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Further than the eye can see

The Integrity of Day/Night All Weather Systems

Certain aircraft, both military and civil, are routinely called upon to fly at low altitudes or in adverse weather conditions for such manoeuvres as emergency, transportation and surveillance operations. The different flying environments expose the aircrew to obstacles such as electricity pylons and radio transmitter masts that can be masked by the terrain or simply lay undetected. Flying at night, in poor weather and when visibility is low further intensifies the problem. Aircrew detection of these threats is crucial to their survival and reliable determination of the visual range to an obstacle is a critical parameter.

In order to extend the operational envelope of low flying aircraft it is necessary to augment the naked eye with additional information from sensing devices. Various visual aids exist, or are being developed to extend the visual range limitations of the naked eye. These range from low light television (LLTV) or infra-red (IR) night vision systems to solutions where synthetic vision systems provide a combined augmented real world image with database data. An important issue in the certification of the airworthiness of the candidate solutions is the ability to assess the range at which obstacles become recognisable as potential threats and still give time for aircrew to make the necessary avoidance manoeuvre. The time available to avoid the threat is obviously dependent on the speed and direction of the aircraft and reaction time of the pilot.

Visual range is an extremely important factor in determining the performance of visual aids that extend the operational envelope of low flying aircraft. The environments in which these vehicles are required to fly are full of obstacles that present a serious risk to the safety of the crew and the vehicle. Some of the obstacles are known beforehand and can be accurately represented in navigation databases and warning displays. However, there are other obstacles whose position changes without notice, or are unknown to the system and therefore present an unknown threat to the vehicle. Consequently, it is impossible to guarantee the position of all obstacles with a high degree of reliability. The pilot ultimately carries responsibility for ensuring safe routing through a hazardous environment.

Technological developments now make it feasible to provide an enhanced view of the outside world by means of electro-optic sensing technology. As meteorological conditions deteriorate or night time operations become a necessity, the need for a method of assessing the performance of poor/reduced visibility flying aids becomes very important.

Synthetic piloting vision systems or Day/Night All Weather (DNAW) systems are intended to extend rotorcraft flight into both the night and adverse weather conditions by the safe use of synthetic vision. This enables the pilot to continue flying low level operations in poor visibility. By integrating appropriate sensors into the mission system, synthetic vision can be provided to the aircrew in order to retain a sense of situation and spatial awareness, which is crucial in maintaining a safe flight.

It is considered essential that any DNAW system provides the pilot with a means of identifying a deterministic 'range to interference' in a timely and reliable manner such as to allow safe flight of the aircraft. This deterministic 'range to interference' is a key element in maintaining situational awareness and orientation and in the case of severely obscured visibility conditions; the information must be provided purely from the DNAW system.

The overall aim of the DNAW Synthetic Vision Integrity Study (a successful collaboration between BAE Systems Electronics and Integrated Solutions and the Research School of Systems Engineering at Loughborough University) is to calculate the integrity of a generic DNAW system by creating computational models of the system components and as a result estimating the errors involved. The models are essentially coupled representing atmospheric transmission, sensor performance, system performance, display performance and eventually human performance models. Integrity in this context indicates the truthfulness of the information supplied.

Errors arise in a DNAW system from a combination of the aircraft's 'real world' position, the aircraft's 'sensed' position and the pilot's 'perceived' position. The study investigates the magnitude, phase lag, behaviour and components of the three sources individually and collectively. The aircraft's sensed position relies upon the accuracy of the navigational onboard sensors combined with database information correlated against the aircraft's real world position. Errors in this information can arise from incorrect installation of the sensors, sensor bore-sighting and database conflicts. The pilot's perceived position is reliant upon the truthfulness of the information provided together with numerous human factor issues.

A systems engineering approach has been adopted in the study to help focus the research and understand the complex interactions between the environment, the DNAW system and the aircrew. The computational models have been developed alongside a Technology Demonstration Programme, jointly funded by the MoD and BAE Systems, involving a flight trials programme with a helicopter fully equipped with a DNAW system. Results from the flight trial are being fed back into the modelling activity to calibrate the underlying system performance model.

John Anders, Sarah Johnson - BAE Systems (Rochester) and Professor Roy Kalawsky - Loughborough University.

For further details, please contact Sarah Johnson (sarah.johnson@baesystems.com)

Organisational Systems Engineering

Within the Systems Engineering field there is a general lean towards the lifecycles of systems as products or services. Within the SEIC a group of researchers considered the enterprise as a system itself and how improvements could be made not only in business terms but also more within the organisational or human aspects.

