the system

Systems Engineering Innovation Centre
Integrating people, processes, tools and technology to create tomorrow's business and product solutions.

NEWS FOR SYSTEMS ENGINEERS
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Supportability solutions get a lift

Have you ever sat in your car, turned the key and nothing happens? You check to see if the lights are working, you look under the bonnet for loose wires or any obvious signs of damage, gradually working through your knowledge and experience to eliminate the most likely causes of the problem. If you are stumped, you call in a mechanic, who also works through potential faults based on the probability of their occurrence until the culprit is discovered and appropriate remedial action can be taken. Ultimately, diagnosis of the cause of a system failure is based on knowledge of the system and the accurate observation of the symptoms or effects of the failure.

Tornado ground crew use information from the pilot debriefing and flight instrumentation to identify and correct reported faults after every mission. Their methodology is the same as the mechanic uses for your car but the increasing complexity and the integration of many systems, means that while accurate and reliable data collection is essential, managing huge quantities of it efficiently and effectively, requires the ability to generate, maintain and utilise knowledge of fault probability.

For many years, Bayesian belief networks have been used in the medical industry as a method for mapping symptoms to diseases using a probabilistic approach. Bayes' theorem is used to calculate the probability of an illness or injury based upon knowledge of the presence or absence of a symptom or symptoms.

This approach has now been embodied in a software tool: the Intelligent Fault Diagnostic Tool (IFDT), developed by the Advanced Technology Centre (ATC) in Filton and funded by Military Air Solutions (MAS). The IFDT is used to help troubleshoot a system. It uses a model of the system which contains information about its failure modes and symptoms. It also allows the user to interact with it in order to aid the process. As well as allowing symptoms to be entered manually (or where applicable via direct interfaces to system measurements) and displaying the probability of a fault being present in the system, the tool can also advise a logical order for which symptoms should be investigated next based on the current observations and the system model.

The performance of this tool can be affected by the suitability and integrity of the underlying system model. Conventionally, information about a system's failure modes and their effects is generated in the design phase and this may or may not be updated with in-service experience. Unfortunately, generating the necessary data is usually time-consuming and prone to transcription errors and inconsistencies. The format of the data may not be suitable for the IFDT.

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The technology is being developed for trials on selected Tornado sub-systems.

Research at the SEIC, under the Integrated Wing Advanced Technology Validation Programme (IWATVP), part funded by the DTI, has provided a potential answer to the building of suitable system models for the IFDT. The solution is a software tool which guides the user through the process of generating system models from scratch, converting existing models into a suitable format or updating system models with current in-service data. This tool, currently being further developed in collaboration with MAS, provides a structured approach to produce component data libraries containing fault and effects information which is then used to automatically generate Failure Mode and Effects (FMEA) tables from a schematic of the system. These tables are populated with component failure and effects data which are then used to identify system effects or symptoms.

The IFDT has been developed further using the fuel rig at the SEIC to both understand and demonstrate its capabilities. This work which was demonstrated to a number of MAS projects culminated in a Chairman's Bronze Award for Innovation for the development team and more recently led to the technology being developed for trials on selected Tornado sub-systems.

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Improving the Bid Proposal Process

Using Organisational Systems Engineering to Analyse the '2A Phase'

As engineers and project managers know, assurance of every aspect of a bid is required before approval can be given with confidence and this rigorous scrutiny can take anything from a few days to several years to complete.

Loughborough University's Organisational Systems Engineering researchers at the SEIC have been using enterprise modelling techniques to build a picture of the activities undertaken by BAE Systems during the planning and preparing of bid proposals and their approval, in particular the latter end of the process known as the 2A Phase (from bid/no bid decision to bid approval).

The 2A Phase has many different types of reviews – commercial, technical and project management – at the back end and the situation is further exacerbated when there are short time scales involved, sometimes as little as three days. Symptoms displayed are:

- too many reviews being conducted;
- bottlenecks around reviews;
- duplication of work and multiple information flows;
- unclear role boundaries and a heavy work load for some participants.

