T-B PHASE: Thales-Bristol Partnership in Hybrid Autonomous Systems Engineering

Business lead: Thales, University lead: University of Bristol, Grant reference: EP/R004757/1

Summary

T-B PHASE is a £5M EPSRC prosperity partnership between Thales and the University of Bristol that aims to deliver design principles and processes for hybrid (human-machine) autonomous systems engineering. The research programme, which started in October 2017, is addressing the challenge of engineering confidence in hybrid autonomous systems, combining fundamental research studies with applications to live use cases within Thales. These include digital rail, maritime mission systems, intelligent surveillance and reconnaissance and unmanned traffic management.

Introduction and background

Hybrid autonomous systems (HAS) include groups of people and autonomous software or robots in direct, ongoing interaction, e.g. a mixture of autonomous and human-operated trains and trams in an integrated transport system. Emerging technologies in Robotics, Artificial Intelligence (AI) and Information and Communications Technology (ICT) mean that systems of this kind will become common in a wider set of situations, including a diverse set of Thales products in different application domains and business units. Smooth, reliable and safe interaction amongst machines and people will be key to their success. As Thales, its customers and its supply chain enter this new design space, a crucial challenge for engineers of hybrid autonomous systems is to have confidence in the system behaviour, requiring fundamentally new, cross-domain approaches to the design and development of these systems.

In response to these challenges, T-B PHASE is working on:

- Innovative new design principles and processes that integrate over the full system life cycle from early stages through to decommissioning to ensure that future systems are delivered to specification and cope with evolving task parameters;
- New analysis and design tools that enable a complex system's interactions to be mapped, understood and bounded at design concept stage;
- Rigorous studies of human factors involved in human-autonomous system partnerships;
- Developing and growing a team of people in both academia and industry with the skills required for leadership in systems engineering.

The partnership between academia and industry has enabled us to implement a programme of impact and integration activities that respond to the real stakeholder needs. The approach allows academic researchers to engage with a set of use cases that span the future of HAS.

The University of Bristol and Thales have a long track record of collaboration, cemented in 2016 by the signing of a strategic agreement to create a common governance framework for current and future collaborations. By engaging in the T-B PHASE programme, Bristol and Thales committed to share expertise and jointly pursue fundamental research questions in the context of highly practical design problems in order to significantly advance the capability to operate confidently in one of the most important emerging areas for modern engineering.

Project achievements 2020-21: outputs, outcomes and impact

1. Multi Agent Simulation Framework

A substantial new cross-project activity involving agent-based researchers from the university and Thales research team involves the design of a common simulation framework. The motivations of this activity are:

- Draw together existing conceptual research from across the programme into a common setting, enabling baseline comparisons and the elicitation of design patterns for multi-agent systems
- Provide contextual demonstration of fundamental findings to Thales stakeholders and ultimately form the basis of a design tool for future platforms and systems.
- Connect research findings to use cases from Thales business units, enabling direct impact from multi-agent research on future products and systems.

After a collaborative process of requirements capture and options evaluation, the team has delivered a first release of the framework, instantiated in flexible common simulator platform with optional web-based graphical interface (Figure 1). The framework permits forensic examination of individual scenarios and batch exploration of sensitivities under parameter variation.

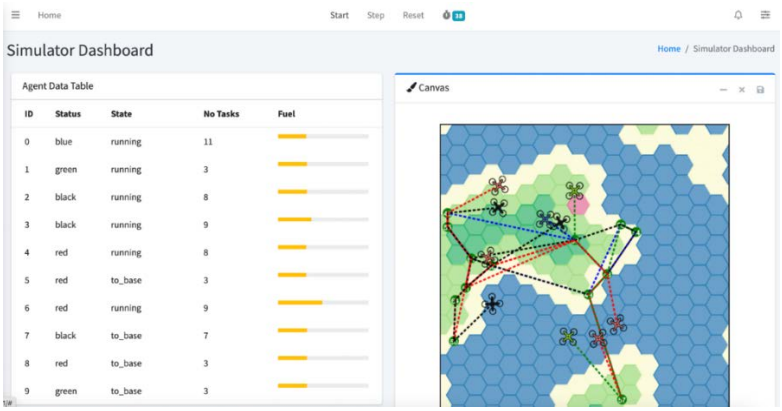

Figure 1 Simulator Dashboard for multi-UAV tasking and allocation. A procedurally generated map with base location (red) and agent fuel constraints and periodic refuelling.

