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Improvements in on-board systems design for advanced sustainable air mobility

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Abstract. This paper describes the activity proposed in the context of National Center for Sustainable Mobility (CN MOST) for designing an advanced core Guidance, Navigation, and Control system together with an effective on-board systems configuration for sustainable air mobility. A Model Based Systems Engineering strategy is adopted to support the design and development phases. The introduction of new sustainability objectives and the U-Space services to support the integration of unmanned air vehicles in the traditional Air Traffic Management drives the need of a full redesign of on-board systems that must be interfaced with different air platform categories. High performance processing units are considered for embedded systems, including but not limited to machine learning based, image processing and data fusion algorithms for advanced navigation. Three use-cases are presented as reference platform and mission types for validating the proposed systems configuration, specifically unmanned electric Vertical Take Off and Landing aircraft, fully electric general aviation aircraft, and hybrid-electric regional aircraft.

Introduction

The worldwide effort to increase technological improvement towards more sustainable air mobility is focusing on advanced propulsion systems, effective route planning, efficient airframe design and high-performance on-board Guidance, Navigation, and Control (GN&C) solutions [1-4]. Moreover, an innovative redesign of on-board equipment and systems is needed to meet new requirements and guarantee high safety levels according to the rapid changes of Air Traffic Management (ATM) that will include manned and unmanned vehicles with different specifications [5].

The need to integrate the so-called Unmanned Aerial Systems (UASs) with the existing traditional aviation is the focus of several programs [6]. The European response to this need has been implemented thanks to the definition of U-Space [7] for operations at Very Low Level (VLL) airspace in the context of the UAS Traffic Management (UTM). The definition of standard services - such as contingency management, traffic information, identification, collision avoidance, tracking - that allow to safely manage several vehicles with different tasks drives the design and development of specific on-board equipment with an increasing level of autonomy. Modular on-board systems configurations [8] can support the development of core enabling modules that can be designed for a wide range of vehicles also thanks to the use of low-cost Commercial Off The Shelf (COTS) processing units [9].

This paper aims at presenting an overview of the design activity focused on on-board systems configuration in the context of integrated ATM/UTM environment. Modular configurations are investigated to adapt innovative features of core GN&C systems to different air vehicles also assessing specific risk analysis evaluations for strategical and tactical mission management.

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Overview of On-board Systems Design

The rapid evolution of air traffic requirements carries out the design and development of advanced on-board systems that must meet new mission profiles. Data fusion algorithms, Machine Learning based methods and modular configurations are the main drivers for innovative enabling technologies that support new generation air vehicles in complex environments.

A groundbreaking approach that follows all the design and development phases by using an advanced implementation method for systems modeling will support the adoption of advanced hardware and software components as well as effective real-time processing algorithms, such as the Model Based Systems Engineering (MBSE). The International Council On Systems Engineering (INCOSE) is developing several initiatives in the field of MBSE [10]. The National Aeronautics and Space Administration (NASA) started the MBSE Pathfinder in space topics [11]. The European Space Agency (ESA) founded the MB4SE and OSMOSE groups to introduce the MBSE concept [12].

The main aim of the proposed activity is the design of an advanced core GN&C system that can be adapted to different types of air vehicles and interfaced with the under development services of the integrated ATM/UTM. The general workflow description is reported in Fig.1 by following an MBSE approach [13] that helps to reduce the risk of unexpected redesign issues.