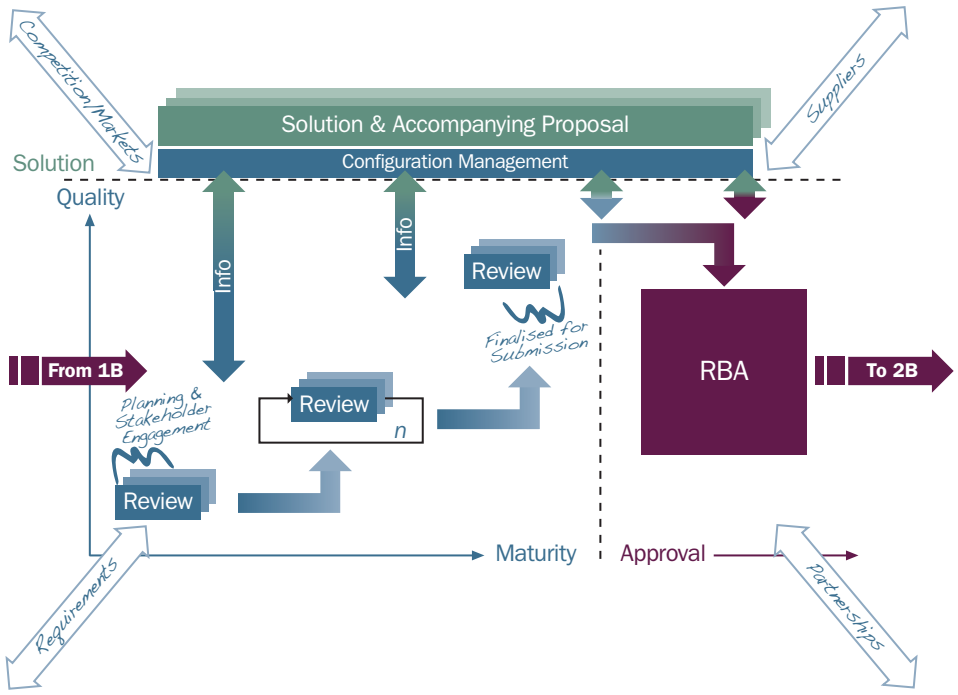
Researchers at the university were approached by the Centre for Performance Excellence (CfPE) to use enterprise modelling techniques to provide insight and recommendations for "decongesting" the 2A Phase.

By gathering data about the "as is" situation through a series of workshops involving different representatives of stakeholder groups, they modelled the 2A Phase. During the exercise, models of process, roles and decision making systems were created from different viewpoints and these were then compared to draw out commonalities and differences. A revised baseline model was created from the comparisons and a new configuration framework was introduced to give a holistic view of the phase.

This exercise provided a clearer picture of the relationship between the process, the reviews and the roles therein. It benefited the individuals involved in the process by identifying and clarifying issues and simplifying the framework within which activities are conducted.

Based on the evidence of the workshops the following interrelated recommendations were made:

Proposed Integrated Activities Framework



- **Enable Tailoring:**

Produce a Tailoring Guide
People were unsure of what could or should be tailored. Production of a guide to help the user decide what tailoring is appropriate and to give "permission" would encourage more tailoring to take place. Any best practice in dealing with different circumstances should be shared in the guide. Adequate governance needs to be maintained by ensuring that tailored differences are approved by an appropriate authority.

Tailor for Different Contract Types
There are many different types of contracts (product to service, duration, customer, position in the supply chain, competitive/non-competitive, etc) and the current review requirements seem to be suitable for product development opportunities. Some of the mandated reviews may not be needed in a services or capability contract. Some participants felt that current processes and support of those processes are useful to only a few types of contract models. 2A Phase activities need flexibility and tailoring to be effective when applied to different types of contracting models.