The software framework supports the deployment of different “apps” to target scenarios of interest. Apps developed so far are:

- Simulation of underwater cable surveying, where agents have limited means of communication, targeted towards Thales’ Maritime Mission Systems (MMS) business unit;
- Interactive simulation of a scenario designed to explore a human’s sense of agency when engaging with an autonomous system, supporting a psychology study (see Human Factors below);
- Evaluation of autonomous systems composition, exploring the effects of platform heterogeneity on the overall behaviour, as part of an autonomy study in the context of the intelligent surveillance and reconnaissance (ISR) use case.

Additional apps will be developed throughout the remainder of the project, adopting agile methodology to streamline team-wide collaboration and forming a common impact pathway from multiple work streams. Future apps will incorporate real-time human interaction, to model tactical and strategic control as informed by the Human Factors and Systems Architecture themes, and look at stability to parameter change (design, changing contexts and aging).

2. Human Factors

The Human Factors theme of T-B PHASE has focussed upon the key question of human performance in active roles versus supervisory responsibility. This exploits the opportunity to engage Thales specialists in human factors with university expertise in experimental psychology (see Staff Highlights below). Initial experiments in this area have commenced over the last year and are investigating how the role of Sense of Agency (SoA, defined as the experience of intentionally performing an action whose consequences are known) relates to levels of automation, timing and workload. This is a novel approach in human-automation teaming as Sense of Agency has not been investigated previously within this context.

Findings show a gradual loss of Sense of Agency with increasing automation. Post-experiment, participant comments supported this as they reported they felt less in control in the fully automated condition. Mental workload was found not to affect participants' Sense of Agency. However, automation and time delay are interconnected in influencing Sense of Agency, which implies the role of mental workload needs further investigation.

The work is key to a variety of business use cases, ranging from the remote control of rail and air platforms to automated operations in maritime search and rescue missions. For an operator, having control and knowing the outcome of one's actions when using a HAS will be paramount.

Further development of the concept of Sense of Agency has been explored through an experiment using the Thales Training and Semi-Automatic Labelling Tool (T-SALT) focused on understanding the impact on operator performance of increasing degrees of machine assistance to complete image analysis tasks (Figure 2). This is directly tied to a number of Thales use cases, from static Electro-Optical image labelling, through to video and sonar/radar plots.

A reusable experimental test bench has been developed as a result, incorporating an eye tracking system, operator performance metrics along with operator feedback. Further experiments will broaden to include a more diverse range of tasks and users to gain empirical evidence to support the design of these important user interfaces.

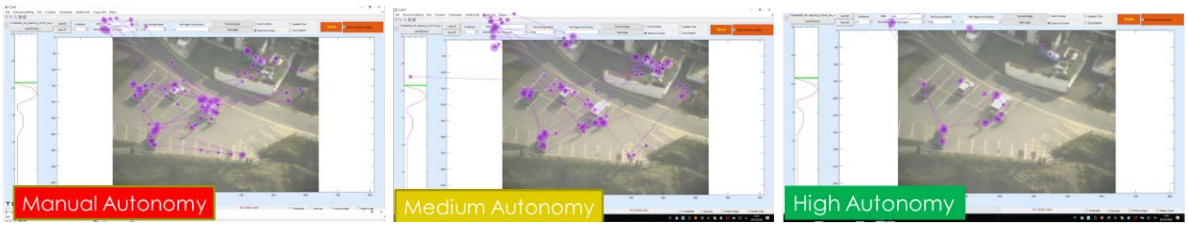

Figure 2: Images from T-SALT experiment. The images demonstrate the difference in eye movement behaviour users demonstrate when different levels of autonomy are used to support them in an image analysis task.

3. Systems Architecture

This theme studies the applicability of different systems architecture paradigms to autonomous systems. The methodologies we apply range from quite classical systems engineering techniques (requirements, V-diagrams etc.) through to systems-of-systems approaches, and problem structuring methods such as soft systems methodology (SSM) which focus on understanding stakeholder viewpoints and the value offered to them by HAS. It follows that there are natural interfaces with the project's other themes, the multi agent simulator framework for hard systems concepts and the human factors theme regarding stakeholder interaction. The investigations are structured around application case studies, principally in UTM (unmanned air traffic management) and digital rail (Figure 3), which are the foci for two Thales-funded PhD students. Work so far has focussed on the development of design patterns for communications systems, and on designing the failure and recovery modes of HAS.

