

Systems Engineering for Through Life Capability Management



A complex path to excellence

BAE SYSTEMS

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About BAE Systems

BAE Systems is the premier global defence and aerospace company delivering a full range of products and services for air, land and naval forces, as well as advanced electronics, information technology solutions and customer support services. With 97,500 employees worldwide, BAE Systems' sales exceeded £15.7 billion (US\$ 31.4 billion) in 2007.

We have assembled this booklet to provide you with information about systems engineering in BAE Systems and the work of the Systems Engineering for Through Life Capability Management working group (SyE4TLCM). We hope that it is interesting and informative. If it has stimulated or re-awakened an interest in systems engineering, or if you would be interested in active involvement in our work then please contact your Business representative.

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Providing profit and growth

Systems engineering has been described as 'the missing discipline'. In fact it is the core capability which underpins profitability and growth in today's industry and commerce, complementing traditional engineering fields.

Systems are all around us. Your car is a system; a major construction project is a system; and systems have been around us for a very long time – it is their scale and complexity that has changed. Today's systems cannot be designed by one person, with a single speciality. What is needed is a team to combine a focused approach with an appreciation of the much bigger picture.

Systems engineering is about applying a systematic approach to develop integrated systems from the earliest identification of need, through the delivery and in-service support phases to final disposal. It integrates all of the engineering disciplines in order to successfully develop systems, products and services. It focuses on defining customer requirements and capabilities early in the development cycle, documenting requirements then proceeding with design, assessment, realisation, and validation against customer needs.

We apply the systems approach at all levels and must consider the complete problem – not just the equipment aspect of a system. We consider the business and the technical needs of all stakeholders with the goal of providing the best value and quality system, product or service that meets user needs. So from the system's earliest inception through to retirement, systems engineering must consider and balance the demands of all aspects. The UK Ministry of Defence (MOD) describes this breadth of developing and sustaining capability as the Defence Lines of Development: training, equipment, personnel, infrastructure, doctrine, organisation, information and logistics. BAE Systems maintains and builds its reputation on successful through life integration of systems in the air, land, sea, space, and command and control market sectors. The higher the value, the complexity, the degree of integration, the risk and

the novelty of the system, product or service, the more important systems engineering becomes.

It is a key element of our engineering and technology capability, featuring in the Defence Technology Strategy and crucially supporting Through Life Capability, not just product design.

Through life

The emphasis of defence spending is moving from equipment-based to capability-based acquisition. The UK MOD bases its needs around Through Life Capability Management (TLCM), defined as 'an approach in which every aspect of new and existing military capability is planned and managed coherently across all Defence Lines of Development from cradle to grave'. This whole-life approach is beginning to shape the way we work, ensuring that operational requirements are met and maintained in the most cost-effective manner.

So much for systems engineering being the 'missing discipline'. It is at the heart of TLCM and as such enjoys an increasingly high profile in the company and the wider business world.

The demands of systems engineering

- Complex problems and operational context
- Need to understand and manage complexity by establishing and applying structured approaches
- Need to establish clear requirements, and manage the engineering response through to validation of the outputs
- Engagement of all business functions – including management, strategy, commercial, and across the supply chain
- Need to manage engineering information through life

Leading by example

The BAE Systems UK/ROW Systems Engineering for Through Life Capability Management working group is the focus for evolving our systems engineering approaches within the business.

The working group objective is to enable the deployment and maintenance of common and effective systems engineering approaches to support business activities in the emerging Through Life Capability Management business context, suitable for all sectors and home markets. The working group is the hub of the community of practice in systems engineering. It is responsible to individuals and the business for professional leadership in systems thinking and systems engineering, including:

- Interfacing external systems engineering stakeholders/institutions
- Sponsoring the International Council on Systems Engineering (INCOSE) on behalf of BAE Systems UK/ROW
- Helping ensure that systems engineering best practice is shared effectively
- Promoting systems engineering capability improvement across the business
- Providing advice regarding systems engineering training, development, education and research.

What does that involve?

