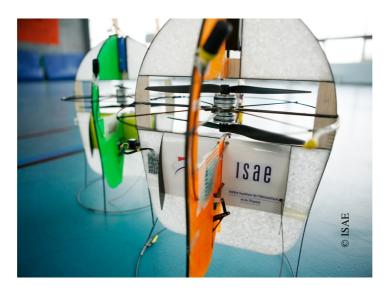# 1st Summer School on Critical Embedded Systems

2-11 JULY, 2013, TOULOUSE, FRANCE

Program

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About

The Summer School on Critical Embedded Systems aims at presenting state-of-the-art techniques, methodologies and tools for the engineering of critical embedded systems across its life-cycle, from early requirement elicitation up to certification. It is organized by the safety-Critical Embedded SystEms Chair – CESEC.

The Summer School will provide students with scientific and technical sessions on hot topics in this domain, but also practical sessions to consolidate new know-hows.

For its inaugural session, the Summer School will focus on a fertile multi-domain theme: engineering of drones, covering paths from system engineering down to electrical engineering, including architecture and control/command aspects.

Animated by practitioners from the industry and the academia, the School will cover the following topics:

- UAVs: introduction to a family of systems for new mission and services
- Operation of UAVs in shared sky, certification and safety issues
- System Architecture: interfaces, dimensioning, sensors, actuators
- Systems Engineering: from mission statements to requirement engineering;
- System Validation and Verification: performance, safety, qualification, etc.
- Design and implementation: control laws, software and electronic design;

Demonstration sessions indoor and outdoor will complete the summer school, turning concepts into live and exciting moments.

The Summer School on Critical Embedded System received the support of the safety-Critical Embedded SystEms Chair – CESEC created by the EADS Corporate Foundation.

The summer school is organized in collaboration with the MAV Research Center.

Program at a glance

Tuesday, July, 2nd 2013

08:30 09:00 Registration

09:00 09:15 Welcome address from Organizers

09:30 12:15 *A general introduction to UAVs: missions, system requirements and technological challenges*
Jean-Marc Moschetta (ISAE/MAV Research Center)

12:15 14:00 Lunch

14:00 16:30 *Rules and laws for operating drones: safety and certification*
Catherine Ronflé-Nadaud (ENAC)

Wednesday, July, 3rd 2013

09:30 12:15 *Developing robotic applications using component-based architectures and SAIL (Software-Architecture-In-the-Loop) simulations*
Charles Lesire (ONERA/DCSD)

12:15 14:00 Lunch

14:00 16:30 *Filtering and hybridation for UAVs*
Vincent Calmettes (ISAE)

Thursday, July 4th 2013

09:30 12:15 *System Architecture using SysML and Avatar*
Ludovic Apvrille (Telecom ParisTech) and Pierre de Saqui-Sannes (ISAE)

12:30 14:00 Lunch

14:00 16:30 *System Architecture using SysML and Avatar – Part 2*
Ludovic Apvrille (Telecom ParisTech) and Pierre de Saqui-Sannes

Friday, July, 5th 2013

09:30 12:15 *Towards Autonomous drones*
Simon Lacroix, (LAAS)

12:30 14:00 Lunch

14:00 17:00 *Demonstration of UAV from CESEC student projects and partners -- outdoor*

Session #2: Engineering of drones, from requirement to implementation, part #2

Monday, July 8th 2013

09:30 12:15 *Software architecture and performance*
              Emmanuel Grolleau (ISAE/ENSMA)

12:30 14:00 Lunch

14:00 17:00 *Risks in Software*
              Jérôme Hugues (ISAE)

Tuesday, July 9th 2013

09:30 12:15 *Safety Analysis*
              Christel Seguin (ONERA/DTIM)

12:30 14:00 Lunch

14:00 17:00 *Certification considerations for UAV*
              Florian Many (DGA/TA), Hugues Bonnin (CapGemini)

Session #3: applications

Wednesday, July 10th 2013

09:30 12:15 *Critical Embedded GNC Systems for Fully Autonomous Space Drones Operations*
              Julien Morand (Astrium)

12:30 14:00 Lunch

14:00 17:00 *Video surveillance and observation*
              Jean-Luc Dugelay (Eurecom)