- **Avoid "Too Little, Too Late":**

Plan Earlier, Plan Better (Left Shift)
A common theme was the need for more left shift and better planning to spread the workload away from the end of the phase and also to allow time for review recommendations or actions to be addressed. There was also an opinion that the maturity of information prior to Phase 2A should be higher to reduce the amount of work to be done. The recommendation is to start early, get and agree the plans for conducting reviews.

Improve Resourcing of Roles
Confusion over the roles and responsibilities within Phase 2A activities and anxiety over whether people with the right skills are being resourced for certain roles can be combated with better training. People in each business area can be trained to prepare for and conduct reviews and this will also improve the perception of congestion.

- **Adopt a Holistic View:**

Change the Emphasis/Ethos
Reviews are often conducted in silos to satisfy a review requirement or a specific function so activities can appear disjointed. Essentially the current activities within the 2A Phase are correct, but there needs to be a shift of emphasis towards a more holistic view of the phase, and the purpose of the activities being undertaken. A new framework was proposed that moves away from a disjointed set of activities/reviews and towards more proactive planning, integration and control of the information flow and review activities.

Deal with the Culture Change
There are legacy cultures affecting the perception of what has to take place in Phase 2A. For example where there has been inertia from a previous change (e.g. Request for Bid Approval (RBA) being included as part of Phase 2A), people need to understand how the change will affect the way they conduct business. When changes are introduced, it is important to ensure that the legacy cultures will not impede or nullify any intended improvements.

Clarify the Purpose of Reviews
Review scope creep and duplication of review material leads to confusion over the separate purpose of each review. More effective and focused reviewing can be facilitated by formulating

a clear statement of the purpose and principles of each review at the outset. When practical, reviews should be combined to bring knowledgeable people together in dialogue and to reduce the actual numbers of reviews.

Produce and Maintain "Living" Documentation/Information
New information should not have to be produced for review specific purposes. With adequate configuration management it is possible to draw together the inputs for the different reviews without having to reformat or create more work for the bid team. If the information requirements are known earlier, then this can be used to shape the format of the information. The information flows should be clarified so that those involved know where information is coming from, what they are using it for and where the information they produce will be used. Strict configuration control will provide a trail of the developing materials and show the evolving maturity of information.

Manage the Interfaces within the Extended Enterprise
Activities surrounding information exchange during 2A with the Extended Enterprise (customers, partners, supply chain, competitors) is often out of sync or reviews are duplicated and the information flow isn't controlled. The interfaces to the extended enterprise and environment need to be managed to ensure up to date information is gathered and also to ensure the relationships are maintained or developed in a positive manner. Early decisions need to be made as to how supply chains and partnerships will be governed (i.e. will they also perform separate Phase 2As or will there be joint activities).

Establish Communities of Practice
Communities of practice can increase review effectiveness by enabling sharing of knowledge, ensuring consistency across individuals holding roles, and provision of a pool of individuals for role selection. The community of practice can also be used for getting individuals with similar issues together to solve problems.

The study concluded that the current set of activities and reviews carried out during the 2A Phase are appropriate but they need to be better planned, tailored and implemented to be more effective. Further work was conducted on the output of this study by the CfPE and the business winning integration team to put tangible actions in place to improve the activity in this Phase.

For more information about Organisational Systems Engineering or about this study, contact: Grace Kennedy at the SEIC (G.A.L.Kennedy@lboro.ac.uk) or Margaret Helsabeck (Margaret.Helsabeck@baesystems.com).

Applying natural computing to systems engineering

Natural Computing Applications Forum (NCAF) Meeting

The Natural Computing Applications Forum (NCAF) is where industrialists, academics and business people share their experiences of natural computing in an informal, lively and interesting manner. Natural Computing covers such things as neural networks, genetic algorithms, fuzzy logic, adaptive systems, machine learning, intelligent agents, Bayesian Belief Networks and decision making.

