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# Preface

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Editorial:

The critical and central nature of computation within Aerospace Systems naturally leads to the development of formalized investigation methods, primarily aimed at improving reliability, predictability and safety. The broad term "Aerospace" can cover many platforms, from piloted fixed/rotary wing vehicles, through unmanned air systems, to satellites and space probes. There are many techniques and technologies used within Aerospace where formal analysis is at least welcome and is often essential: flight control, "detect and avoid" mechanisms, fault diagnosis and recovery, autonomous docking and landing, coordination of multiple vehicles, autonomous decision-making, etc.

The complexity of computations within Aerospace applications means that no single formalism is universally suitable for all scenarios, and so many techniques have been utilized, from across many distinct disciplines. Specifically, work in this area underlines the importance of research problems derived from Aerospace scenarios to the Logic, Mathematics and Artificial Intelligence communities. In addition, new techniques within, and new ways of combining techniques from, Logic, Artificial

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Intelligence, Hybrid Systems, Control Engineering, etc., are vital to progress in the Aerospace area.

Logic-based formal methods provide a link between many of the different techniques we might wish to explore. For example using logic-based methods we can express properties of complex temporal structures, of hybrid and continuous systems, of probabilistic behaviours, of resource-boundedness and reliability, of concurrency and of autonomy. Thus, the wide diversity of Aerospace systems provides a strong source of new problems for formal logical, mathematical, or AI techniques. Such systems can be involved in complex activities such as space exploration, telecommunication support, disaster monitoring, environmental sensing, mapping, weather prognoses, search and rescue, naval traffic surveillance, etc. From these applications, new requirements appear: autonomy, collective behaviour, information fusion, cognitive skills, coordination, etc. In addition, new concepts must be formalised: digital pheromones, swarms, systems of systems of robots, sensing, physical actuation, and so on.

Aerospace is a complex area and so often requires extension and integration of formal modelling and analysis approaches with techniques from other disciplines, and many such opportunities are now appearing. A good example is the problem of coordination for platoons of UAVs or satellites, which have been successfully tackled using various techniques from control engineering and numerical tools from dynamic programming. In addition, there exist an abundance of examples of AI techniques in Aerospace (target tracking, rover planning, multi-agent technologies and so on). The implementation of these methods could benefit from formal analysis and development. From the cross-fertilization of related multidisciplinary approaches, we expect more robust, safe and mechanisable modelling, development and verification methods for Aerospace systems.

In this special issue, we highlight three different directions concerning the application and development of formal methods within Aerospace.

In “Formal Testing for Separation Assurance”, Giannakopoulou, Bushnell, Schumann, Erzberger, and Heere, consider the crucial problem of controlling air traffic in our increasingly crowded skies. In particular, they use formal testing techniques to assess whether aircraft will get closer to each other than a minimum safe distance (called “loss of separation”). They develop a range of automated test-case generation techniques that are based on model checking, and assess their viability for use in ensuring safe separation of air vehicles.

In “Kripke Modelling and Verification of Temporal Specifications of a Multiple UAV System”, Sirigineedi, Tsourdos, White, and Zbikowski consider a quite different approach. Their context is of a collection of unmanned air vehicles coordinating with each other to carry out ground monitoring. They logically model the scenario, and show how a temporal logic model-checker, SMV, can be used to verify correctness conditions of such cooperating air vehicles.

Finally, in “Using Formal Methods with SysML in Aerospace Design and Engineering”, Graves and Bijan consider another approach, distinct from testing and verification. In particular, they address the problem of how one can actually design and develop Aerospace systems in a reliable way and their approach is to combine model-based systems engineering with formal methods to alleviate some of the problems in Aerospace systems development. In particular, they use a SysML based Model-Based System Engineering process to describe and develop models for typical air systems and their operating contexts. The authors couple this with formal

methods based on theorem-proving within type theory in order to show how proof-based verification can be utilized within this model-based approach.

While the papers in this special issue cover very different approaches, there is, of course, a vast range of topics beyond those considered here, for example: formal verification of hybrid systems; formal models for cyber-physical systems; autonomous and autonomic systems; performance modelling and verification; multi-agent systems and coordination technologies; stochastic modelling and verification methods; etc. Indeed, there are active research events tackling such problems specifically within the Aerospace domain, including

Formal Methods in Aerospace (FMA) workshop series
http://personalpages.manchester.ac.uk/staff/Manuela.Bujorianu/FMA.htm
NASA Formal Methods (NFM) symposium series
http://shemesh.larc.nasa.gov/nfm2012