Thursday, July 11th 2013

09:30 12:15 *Human factors issues and human centered design of UAS*
              Patrick Le Blaye (ONERA Salon de Provence)

12:30 14:00 Lunch

14:00 17:00 Demonstration of UAV from CESEC student projects and partners -- indoor

Detailed program

A general introduction to UAVs: missions, system requirements and technological challenges
Speaker: Jean-Marc Moschetta (ISAE/MAV Research Center)

Unmanned Aerial Systems offer a large variety of civil and military applications, ranging from pipeline surveillance missions to search & rescue missions in collapsed buildings. Their potential is virtually unlimited but is currently greatly restricted by regulation issues. The presentation will describe various missions and scenarios where UAS may really add extra value as compared to conventional solutions. Special attention will be paid to the technical challenge of mini and micro-UAVs, which are believed to be the most promising aeronautical breakthrough of the next decades. Novel aerodynamic configurations will be illustrated and discussed.

Dr. Jean-Marc Moschetta has been a Professor of Aerodynamics at ISAE since 2000. He is currently leading the group of research "Aerodynamics and Propulsion of Micro Air Vehicles" which focuses on the design of convertible tilt-body micro air vehicles. His research is devoted to the design of novel aerodynamics configuration as applied to mini and micro-UAVs. Since 2011, Dr. Moschetta is founder and director of the MAV Research Center that fosters the development of MAV technologies in Toulouse. He is also in charge of promoting multi-disciplinary research activities in UAVs at ISAE.

Rules and laws for operating drones: safety and certification
Speaker: Catherine Ronflé-Nadaud (ENAC)

The objective of the presentation is to explain the basis of the Air Traffic Management and then to address the issue of the RPAS (Remotely Piloted Aircraft System) integration in the civil airspace. The stakeholders (ICAO, EASA, Eurocontrol, National Regulators, EUROCAE ...) involved are presented. RPAS CONOPS (Concepts of operation) are tackled. An introduction to the actual regulations is done (ATM, Airworthiness, Licenses, communications, ...) and the problem of their application to the UAS is highlighted.

Catherine Ronflé-Nadaud is the Head of the UAV Program at ENAC since January 2006. In 1989, she received the ENAC engineer diploma, then a Master of Science in "Fundamental Computer Science and Parallel Computing" from INP Toulouse. She became a DGAC Professional Pilot in 1991 (IFR November 2000, Twin Engine Qualification May 2010). From 1994 to 2005, she was the Head of the Computer Network Team at ENAC.

Developing robotic applications using component-based architectures and SAIL   (Software-Architecture-In-the-Loop) simulations
Speaker: Charles Lesire (ONERA/DCSD)

Robotic applications need a lot of flexibility in the development of embedded software, because a same robot, with modular sensors, must be able to be part of several missions. Software development for robotics is hence wise to use a component-based paradigm. Component-Based Software Engineering (CBSE) adds modularity, flexibility, and maintainability to the development process, hence helping developing and reusing parts of the architectures on an efficient way.

This presentation introduces CBSE for robotics, and illustrates its use through several case studies at Onera and ISAE, based on the Orocos framework. The evaluation of component-based software architectures for robotics is also discussed through the use of SAIL simulations.

Charles Lesire has been a researcher at Onera, the French Aerospace Lab, since 2007. He previously passed a MSc. from ENAC (The French Aviation University, Toulouse, France) on computer sciences, and then passed a Ph.D. on computer sciences from University of Toulouse. His topics of interest include software development for robotics, validation of robotic architectures, and algorithms for multi-robot cooperation.

Filtering and hybridation for UAVs
Speaker: Vincent Calmettes (ISAE)

The development in semiconductor technologies allows manufacturers to design innovative sensors with higher performance. These sensors such as MEMS technology inertial sensors, GPS modules, magnetometers, barometers, image sensors have rendered navigation systems affordable for UAV applications. Indeed they fulfill stringent constraints related to the size, the weight, the power consumption. This presentation aims to address UAV navigation issues. The most important characteristic of a navigation system is its ability to adapt to the UAV environment. A Bayesian estimation of the vehicle state, that required an accurate description of the state-space model of the dynamic system, is proposed. In this context the navigation process has to be able to choose the most relevant set of sensors and the most appropriate approach depending on its situation. Technical implementation aspects will also be discussed.