Natural Computing is the field of research that works with computational techniques inspired in part by nature and natural systems. To quote Peter Cowley (former chairman of NCAF):

"Neural (the original 'N' in NCAF) networks were originally inspired by simple models of the neurons in the brain. … (and) are now entering the statistical and operational research main stream and they form one of the most powerful tools for finding patterns in large volumes of data. …. Man made systems, particularly networks, be they power distribution, communications or manufacturing plant, can exhibit inimical emergent behaviour. That is, individual parts of the system can follow apparently well ordered well behaved, simple rules, but large collections of these individual parts develop new, complex and frequently destructive behaviour. At the trivial end we have buses arriving in threes. At the near catastrophic end we have trans-continental power system instabilities. The natural world has evolved solutions to emergent behaviour. Social insects, flocking birds and mammals manage to produce complex beneficial behaviour from individuals which follow relatively simple rules. Perhaps we can emulate this constructive, emergent behaviour and harness it to our programming and network control problems. Evolutionary algorithms have already proved their worth for scheduling and optimising complex engineering systems. Unfortunately they do not scale well to generating (evolving) complex software. Perhaps combining distributed computer systems with simple software generated by evolutionary algorithms will enable benign and usefully complex emergent behaviour to develop."

Likewise a system can be defined as a combination of elements which form a unitary whole. These elements can be complex in nature and show emergent behaviour. Systems engineering is an inter-disciplinary approach to problem solving applicable across many sectors. It spans the whole system lifecycle from concept through design and manufacture into use and finally disposal. It helps define customer needs, required functionality, design synthesis, and aids system verification and validation by considering the entire problem domain. The aim is to produce a system that satisfies defined customer and technical requirements within cost and timeframe constraints. Other important issues such as customer training, product maintenance/upgrade and product disposal are an integral part of the overall systems engineering process.

September's NCAF meeting at the SEIC was entitled 'Utilization of Natural Computing in Systems Engineering.' The wide spectrum of systems engineering provided an opportunity for numerous specialists to contribute, and develop the system-wide point of view. As an example, the utilization of genetic algorithms for optimisation needs to look at the overall system rather than individual sub-systems and needs to consider the whole lifecycle from conceptualisation through design and manufacture to disposal.
Themes addressed at the meeting included:

A tour of the Advanced VR Research Centre at Loughborough University.

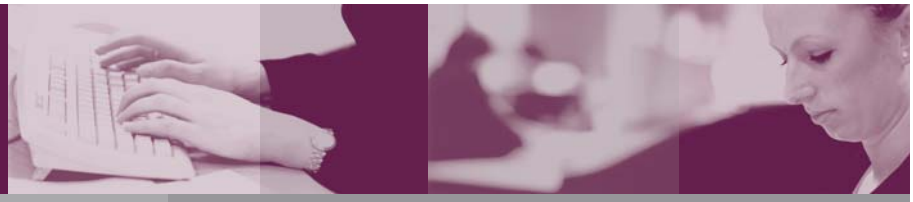
- Autonomous vehicles and a demonstration of autonomous system interaction, an approach to the MOD grand challenge and the information processing objectives of the SEAS DTC.
- Utilising Fuzzy decision support to compare modelling tools and to ensure the model is fit for purpose.
- Utilising data mining to predict which crime scenes potentially offer the best opportunity of recovering forensic samples.
- Mathematical based presentations on hybrid reasoning systems to support the modelling of estuaries and real-time implementation of genetic algorithms in dynamical environments.

A skittle match and a puzzle competition provided friendly rivalry and proof, if proof were needed, that ability is inversely proportional to alcohol consumption.

And the puzzle? If a 6" long cylindrical hole is drilled through the centre of a sphere, what is the volume remaining? Answer in the next issue!

For further information about NCAF see www.ncaf.org.uk or contact Steve Whittle at the SEIC (S.Whittle2@lboro.ac.uk) .