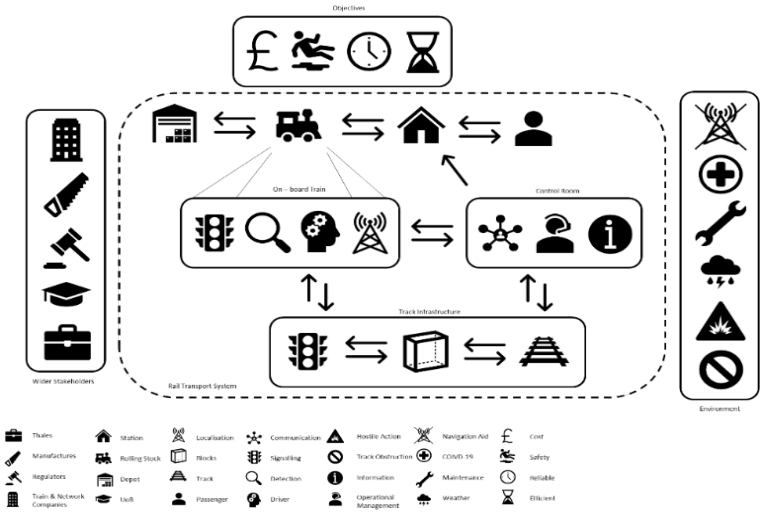

Figure 3 The problematic situation of introducing autonomous operations in an existing rail environment.

New collaborations

Opportunity for cross-cutting impact at Thales is greatly enhanced by the addition of Andrew Nicholson, Director of Thales Research, Technology and Innovation (RTI) to the T-B PHASE Senior Management Committee. This puts Thales' business strategy at the core of T-B PHASE activities through monthly interactions and will provide a consolidated impact route to Thales across all project outputs, ensuring the research can be taken forward by Thales for in-house development.

T-B PHASE welcomes Dr. Edmund Hunt, Research Fellow at the University of Bristol, as a new affiliate to the project. Dr. Hunt's work on bio-inspired swarming provides a new perspective on the multi agent systems work already on-going in T-B PHASE and will influence future directions in autonomous algorithms and modelling.

We have been developing our understanding of the maritime use case through whole team interactions with key Thales stakeholders in this area, most recently through discussions with Dr. Stewart Radcliffe, their Maritime Autonomous Systems Technical Lead, who provided invaluable insights on the onward trajectory of Thales research and development in this area and the technical difficulties that T-B PHASE could seek to bring solutions for.

Tom Bewley has joined the project as an affiliated researcher, currently in the second year of his Thales-supported PhD on "Explainable AI for Black Box Autonomous Agents". This work enhances our Hybrid Systems theme by considering a different type of human interaction with the decision-making part of an autonomous system.

Staff Highlights

We are delighted to welcome Jan Noyes, Professor in Human Factors Psychology, as an additional T-B PHASE Co-Investigator. Professor Noyes will deploy her enormous experience of Human Factors over some 40 years, including extensive industry collaboration, to lead the T-B PHASE theme in this area.

T-B PHASE also welcome Dr. Marko Radanovic who joined us as a Senior Research Associate in late 2020. Dr. Radanovic will research a framework for autonomous operations under UTM under the Systems Architecture theme. A second Research Associate is being recruited with start anticipated in Spring 2021.

Finally, Emily Morey joined our group of PhD students in September. Emily will investigate the pathway from the current rail environment to a fully functioning autonomous system, adopting a multidisciplinary approach that crosscuts all T-B PHASE themes. It is envisaged the project will attract interest from a range of stakeholders within Thales as well as from the rail industry itself.

We congratulate Dr. Bugra Alkan, formerly Senior Research Associate in T-B PHASE, who left in October 2020 to take up a lectureship in Artificial Intelligence at London South Bank University, focusing on secure systems research. During his year in T-B PHASE he identified gaps in current knowledge on autonomous systems architecting and conducted a simulation study using a series of cyber-physical human-machine system topologies. His results were published in the Journal of Computers and Industrial Engineering and presented at the Complex Systems Design and Management Conference 2020. Work on the Systems Architecture theme will be further developed by new researcher, Dr. Radanovic.

Despite Covid-19 impacts on working practices this year, team members have still been able to participate in a number of conferences, including the 2020 Conference on Artificial Life, the European Conference on Multi-Agent Systems (EUMAS 2020) and the 29th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN), enabling T-B PHASE research to reach international audiences within both academic and engineering/industrial communities over a virtual platform.

Acknowledgements

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