Vincent CALMETTES received a Ph.D. degree in signal processing from ISAE (French Institute of Aeronautics and Space, Toulouse, France). He is a training and research scientist at the signal, communications, antenna and navigation laboratory of ISAE. His research interests include Bayesian filtering and multi-sensors data fusion, with applications to tracking and navigation in harsh environments. He is also working on new Galileo signal processing and GNSS receiver architectures and is involved in several projects devoted to the development of embedded navigation system based on DSP and programmable logic devices.

System Architecture using SysML and Avatar
Speakers: Ludovic Apvrille (Telecom ParisTech) and Pierre de Saqui-Sannes (ISAE)

The purpose of the tutorial is to share an experience in real-time embedded systems design. The tutorial will shuffle presentations of an environment called AVATAR and applications using a toolkit called "TTool".

The OMG-based System Modeling Language, or SysML for short, is a reference language for system engineering. The AVATAR modeling language customizes SysML to meet expectations of real-time systems designers. AVATAR, which is defined by a SysML syntax and a formal semantics, is supported by TTool and associated with a method. TTool includes a diagram editor, a model simulator, a user-friendly interface to the UPPAAL model-checker, a verifier that searches for mutual exclusion situations, and a POSIX-C code generator.

Besides educational case studies, attendants will be proposed to model a subset of a UAV.

Ludovic Apvrille obtained his M.Sc. in Computer Science, Network and Distributed Systems specialization. He then completed a Ph.D. in collaboration between the Department of Applied Mathematics and Computer Science at ISAE, the LAAS-CNRS and Alcatel Space Industries (now, Thalès Alenia Space). After a postdoctoral term at Concordia University (Canada), he joined LabSoc as an assistant professor at Telecom ParisTech, in the Communication and Electronics department. His research interests focus on tools and methods for the modeling and verification of embedded systems and Systems-on-Chip. Verification techniques target both safety and security properties. He's the leader of the open-source UML/SysML toolkit.

Pierre de Saqui-Sannes received the Ph.D. and "Habilitation à Diriger les Recherches" in computer science from Université Paul Sabatier and Institut National Polytechnique de Toulouse, respectively. He is now a full professor at the department of Mathematics, Computer Science and Control Theory at ISAE (Institut Supérieur de l'Aéronautique et de l'Espace) in Toulouse, France. His research interests include Real-time systems modeling, bridging the gap between SysML and formal methods, and protocol engineering. He has a two decades experience in teaching modeling techniques (formal methods, real-time UML, SysML) to industry practitioners.

Towards Autonomous drones
Speaker: Simon Lacroix, (LAAS)

One of the current frontiers researchers are exploring for drones is the development of autonomous behaviors. For a drone or a mobile robot, autonomy can be defined as the ability to achieve high level abstracts tasks, such as "explore these buildings, detect and locate abnormal events", in a dynamic and mostly unknown environment. This ability calls for decision making or planning processes, that exploit the various information gathered by the

drone on the environment as the mission is executed. After an introduction of the notion of autonomy and the associated functionalities, the talk first focuses on the environment representations required for the higher level planning processes, and on the means to derive them from sensory data. The localization problem in general, and the ways to solve it in GPS-denied areas will be discussed. The second part of the talk focuses on the decisional processes that plan motion and observation tasks. The problems raised by the deployment of multiple cooperative systems will also be discussed, and some solutions presented. Throughout the talk, various illustrations of developments achieved in the robotics community will be presented and discussed.

Simon Lacroix graduated from Ecole Centrale de Paris in 1990. He then prepared a PhD at LAAS, on autonomous navigation for planetary rovers. After a one-year postDoc in the Center for Intelligent Machines of McGill University, Montreal, he joined LAAS as a permanent research scientist in 1996. He currently animates the field robotics activities of the laboratory, and his research is focused on the deployment of teams of multiple heterogeneous autonomous robots for exploration, surveillance or intervention missions. His main interests are perception and navigation for autonomous aerial and terrestrial robots (environment perception and modeling, localisation, perception control and autonomous navigation strategies), and decisional processes for autonomous cooperation within multi-robot teams.