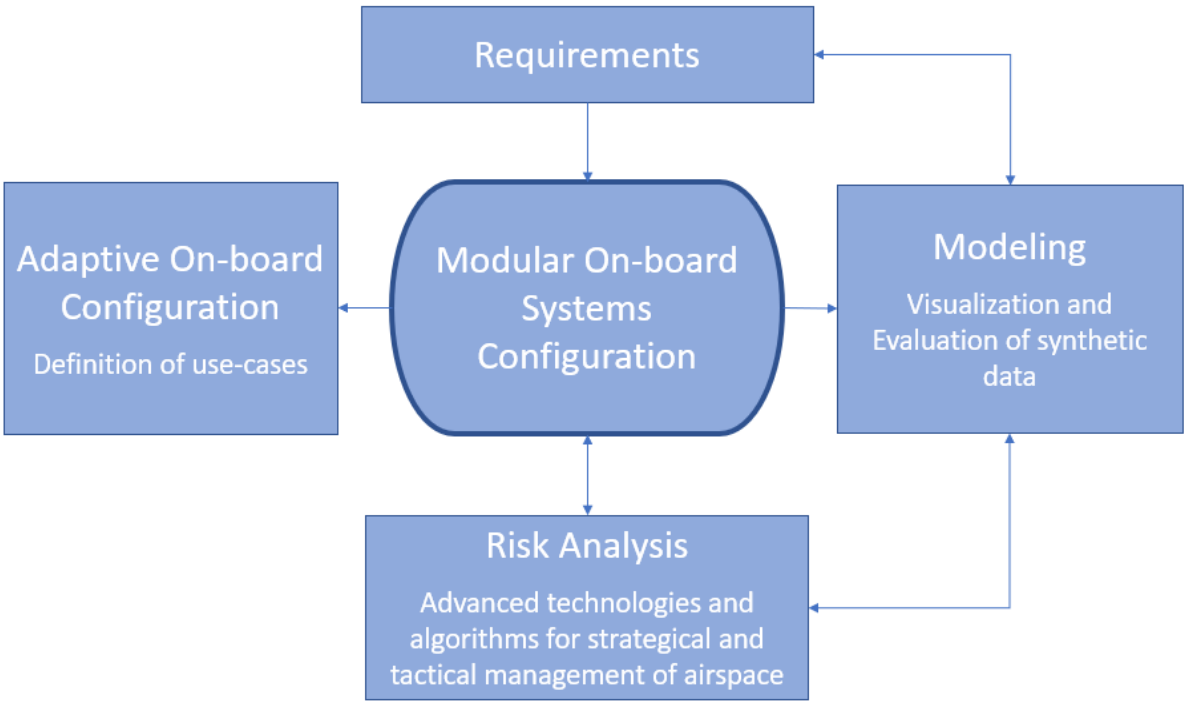

Fig. 1. Schematic description of the workflow for the proposed on-board systems design.

The requirements definition involves the selection of possible stakeholders and the regulatory framework analysis. Specific user needs must be highlighted, such as business goals, safety and security issues, and typical mission profiles must be identified. A model-based design strategy helps the development of a modular configuration and thanks to the evaluation and visualization in dedicated Human Machine Interfaces (HMIs) of synthetic output data, a risk analysis of the designed aerial system can be carried out to safely manage the mission at both strategical and tactical levels. The development of specific systems models allows to refine the initial requirements and associate each requirement to the related system module. Ad hoc use cases must

be designed to validate the identified requirements and test the developed modular configuration in different scenarios.

Definition of Use Cases

The preliminary analysis of requirements for the proposed design solution involves the identification of reference platforms and missions. The aerial vehicles that are included in the analysis are: i) unmanned electric Vertical Take Off and Landing (eVTOL) aircraft, such as [14], ii) fully electric general aviation aircraft, such as [15], and iii) hybrid electric regional aircraft, such as [16].

The unmanned eVTOL platform is involved in the context of Smart Cities [17] for Urban Air Mobility (UAM) purposes. Typical mission profiles include package delivery and air-taxi operations.

The fully electric general aviation aircraft is one of the reference platforms for fully electric propulsion as well as electric on-board systems implementation. Personal transport and dedicated professional applications, such as surveillance and mapping are some relevant missions.

The hybrid electric regional aircraft involves the challenge of developing more electric on-board systems configuration for medium haul routes. The main designed task is related to commercial aviation transport with less than 100 seats also considering high efficiency sustainability features.

The mentioned platforms are the reference case study for the design of an adaptive on-board system configuration, identifying the core modules and enabling technologies to meet the developing requirements of air mobility.

Conclusion

This paper describes an overview of on-board design activity carried out in integrated manned and unmanned aviation with new needs and services. The development of proper design strategies for on-board systems helps address the increasing complexity level. During the activity, the on-board systems design can be carried out according to an MBSE strategy to manage more complex implementations. Tha main expected advantages of the proposed strategy include the rapid integration in the digital environment, the assessment of inter-modules interactions, the increase of overall system reliability level and the reduction of commercial implementation.

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