A portfolio of three research projects were undertaken by Loughborough University at the SEIC between 2004 and 2006. This portfolio included the Virtual Organisational Rig for Testing and Investigating Company Structures (VORTICS), Good Engineering Governance (GEG), and Managing Tacit Knowledge in Design Reviews (MTKn) projects. The projects were funded through the EPSRC with sponsorship from BAE Systems. Figure 1 shows how the different projects relate to each other.

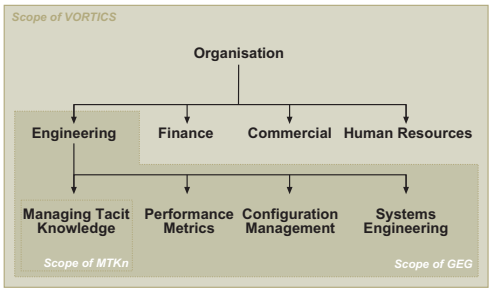


Figure 1: Organisational Systems Project Contexts

VORTICS

The main aims of the VORTICS project were to create the building blocks of a coherent enterprise modelling capability, and to derive detailed user requirements and high level technical specification for a test rig to model organisations. This would be done through:

- Identifying gaps in current enterprise modelling capability and determine a set of requirements for a comprehensive set of integrated models.
- Using existing models and new models of enterprise characteristics provide a usable and useful portfolio of enterprise modelling technology that fulfil fill the gaps in modelling capability.
- Integrating these gap models with current enterprise models within a given operational scenario
- Developing a detailed requirements specification and high-level technical architecture for the VORTICS system.

Within the work undertaken in the VORTICS project a number of soft enterprise characteristics were identified as gaps in current enterprise modelling capability. Models/tools for investigating Role Interactions, Enterprise Strategy, Competency, Cultural Values and Decision Making Systems were developed. These new models/tools were evaluated and refined through three case study scenarios (Typhoon Engineering, DSTL Smart Acquisition and SEIC Research) with analyses and recommendations for change. A UML class diagram model of the enterprise system was created that integrated more traditional forms of enterprise modelling (e.g. process, information, resource) with these new soft enterprise characteristic models.

Good Engineering Governance (GEG)

Engineering governance is defined as "a functional governance frame work which is a sub section of corporate governance, it is the whole set of legal, cultural, and institutional arrangements that determine what Engineering functions can do, who controls them, how that control is exercised, monitoring the performance in terms of cost and quality, and identifies the risks and return from the activities that they undertake."(Hassan, et. al., 2006)

As engineering products are becoming more complex, organisations need greater integration and control in order to meet the customer's requirements. Without governance in these organisations it is difficult to have a central and cohesive view of activities. The main aims of the GEG project were to;

- investigate and understand the sponsor company's governance context specific to the engineering environment; its processes, difficulties, goals, and timescales for achieving these goals.
- identify 'best practice' for sponsor company, based on the findings, coupled with published best practice as reported by other organisations.
- develop a road-map, with supporting documentation, to tailor and instantiate this 'best practice' within the sponsor company.

For a commercial business, governance must address four aspects:

- Meeting legal requirements, for health & safety, probity, etc.
- Ensuring the development, at acceptable risk, of competitive offerings for its customers.
- Ensuring the offerings are to specification.
- Delivering the offering to the customer to the business benefit of the enterprise.

Some governance mechanisms will already be in existence; such as design reviews. Others may need to be extended, or developed; an example of this being appraisals of individuals and their contributions. There are three key issues that must be borne in mind when developing governance:

- Essentially, governance involves humans. Therefore, the processes and the metrics must be human-sensitive (i.e. as unobtrusive as possible), else false data or no data will accrue.
- Governance should measure only that which is necessary to achieve the business objective. It is a mistake to try to measure everything. With a little subtlety, it should be possible to adopt metrics (Grisogono,2004), which will indicate emergent behaviour and its likely source to enable containment of the complexity to occur.
- There must be clear responsibilities to act on the basis of the measures and procedures and resources available for actions to take place (Reason, 2001).

A generic framework for engineering governance was created through a number of case studies within the sponsor company as well as best practice identified from other forms of governance (e.g. clinical governance, school governance) together with a process for using it. This framework and process can be utilised by organisations to structure and model their own engineering governance.