Representatives from each Business collaborate to address common priorities by maturing and delivering elements of engineering capability (e.g. process, training, template). These priorities are determined not only by the demands of realising through life solutions, but also by an assessment of existing and future company systems engineering capability, an awareness of other related activities and a gap analysis against business requirements, priorities and

aspirations. Maximum use is made of opportunities to re-use or adapt capability elements available from individual Businesses or from suitable external sources.

The working group uses expert/practitioner workshops both to collect information and experience, and to share results across the company. As specific topics mature, increasingly formal training packages will be identified and developed as the need arises.

"Despite systems engineering as a discipline having begun its development around sixty years ago, its scope and definition remain subject to debate even among qualified practitioners..."

From the MOD Defence Industrial Strategy

Spreading the word

The working group is also the hub of the internal company systems engineering community of practice. As well as internal collaboration, it engages with wider customer, supplier and partner organisations and academic and professional bodies including contacts via INCOSE UK and INCOSE International.

Through Life Capability Management is "an approach to the acquisition and in-service management of military capability in which every aspect of new and existing military capability is planned and managed coherently across all Defence Lines of Development..."

Enabling Acquisition Change, June 2006

INCOSE – an international voice

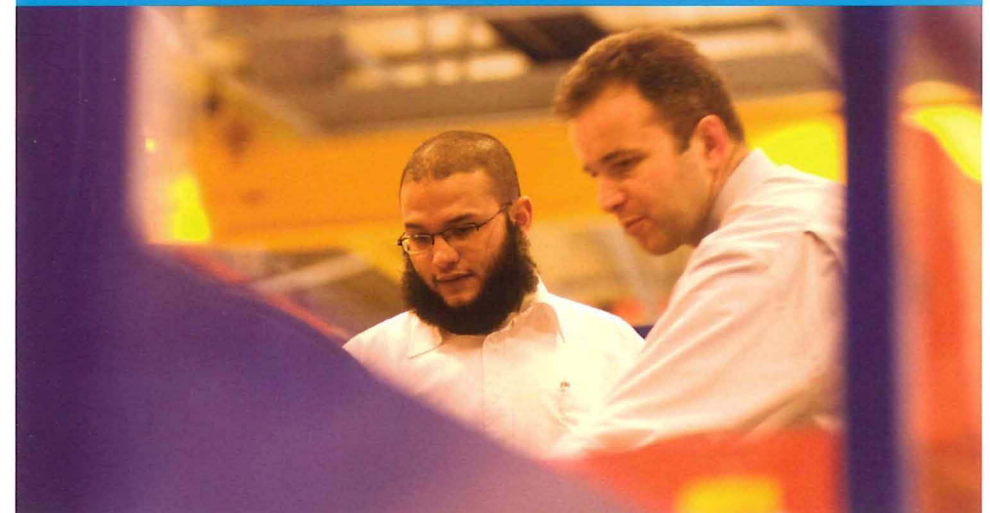
The International Council on Systems Engineering (INCOSE) is a not-for-profit organisation founded in 1990. Its mission is to advance the state of the art and practice of systems engineering in industry, education and government by promoting interdisciplinary and scaleable approaches for technologically appropriate solutions to meet society's needs.

BAE Systems supports INCOSE at both corporate and individual levels because INCOSE is an important forum in which we can participate in maturing both systems thinking and the systems engineering discipline, and we can enable our engineers to develop their individual capabilities:

- At a business level INCOSE allows BAE Systems to engage with customers and industry leads and to help shape best practice, standards, the wider engineering agenda, and to derive institutional learning from these other bodies
- At an individual level staff benefit from attending INCOSE International and regional/local events; the use of the INCOSE reference materials and assuming leadership roles in INCOSE locally, regionally and internationally.

The close relationship between BAE Systems and INCOSE is mutually beneficial.