In the **News**



Loughborough University is delighted to welcome Professor Charles Dickerson to the BAE Systems, Royal Academy of Engineering and EPSRC Star appointment, Chair in Systems Engineering. Professor Dickerson will be based in the Department of Electronic and Electrical Engineering and become a key member of the university's Systems Engineering research and teaching team.

Before joining the university, Charles was a Fellow of BAE Systems and technical leader for the architecture-based family of systems engineering efforts. Prior to that, he served as Director of Architecture in the office of the Assistant Secretary of the US Navy for Research, Development, and Acquisition and the technical work he carried out there was documented in an internationally recognized book*. At the MIT Lincoln Laboratory, Charles has also conducted research and directed flight tests, investigating low-altitude radar propagation and electronic countermeasures. His aerospace experience includes advanced air vehicle design and survivability at both Lockheed's "Skunkworks" and Northrop's Advanced Systems Division.

Professor Dickerson gave an inaugural lecture on the theme of Model Driven Architecture for Systems Engineering.

Chair of the INCOSE Architecture Working Group, Charles works with the international community on architecture issues and standards, and also supports the Office of the Secretary of Defense on System of Systems Engineering guidelines.

* Using Architectures for Research, Development, and Acquisition: Dickerson, Soules, Sabins, and Charles.

The SEIC hosted a visit by Dr Paul Stein, the MoD's Director for Science & Technology. The aim of the visit was to acquaint Paul Stein with the SEIC, its objectives and operational framework in order to enhance the MoD's support for systems engineering, in general, and the SEIC, in particular. He observed that the SEIC could benefit from a common theme running through the presentations and a flavour or approach applied across the disciplines in order to show how the whole is bigger than the parts.

The SEIC was pleased to welcome back Professor David Oxenham, Senior Programme Leader Precision Attack and Strategic Systems, DSTL. David emphasised the priorities for DSTL in the context of systems engineering and laid the foundations for the forthcoming visit by Mike Steedon (Technical Director at DSTL) and Chris Gibson (Programme Director for Systems).

On the 29th and 30th October, the SEIC is the venue for the 3D MINTEGRATION 2007 Conference. This multi-disciplinary programme sets out to create a paradigm shift in manufacturing by developing the technologies and strategic approaches required for the production of highly-integrated, cost-effective and reliable multi-functional 3D miniaturised/integrated devices.

For more information or to register, visit www.3d-mintegration.com

On the 11th December, the SEIC is hosting a bridging session between micro-nano-technologists and systems engineers to introduce the value of systems engineering to the former. All are welcome to this event which is co-sponsored by PATENT-DfMM, NEXUS and CEMMNT.

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).

▶▶▶ Procurement models which contract to deliver capability rather than products have increased the importance both of ensuring availability of systems and reducing through life costs in maintaining them. Coupled with decreasing resources and an ever changing skills base, this leads to an urgent demand for improved system support tools. The benefits of this tool are a reduction in the time to generate FMEAs, a decrease in transcription errors and inconsistencies and the generation of a format which can be read by the IFDT. It also collates test results from the IFDT and where applicable uses them to update and refine the system model. By reducing the number of 'no fault founds' (systems removed and tested only to be found to be functioning correctly) and isolating faults more quickly and reliably, significant savings on time and costs can be made.

Acceptance and adoption of new technologies depends on taking into account operational pressures, establishing users' trust in the new technology and demonstration of clear benefits from its use. Therefore the IFDT and system modeller technologies are now being trialled and test results from several Tornado sub-systems will be evaluated early in 2008.

For more information please contact:
Dr Tony Martin at the SEIC (T.Martin2@lboro.ac.uk) or Richard Bovey (Richard.Bovey@baesystems.com).

FUTURE ISSUES

- TRAiDE
- Supporting Undergraduates

FEEDBACK

Please email your feedback, news and views to seic@lboro.ac.uk.
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