Managing Tacit Knowledge in Design Reviews (MTKn)

The main aim of the MTKn project was to increase the effectiveness/efficiency of the design review process via improved management of tacit knowledge through;

- improveing the decision making process among reviewers
- supplementing of training course mechanisms e.g. informal networks for expertise exchange, advice, mentoring & shadowing etc.
- providing Design Review (DR) team profiles and selection criteria / processes
- optimising the potential for identification / closure of 'known unknowns' and 'unknown unknowns'
- capturing, sharing and reusing lessons learnt across DRs
- measuring of the effectiveness of current review practice and actors

The researchers observed various activities undertaken as part of design reviews within Air Systems. The project yielded three key deliverables these being:

1. A Baseline Design Review Process (DRP) that represents and maps out design review processes, the necessary activities and sequence of events that are involved; it is an ideal viewpoint and can be tailored in a modular fashion to suit specific projects. It is a formalised view based on experience gained across a number of projects and contains core activities along with support activities in an integrated way.
2. Recommendations for resourcing of the Design Review Process, which includes role definitions, role interactions, role boundaries (authority, responsibility, autonomy), knowledge profiles and selection criteria.
3. Improved operation of DRP by provision of metrics (efficiency & expertise), training recommendations and methods for managing tacit knowledge more efficiently.

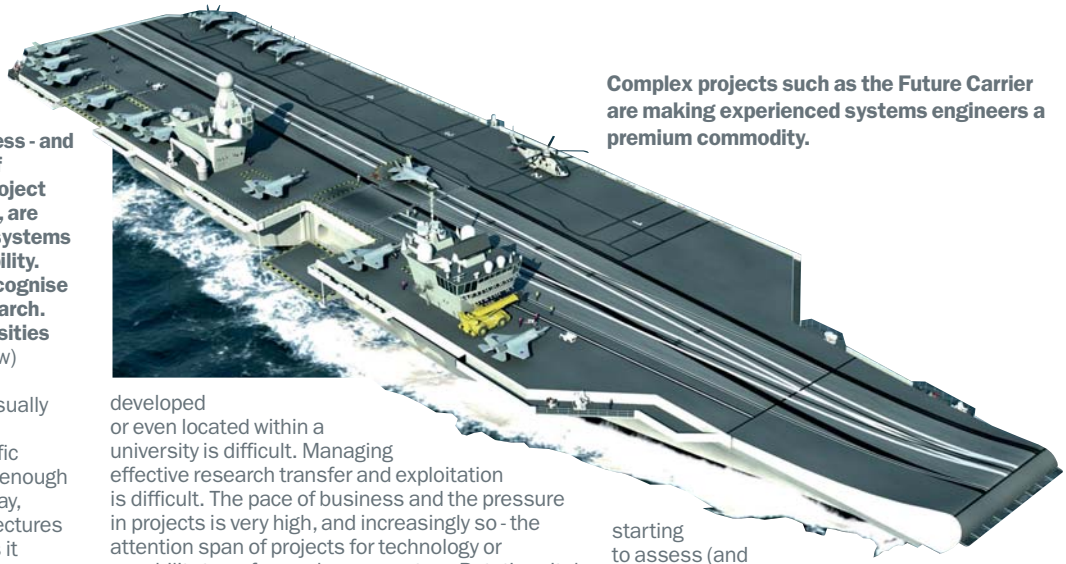
Grace Kennedy, Mohamed Hassan and Dr Esmond Urwin

For further information, contact Grace Kennedy (G.A.L.Kennedy@lboro.ac.uk)

Integrating Academic and Industry Strengths or…

what must we do together to provide systems engineering capability and skills into the UK workforce?

Part 2 - Research



Complex projects such as the Future Carrier are making experienced systems engineers a premium commodity.

Here's the next challenge. Systems Engineering is increasingly recognised by industry as a key enabler for project success - and project success is the only determinant of sustainable business success. Chronic project failures, both in business and government, are increasingly being attributed to a lack of systems thinking and a shortage of systems capability. And yet, in general, academia does not recognise systems engineering as a subject for research. Why does such a difference exist? Universities are stuck in a vicious circle. (see box below)

Advances through industrial application - usually improving through trial and error, luck and judgement rather than rigorous and scientific academic attention - have been productive enough in the past. In its practical and pragmatic way, industry produces tools, processes, architectures and life-cycle models to solve the problems it faces. So why is the involvement of academia so important to us now?