"There is great value in the way the company has supported its staff as leaders within INCOSE. BAE Systems sees systems engineering as an extremely important discipline, something that must be nurtured, and INCOSE is a premier organisation for developing and disseminating systems engineering skills and knowledge on a global scale. For me, the excitement in systems engineering is the constant challenge – a challenge to develop and produce appropriate, balanced products and services to meet customer needs effectively; a challenge of multiple disciplines, techniques, mathematics and human factors, amongst other issues. I like to look at both the detail and the big picture, and that is what effective systems engineering is; not just focused internally but also understanding the end users, the maintainers and the political environment. The scale and complexity of systems continues to grow, and we must grow too." Andrew Daw – INCOSE UK Chapter President, BAE Systems Frimley.



Opportunities for all

If systems engineering requires a new breed of engineer – where do they come from? Training and education are the keys.

A systems engineer needs in-depth knowledge across a wide range of real world subjects and the ability to analyse a problem, taking into account every factor to organise solutions and assemble them as a holistic answer. He or she needs to keep an eye on the future too – systems have a habit of evolving. So the best systems engineers are not 'jacks of all trades', more a master of several and they must be highly effective team players, because a system can only be successful if it meets the requirements of the overall 'super system', which always calls for collaboration. As demand for systems engineers has risen, the pool of talent has shrunk. In the UK the number of students enrolled in engineering and technology courses has fallen considerably in recent years. This means that there will be fewer future candidates for technical positions and this could affect our competitiveness and the future capability of the engineering industry.

BAE Systems has taken a proactive approach to address this skills shortage, establishing some ground-breaking collaborations between industry and academia. The degree course at Loughborough University is a prime example. Did you know that BAE Systems sponsors a number of undergraduates on the MEng course at Loughborough University in order to build a long term relationship aimed at recruiting them successfully into the business, rather than their joining other sectors such as banking and consultancy which also value their way of thinking?

Engineering Developing You... and you

The company has also developed a successful 'in-house' suite of courses under the banner Engineering Developing You (EDY) which, since its launch in 2001, has provided around 240 courses for more than 4,000 delegates, totalling more than 11,500 days! Systems engineering forms the backbone of these courses. EDY encourages engineers to take a rounded view of their own capability and use other functional Developing You programmes, as well as technical education and training, to provide them with the knowledge and experiences they need, and this applies

particularly to systems engineers. The Integrated Development Portfolio contains numerous learning opportunities:

Visit: <http://www.vuni.intranet.baesystems.com>

Work is underway to produce a two day introduction to Systems Thinking – watch out for a summer 08 launch.

And remember to look at the quarterly EDY Ezine – news and views about engineering learning and development activities. Goes live in June, September and December 08.

EDY and professional recognition

Many systems engineers want to attain recognition of their professional status through membership of one of the engineering professional institutions and thereafter registration, for example C.Eng, IEng, and Eng.Techs. Knowledge gained through EDY training programmes already provides a foundation for the development of engineering competencies that will support that aim. Discussions are taking place to see whether EDY-based competency evidence could be used to support the registration process.

Competency framework

INCOSE's advisory board was behind the development of a systems engineering competency framework which BAE Systems and other organisations have adapted to help develop their people through schemes such as EDY.

For more information see: <http://www.incose.org.uk>

Systems Engineering Doctorate Centre

Have you identified a piece of research that needs to be done? Would you be the person to do it? Then maybe the Systems Engineering Doctorate is for you.

Coordinated at Loughborough University, the SED is a four year full-time programme resulting in an Engineering Doctorate in systems engineering (EngD). Research engineers spend ¾ of their time working with the company on a research project. The

other time is spent undertaking masters-level training in systems engineering skills and specialist technical subjects directly related to their research, as well as developing management capabilities.