Software architecture and performance
Speaker: Emmanuel Grolleau (ISAE/ENSMA)

This presentation is a survey of the basic problems arising in real-time systems performance, especially in terms of resource management (CPU(s), network), and the link between conception and efficient resource utilisation. It mainly focuses on on-line scheduling policies (fixed priority policies - FPP, and dynamic priority scheduling) on a preemptive scheduling scheme, and insists on the basic concepts of busy period and processor demand. A case study based on an UAV will be used to illustrate the concepts of temporal analysis, and of the underlying models. We will first focus on the link between real-time programming and task models. Then, the temporal analysis for FPP in uniprocessor systems will be presented, using the concepts of critical instant and busy period, to introduce the Response-Time Analysis. In this context, the way to handle structural constraints (mutual exclusions, precedence constraints) is presented. We then focus on fixed-job (Earliest-Deadline First) priority scheduling, and on the validation methods based on the study of the processor demand. Finally, we introduce the network scheduling, as well as some openings in multiprocessor systems.

Emmanuel Grolleau is full-time professor in ISAE-ENSMA. His research focuses on real-time scheduling, as well as real-time design and temporal validation. He teaches real-time and embedded systems in ISAE-ENSMA, Université de Poitiers, as well as in several international programs (SIAE Tianjin China, PFIEV Polytechnic institutes in Vietnam).

Risks in Software
Speaker: Jérôme Hugues (ISAE)

Software is a key element in the implementation of an embedded system, at the interface between physical world and the logic in place to control the system. In this talk, we will review potential sources of risks when implementing software, reviewing each technology layers involved: programming language, operating systems, hardware, environment and operational conditions. We will illustrate on various examples potential culprits and discuss how to reduce or avoid them, and lessons learnt for future projects.

Jérôme Hugues is associate professor at the Department of Mathematics, Computer Science, and Control of the Institute for Space and Aeronautics Engineering (ISAE) in Toulouse. He holds a PhD (2005) and engineering degree (2002) from the ENST. He lectures on real-time operating systems, languages and architectures. Since 2010, he is the co-head of the "Embedded Systems" Master Program at ISAE, and of the last year Computer Science program for ISAE engineers. His research interests are focused on software architecture to support the design of complex software-based real-time and embedded systems; and programming languages and artifacts to support them. He is also a member of the SAE AS-2C committee working on the definition of the AADL architecture description and is involved in the Ocarina and TASTE projects.

Safety Analysis of UAV systems
Speaker: Christel Seguin (ONERA/DTIM)

System safety assessment is one key activity of the aircraft certification process. After introducing the qualitative and quantitative safety requirements usually applicable to the aircraft systems, the presentation will give an overview of the models and techniques that support the safety assessment. Both classical methods (failure mode and effect analysis, fault tree analysis) and newest ones (model-based safety assessment) will be illustrated on an UAV flight control system.

Christel Seguin, PhD, is senior researcher at ONERA, the French aerospace lab and lecturer at ISAE. She is working on the model-based system safety assessment approach in aeronautic and space context and she is more particularly applying her results to ONERA UAV.

Certification considerations for UAV
Speakers: Florian Many, DGA/TA and Hugues Bonnin, Cap Gemini

Producing software, with a near-zero default level, is really a big challenge for software industry. In this joint presentation, we will discuss certification concerns applied to UAV. Certification main objective is to demonstrate to authorities that "all" has been done to guarantee the safety of the system and the human that are either operating it, or depend on it (e.g. passengers, surrounding population, etc).

In this talk, we will highlight key elements of current certification practice such as DO-178 and associated normative documents produced by EASA, FAA and other regulation bodies. UAVs are quite different from regular planes: they have a degree of autonomy that goes well beyond a simple autopilot under the supervision of the cabin crew. We will illustrate these new challenges, and discuss the limits of the current documents, and current plans to address them.

In a second part, the example of Capgemini and IS2T, through their common project JERTIF, will be given as an illustration of this challenge. Taking as inputs the hardiest standard of avionics, ED-12/DO-178 level A, with one of the most productive software technology, Java, we will show how these contraries can be mixed together to produce a mini-UAV control software, with a very high level of confidence. In particular we will show how to address determinism, layering and compositionning, all that in a very structured and strict production process.