As increasingly complex projects demand increasing levels of manpower, the experienced systems professional is truly a premium commodity with little or no spare capacity to indulge the luxury/necessity of research. Important emerging problems, such as how to develop architectures for systems of systems, or how to manage capability through life, remain unresolved. So whilst industry could, in theory, continue to work independently, it does not have the capacity to staff research, nor does it have the academic reach to access the best thinking globally.

Does it matter enough for industry to invest? For BAE Systems, the answer is a definite "Yes". The company wholeheartedly embraces the need to work with academia at all levels in order to encourage the growth of academic capability needed to support industry. This means supporting and commissioning research - whether directly funded by the company, or through a joint approach to secure government funding.

That is not to say such engagement is easy or even straightforward. Showing clear business benefit when the research capability and knowledge is developed or even located within a university is difficult. Managing effective research transfer and exploitation is difficult. The pace of business and the pressure in projects is very high, and increasingly so - the attention span of projects for technology or capability transfer can be momentary. Rotating vital systems engineering staff is never easy, and technology route maps are like battle plans - they rarely survive the first engagement. Despite these obstacles, significant mutual benefit can be achieved.

"We could just look after our own houses, but this would be to miss a major opportunity"

Getting to know each other (better)
UK Universities are just as financially astute and focused as industry. So as the relationship between industry and academia gets closer, we have to understand each other's financial models, and indeed each other's management and leadership models. We each have distinct prime drivers - commercial success for industry, academic excellence for academia - yet both of us are deeply interested in and motivated by new, useful knowledge. Furthermore, as an inter- and multi-disciplinary discipline, systems engineering could appeal to academics from a broad spectrum. Yet, getting academics from different disciplines and departments to work together on integrated systems engineering research projects can be as tricky as getting industrial aerodynamicists and structures engineers to work together. A little financial incentive can help! UK Government is starting to assess (and hence fund) universities not just for excellence, but also for relevance. Proposed changes in RAE metrics mean that industrial relevance and industry funding are likely to be important determinants of a successful research group or department in the future. This gives industry new power to influence and steer the course of Systems Engineering research and technology development

Ways to engage
Even at a basic level, our education and training partnerships have borne significant research fruit, via the team based project which forms such a vital and differentiating feature of the Master programmes. Each year the cohort of MSc students is provided with a challenging and business critical research problem - business critical for BAE Systems but often with broader application potential. Invariably an innovative research product is delivered back, some of which have been directly utilised on front-line projects.

A more recent approach - integrated academic and industrial research programmes - require a higher level of involvement but is aimed at a much higher return, both in the effectiveness of technology transfer, and in the ability to secure government funding for the work. Government funding brings its own challenges, however - the need to work ▶▶▶

The Vicious Circle

- Government funding bodies do not fully recognise systems engineering as a discipline and so do not direct funding for Systems Engineering research - which means that, even when problems are identified and defined, academic research is not done.
- Research papers aren't produced, this is reflected in the UK government's Research Assessment Exercise (which rates every department in every university according to the quality of its research) and the lack of recognition and lack of funding continues.
- Lack of recognition for and poor public awareness of the subject also means that students don't choose to study it, so there is little demand and hence little funding for courses.
- These two combine to ensure that there are few academics either researching or teaching systems engineering - ie a limited Systems Engineering skillset in UK Universities.

Whilst universities are interested in systems engineering, they are not able to break the vicious circle on their own. Only with the support of industry or government - preferably both - will they be able to change their approach.

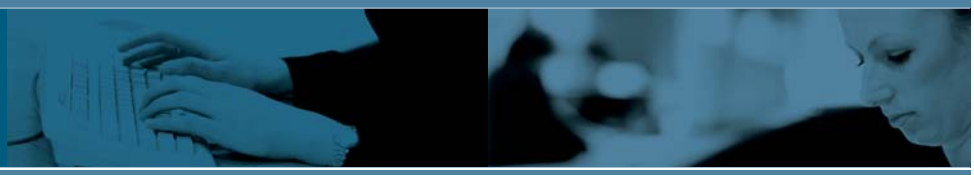
Explaining customer benefit from an MSc Group Project

1 The two areas are Autonomous Systems and Network Enabled Capability.

2 Systems Engineering - the Road to Perdition, Professor David Stubbles, 2005.

Systems Engineering Degree Programs In the United States Fabrycky, Wolter; McCrae, Elizabeth 2005.

