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SUMMARY

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2. INTRODUCTION

In the development and in-service improvement of modern aircraft whose controls and flight control surfaces are managed by a flight controller, an accurate model of the aircraft's aerodynamic characteristics is required. That model is needed to provide the controller with the necessary information on the aerodynamic characteristics of the aircraft, to be able to compute the correct control commands for a given target. To describe the aerodynamic characteristics for use in a flight control system (FCS), the from aerodynamics resulting flight mechanical forces and torques are of interest, to describe the behavior of the aircraft as a single object in the airflow. These forces and torques can be calculated for any arbitrary

Those six variables are suitable to describe the aircraft's aerodynamic characteristics at any given flight condition and control setting, including its maneuverability and stability. Thus the aerodynamic characteristics, in this case, do not describe the kind of flow that develops around the aircraft, but the resulting forces and torques pushing the aircraft in certain directions and rotating around the rotational axes. An example of aerodynamic characteristics reflected in such a model are lift and drag, but also more complex behaviors like pitch instabilities can be described. These instabilities can be observed in a resulting moment acting towards even greater rotation, thus leading the aircraft to depart and potentially disintegrate, making the accurate characterization of such behaviors essential. In the case of unstable aircraft, these torques have to be equalized by the FCS to create a stable closed-loop system by introducing a flight controller. To allow for such flight controllers to be designed, the resulting aerodynamic characteristics model (ACM) is essentially comprised of functions that describe the aircraft's behavior for all relevant conditions in flight. With that model, the FCS team can then design and simulate the flight controller's behavior based on the model's aerodynamic representation, improving the handling qualities and stabilizing the aircraft in the closed loop. To do so, the model requires certain variables defining the aircraft's current configuration, flight condition and more as inputs. Examples of these variables could be the airspeed, the angle of attack, or the flight control surface settings. For the flight controller to be designed for the correct response to all possible inputs, the model has therefore to cover the entire range of possible combinations and flight envelope. Thus the model has to be able to return the flight characteristics for flight conditions that lie in between the min and max speeds, in between the expected angles of attack and the range of loads carried by the aircraft. What is needed is therefore a precise model, taking into account all relevant variables and variable combinations describing the aircraft's configuration and flight condition, that returns the three forces and three torques:

The creation and updating of the ACM for the Eurofighter Typhoon is the main task of the TEYGA-TL2 Dataset team in the aerodynamics department at Airbus Defense and Space Manching. While the described kind of ACM is necessary for all kinds of controller-based aircraft FCS, there is an added complexity in military aviation. That complexity is even higher for combat aircraft because of two main factors: The first is, that the flight envelope, e.g. the performance limits like speed and angles of attack go beyond those of conventional civil aircraft. That increases the size of the multidimensional space of variables and thus the various combinations that have to be covered by the ACM. In addition to that, combat aircraft like the Eurofighter exhibit a high interaction between their control surfaces and rotational axes due to their control surfaces having multiple applications. Canards, for example, are used for roll and pitch, while ailerons also act as flaps (flaperons) as shown in The comparatively simple direct coupling between control surfaces and the aircraft's nearly one-dimensional response to the actuation of flight control surfaces in conventional aircraft does not apply to the setup of most combat aircraft. That coupling behavior has to be depicted precisely in the model, thus adding complexity.

Secondly, the ACM has to be available for a variety of different configurations of the aircraft. Configurations in the case of combat aircraft usually refer to the aircraft version and store configuration, stores being any device intended for internal or external carriage and mounted on aircraft suspension and release equipment Examples in the case of the Eurofighter would be any kind of externally mounted weaponry or fuel tanks. Relevant to the aerodynamic model are in that case any kind of stores and more generally any kind of modifications to the aerodynamic shape that influence the aerodynamic characteristics of the aircraft. Since combat aircraft usually have a long life expectancy of 30 to 40 years, a continued effort to update the aircraft and the stores it is able to carry, is made. Specifically, the regular integration of new capabilities through new stores makes it necessary to continuously update the ACM for new setups of the aircraft. That is why the creation and maintenance of the ACM is an ongoing task throughout the aircraft's service life.

To generate the model, the multidimensional space of variables for the different setups has to be filled with data to support the creation of the ACM. That data can be provided by three different sources: Wind tunnel (WT) testing, computational fluid dynamic (CFD) simulations and via flight testing (FT). Each of these methods is different in the way the data is gathered and stored and thus in the way it can be used. The goal of the Dataset team at Airbus Defense and Space is to define and gather the necessary data from the available sources and to combine them into the ACM.

Because the structure, availability and quality of the aerodynamic data are different for each data source (WT, CFD and FT), the ACM development process has to be performed manually, with engineering judgment at the center of modeling. Due to the development and maturation of new database and data analysis technology, like easy-to-use database management systems (MySQL, Oracle, etc.) and accessible data analytic/machine learning toolboxes in recent years, new possibilities are emerging that show potential to improve ACM development.

That is why at Airbus Defence and Space, there is an ongoing effort to harvest that new potential, with one area of research being the automated fusion of the discussed three data sources. It is expected that by deploying data fusion algorithms to the three data sources, the ACM of the aircraft can be described more precisely and more efficiently. The goal of this thesis is therefore to take a first step towards such data fusion, by creating a data fusion approach for supersonic aerodynamic characteristics, that can be applied to WT and CFD data resulting from Eurofighter aerodynamic testing. To do so, a database is designed and implemented to store computational fluid dynamics data in alignment with an already existing database for WT data, to be able to store and search the available CFD data as required for the application of data fusion. In the second phase of the thesis, then the first approaches to data fusion are conceptualized and implemented, with the goal of a first working algorithm to give insights into the feasibility of such algorithms in the context of the Eurofighter ACM.