Florian Many is a member of the certification team at DGA/TA. He received an engineer degree from ENSIETA in 2009 and a PhD from ONERA in safety aspects of real-time scheduling in 2012. His main area of expertise is UAV system for military and civilian operations as part of DGA/TA, the French Delegation to Army Procurement, Aeronautics division.

Hugues Bonnin, is head of the Capgemini Aerospace & Defense Safety Risk Management Unit. As a critical and real-time software expert, Hugues leads the unit responsible for risk assessment for safety critical systems. He is a member of Aerospace Valley "Certification Together" center, and was a member of RTCA/EUROCAE SC205/WG71 working group, defining newly released DO-178C & DO-278A. He has a strong experience in evaluation, definition, settings and process monitoring of safety-critical software developments, in domains like railways, aeronautics, space, and air traffic management. Hugues also coordinates R&D projects of the Aerospace&Defence unit, with a focus on critical real-time software.

Critical Embedded GNC Systems for Fully Autonomous Space Drones Operations
Speaker: Julien Morand (Astrium)

Through the examples of future space missions requiring a high level of autonomy during critical phases Planetary landing & rovers, In-Orbit Rendezvous & Proximity Operations, Formation Flying), the design and development challenges of their autonomous Guidance, Control & Navigation (GNC) avionics system are presented.
As the development steps, from concept to operational mission, are reviewed, the importance of concurrent engineering between system architects, GNC designers, data-processing experts, HW/SW implementation teams, and equipment suppliers is highlighted.
A particular focus is also proposed on the integration of on-line image processing capabilities, a ley feature to enhance the autonomy of such vehicles in poorly known/GPS-less environments.

Video surveillance and observation
Speaker: Jean-Luc Dugelay (Eurecom)

Jean-Luc Dugelay obtained his PhD in Information Technology from the University of Rennes in 1992. His thesis work was undertaken at CCETT (France Télécom Research) at Rennes between 1989 and 1992. He then joined EURECOM in Sophia Antipolis where he is now a Professor in the Department of Multimedia Communications. His current work focuses in the domain of multimedia image processing, in particular activities in security (image forensics, biometrics and video surveillance, mini drones), and facial image processing. He has authored or co-authored over 235 publications in journals and conference proceedings, 1 book on 3D object processing published by Wiley, 4 book chapters and 3 international patents. His research group is involved in several national projects and European projects. He has delivered several tutorials on digital watermarking, biometrics and compression at major international conferences such as ACM Multimedia and IEEE ICASSP. He participated in numerous scientific events as member of scientific technical committees, invited speakers or session chair. He is a fellow member of IEEE and an elected member of the EURASIP BoG. Jean-Luc Dugelay is (or was) associate editor of several international journals (IEEE Trans. On IP, IEEE Trans. On MM) and is the founding editor-in-chief of the EURASIP journal on Image and Video Processing (SpringerOpen). Jean-Luc DUGELAY is co-author of several conference articles that received an IEEE award in 2011 and 2012. He co-organized the 4th IEEE International Conference on Multimedia Signal Processing held in Cannes, 2001 and the Multimodal User Authentication held in Santa Barbara, 2003. In 2015, he will serve as general co-chair of IEEE ICIP and EURASIP EUSIPCO.

Human factors issues and human centered design of UAS
Speaker: Patrick Le Blaye (ONERA Salon de Provence)

The presentation aims to provide notions and tools for a better integration of human factors at the design stage of unmanned aircraft systems. As a matter of fact, unmanned aircraft are peculiar aircraft, which remote control raises specific issues. In a first part we will review the basic notions regarding the human factors of remotely operated vehicles. Next we will propose a generic human centered design methodology and we will illustrate its application in various use cases, such as time latency compensation, implementation of a sense and avoid function and coordination of multi-UAS operation.

Patrick Le Blaye graduated from Ecole Centrale de Paris in 1990. He is now a research engineer in the Systems Control and Flight Dynamics department at ONERA. His main research topic is human-automation interaction. He is involved in several projects related to innovative cockpits and remote pilot stations, human system integration and safety assessment of new concepts of operations, including airspace integration of UAS. Within the human factors team of ONERA, he specifies and develops the HMI functionalities of a generic remote pilot station used in human-in-the-loop experiments.

Practical information

Map of the ISAE/Supaero campus
The school will be hosted in room 11-114 in H. Fabre building