In the **news**



The latest Dstl secondee arrived in December. Dr Matt Knight from the Land sector is exploring issues of commonality across the land vehicle fleet and looking at tools and methodologies for assessing the potential impact or benefit. Matt has a background in operational availability and integrated logistics modelling.

SEIC hosted a workshop on Architectures and Architecture Frameworks under the auspices of the NECTISE programme. This was well received, and provided a useful overview of a number of current developments in this area, including inputs from Telelogic and the MoD's Integration Authority.

Business Events

The SEIC hosted the second INCOSE Midlands Group SysML/ UML Practitioners group meeting where the 'Chip Fryer' prototype was demonstrated. Chip Fryer is a novel tool developed at Loughborough University to bridge the gap between UML-based system level design and conventional hardware design flows. The event generated a lot of interest from industry.

Two well-received events specifically tailored for smaller enterprises concentrated on themes relating to business improvement: a workshop on delivering effective internal communication within businesses and a demonstration on developing effective metrics using ERP and MRP systems.

The next INCOSE Midlands Group SysML/ UML Practitioners group event will be a **SysML workshop**, which will be delivered by Francis Thom of Artisan Software Tools Ltd. on Thursday 8th February.

'How to become an employer of choice' is the subject of an event on April 24th . This is an initiative backed by our partner *emda* and aimed at helping businesses analyse their performance in recruitment and retention.

We are also co-hosting an event with the INCOSE Rail Interest Group on the theme of Light Rail and Tram Schemes. Details to follow.

We are always pleased to hear from anyone who wants to contribute to an event or suggest something new. For this or to find out more about any event, please contact Ken Astley (tel: 01509 635208 or e-mail: k.r.astley@lboro.ac.uk).

In December, the SEIC welcomed Chris Shaw, the Clerk of the Science and Technology Committee of the House of Commons. His visit provided a valuable opportunity to showcase how ventures such as the SEIC - engaging government, academia and industry - provide ideal platforms for delivering innovative collaborative research and technology solutions. A more comprehensive visit by members of the House of Commons Science and Technology Committee to the SEIC will be planned for the new year.

If you or your company are interested in getting involved or would like any more information on any of these topics, contact Ayman El-Fatatry, Customer Manager, (a.el-fatatry@lboro.ac.uk)

▶▶▶ with a range of universities and other companies, and to handle intellectual property and security issues by focusing on generic and pre-competitive research areas, so that the outputs can be made publicly available. BAE Systems now leads two, multi-million pound, government-funded research programmes where Systems Engineering forms a major element of the programme. In each case, the research is focused on an application area to provide the essential context for the systems engineering issues and in each case, academic work is centred round a small group of universities with a growing skill base in this area, and leads to published papers and PhD theses. Since doctoral research takes around three years, progress is inevitably slow. But there **is** progress and the longer term effect is a growing recognition within UK academia and government that systems engineering is a subject worthy of academic research - and therefore of research funding. The circle can be broken.

These highly integrated research programmes get added impetus from the collocation of industrial and academic researchers, as happens in the SEIC. Staff are seconded to the centre, delivering back the output technologies and capabilities to their home business unit. The research projects could be of any duration according to need but the emphasis is always on cross-sector, pre-competitive research into some of the key systems engineering challenges that pervade a number of industries.

My call to arms here is for an increased take up of this integrated approach because we are tackling an integrated set of issue. We could just look after our own houses, but this would be to miss a major opportunity. Recent papers surveying the state of Systems Engineering Teaching and Research in Universities show a vibrant postgraduate picture in the US, with Europe, and particularly the UK, trailing (even on a per-capita basis). The exceptions in the UK include those institutions involved in the programmes described above. Far-sighted universities and businesses, who are already engaging and investing in systems engineering and are responsive and ready to seize the opportunities presented, are likely, in my opinion, to reap rich rewards.

Dr Andrew Bradley, Chairman of BAE Systems' Systems Engineering Council.

If you would like to find out more about any of the research initiatives taking place at the SEIC or at Loughborough University please contact Professor Roy Kalawsky, Technical Head of the SEIC and Director of the Research School of Systems Engineering, Loughborough University (r.s.kalawsky@lboro.ac.uk)

FEEDBACK

Please email your feedback, news and views to seic@lboro.ac.uk. Edited by Ayman El-Fatatry and Amanda Pearce.

FUTURE ISSUES

- ASTRAEA
- Performance Modelling Toolset Development

*SEIC is a contractual arrangement between Loughborough University and BAE Systems plc, with support from the East Midlands Development Agency