to support testing. Chapter three provides an in-depth discussion of the various types of simulation and the unique test role played by each of those simulations. Chapter four focuses on what needs to be considered when developing a simulation including the types of models, the visual scene presented to the pilot, and how to verify and validate the simulation. Chapter five presents a discussion on how to apply simulation to a flight test program. Chapter six presents some ideas as to where simulation in support of flight testing is headed in the future. The book ends by drawing some conclusions. First, the type of simulation is based on the intended use of the simulation. Second, the simulation models must be built from adequate data and they must be verified and validated for use in the simulation. Third, a simulation visual system is required and must be tailored to fit the designed use of the simulation. Fourth, simulation will continue to be a tool used to increase the effectiveness and efficiency of flight testing and should not be used as a total substitute for flight dynamics flight testing.

la Simulation pour le soutien des essais en vol

(RTO AG-300 Volume 19)

Synthèse

Les essais en vol continuent de représenter une étape indispensable dans le développement ou la modification d'un aéronef. Les aéronefs à voilure fixe modernes sont des systèmes très complexes à la pointe des technologies de l'aérodynamique, de la propulsion et des systèmes de pilotage. Beaucoup de ces technologies sont intégrées et interdépendantes. Il est certain que les spécifications des avions de combat modernes, allant du F22 à l'EF 2000, se situent aux limites des capacités pouvant être intégrées dans un aéronef. Les avions commerciaux tels que l'Airbus A310 et le Boeing 777 incorporent bon nombre d'avancées technologiques utilisées d'abord dans des avions militaires. La complexité sans cesse croissante des aéronefs présente de nouveaux défis à relever pour ceux qui sont impliqués dans les essais en vol de ces véhicules. Depuis plus de 40 ans, la simulation joue un rôle clé dans les essais en vol. Avec l'évolution de la complexité des aéronefs modernes, le rôle de la simulation ne cesse de s'amplifier. Chaque avionneur, qu'il soit commercial ou militaire, fait appel, dans une certaine mesure, à la simulation. L'application de ces simulations aux essais en vol est un aspect important du développement d'un aéronef. Chaque année, des dizaines de conférences sont organisées dans le monde entier pour discuter de la simulation et de ses applications. L'évolution des techniques de simulation suit l'évolution fulgurante de l'informatique. Malheureusement, il n'existe que très peu d'indications sur l'application de la simulation aux essais en vol.

Cette AGARDographe a pour objet de fournir une introduction à la simulation et à sa mise en oeuvre pour le soutien des essais en vol des aéronefs à voilure fixe. La simulation du vol des aéronefs à voilure tournante est un sujet distinct, qui mériterait d'être traité dans un autre rapport. Cette AGARDographe est destiné aux ingénieurs d'essais en vol. Elle fournit un certain nombre d'informations essentielles concernant la mise en oeuvre efficace de la simulation pour le soutien des essais en vol, ainsi que les différents éléments à prendre en compte lors du développement d'une simulation pour le soutien des essais en vol. Le premier chapitre présente la simulation et son rôle dans le soutien des essais en vol. Le chapitre deux fournit un historique et un aperçu de la simulation et des avantages liés à sa mise en oeuvre pour le soutien des essais en vol. Le chapitre trois présente une discussion détaillée des différents types de simulation et du rôle unique que joue chacune de ces simulations dans les essais en vol. Le chapitre quatre porte sur les éléments à prendre en considération lors du développement d'une simulation, y compris les différents types de modèles, la scène visuelle présentée au pilote, et la vérification et validation de la simulation. Le chapitre cinq traite de l'application de la simulation aux programmes d'essais en vol. Le chapitre six présente un certain nombre d'idées concernant l'avenir de la simulation en tant qu'outil pour les essais en vol. L'ouvrage se termine par un certain nombre de conclusions. En premier lieu, le type de simulation à employer dépend de son utilisation finale. En deuxième lieu, le modèle de simulation doit être conçu à partir de données adéquates, vérifiées et validées pour utilisation. En troisième lieu, il y a lieu de prévoir un système visuel de simulation conçu en fonction de l'application de la simulation. Et enfin, la simulation restera un outil permettant d'améliorer la qualité et l'efficacité des essais en vol. Elle ne doit pas être utilisée pour remplacer en totalité les essais en vol de la dynamique du vol.

Contents

Preface

For over 40 years simulation has been an important tool supporting flight testing. The use of simulation has improved flight test planning, execution and safety. The incredible growth in computational capabilities has created new possibilities on how modeling and simulation can be used to support flight dynamics flight testing. However, even with improved computers, high-fidelity simulations still depend on the ability of the engineering team to create models that accurately represent the aircraft or the environment that they are testing. Flight dynamics flight testing inherently involves non-linear aerodynamics that can be very difficult to accurately model. Because of these factors, the use of simulation will never replace flight testing as a method to clear the aircraft's flight envelope. Instead, simulation is a tool that greatly improves the efficiency and effectiveness of a flight test program, but it must be used in conjunction with the actual testing.

The various types of simulation can support all aspects of a test program. It is critical that the correct type of simulation be matched to the appropriate test requirement. To make simulation an effective tool there are many factors that must be considered when building a flight test simulation. The level of fidelity of the models, simulator cockpit, and simulator out-the-window visual scene must be well understood by the whole test. Inherent in this is a rigorous verification and validation process that must be followed by the engineering team. All team members must understand the limitations of the flight test simulation when using it. The simulation tool must be properly applied to obtain maximum effectiveness.

This AGARD report provides an in-depth look at how simulation is used to support flight dynamics flight testing. The aim was to provide guidance to flight test engineers who are interested in using simulation as a tool on their test program. The information contained herein provides the test engineer with the information to justify, build, validate and use a flight simulator as an integral part of a flight test program.

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14. Abstract

For over 40 years simulation has played a key role in flight testing. The purpose of this AGARDograph is to provide an introduction to simulation and how it can be used to support flight testing of fixed-wing aircraft.

The document starts by considering the role of simulation, including a brief history and the costs and benefits associated with it. It then discusses the following types of simulations:

- analytic (non real-time)
- engineering or man-in-the-loop (real-time)
- hardware-in-the-loop
- Iron Bird
- in-flight

Simulation development considerations described include:

- requirements definition
- modelling of flight control systems, aerodynamics and the environment
- cockpit fidelity, displays and force-feel systems
- visual scenes
- data display and analysis, including simulation and flight test integration
- verification and validation

The final sections consider how to conduct a simulation-based test programme and the future direction of simulation.

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