MSc at UCL tailored for industrial delegates

The Systems Engineering Management MSc at UCL has a broad portfolio of course topics. Six taught modules are required for the MSc, and a project carried out in the delegate's usual workplace. Together with the project elements, three modules form the core of the course, leaving another three to be selected from the range of options. These modules are provided in a format which allows sufficient flexibility to tailor to the needs of individual delegates and companies. Because industrially-based delegates have pressures on their time, the course:

- Offers flexibility in the timing and location of the project work
- Makes use of direct teaching and distance learning
- Delivers taught elements over one week (reading and assignment work will be necessary to complete each module)
- Publishes the module timetable well in advance of module delivery

For more see:

<http://www.mssl.ucl.ac.uk/syseng/pages/mscse.html>

Masters in Advanced Systems Engineering – Now in its 8th year, Loughborough University designed this two-year part-time course to meet the needs of the UK defence and aerospace industry. It is run through Loughborough's Department of Electronic and Electrical Engineering with strong support and input from experienced systems engineering professionals from the industry. <http://www.lboro.ac.uk/departments/el/postgraduate/advanced-systems-engineering-msc.html>

This MSc is about providing knowledge and technical expertise in a selected range of defence and aerospace technologies, but most importantly, within an integrated systems engineering framework, allowing effective use of related technologies and techniques. Aimed at senior product development engineers who want to develop and broaden their existing capability to include systems engineering, the study is done largely independently but is supported by a personal tutor.

Cranfield University Systems Engineering MSc

The Systems Engineering for Defence Capability MSc is a Defence Academy (DCMT) course used by the UK MOD as the educational element of their career development activities for systems engineers in acquisition. The course makes specific reference to systems engineering competency frameworks and relates them to best practice process, methods and tools. The Systems Engineering for Defence Capability course is focused on the basic principles of systems engineering, and how they can be applied to any level of systems problem. It covers the application of these principles to the acquisition lifecycle and the through life delivery and support of integrated capability, as well as general defence technologies and technology maturity. Although it doesn't look in detail at the system design process for specific application domains, the course is of interest to those in industry who need to work directly with the MOD customer to support capability acquisition.

For more information see:

<http://www.cranfield.ac.uk/dcmr/>

Learning online

LearningZone is free and available to all employees 24/7. Take advantage of the 500 videos, 2,000 online books and 6,000 abstracts, including some bespoke EDY eLearning courses. <http://elearn.intranet.baesystems.com/YourLearningZone/user/login/login.asp>



Systems Engineering in the Businesses



The path to excellence

Systems Engineering for Through Life Capability Management working group involves every Business and its influence will reach external and partner organisations too.

The working group's aim is to deliver the systems engineering capability enablers needed for the Businesses to produce, maintain and evolve world beating platforms, products and services in the emerging Through Life Capability Management business context.

The key enablers are process, tools and facilities, formal/informal learning and development, and knowledge/information management. This brochure contains examples of each of these areas and it's important to note that the working group represents the views of all parts of the Business.

Each Business is represented in the working group, and as well as sharing in the development work, representatives assert individual business priorities; feed back information on progress into their Business and are the principal route by which improved capability elements are rolled out in the company.

How it works

The Business representatives play an active part in the working group activities, taking responsibility for:

- Establishing and articulating Business needs

- Bringing forward relevant current capability, and information on ongoing capability improvement programmes
- Participating in the main activities of the working group
- Providing additional engineers and subject matter experts to contribute to the group's activities
- Communicating relevant outputs into their Business. Each representative communicates outputs and works to embed new approaches into their Business

Outputs are expected to include:

- New or updated processes suited to realising and delivering TLM solutions
- Information regarding tool use to underpin processes
- Access to the wider knowledge base of information available within BAE Systems
- Learning/teaching material to support individual development.

Developing our expertise

Research is relevant

Systems engineer Samantha Brown is part way through an Engineering Doctorate at Loughborough University. It is almost 20 years since she first graduated, and being a student once more has its challenges – especially as she is also a busy mum! Her four year course is research-based, and the projects she is currently working on are directly relevant to her position as part of the BAE Systems team at the Systems Engineering Innovation Centre.

She said: "It's quite a commitment to become a full time student again, but it is a real luxury to have time to take a step back from the frontline and think.

"Too often we are faced with problems and complexities that other people have seen before, but we don't always have time to look back and find existing answers. As part of my research I can do just that. I have had 20 years in engineering and am used to problem solving, but it is great to be able to look for systems engineering solutions on a broader scale which will benefit the business as a whole.

"Systems engineering as a discipline is still very young, and it is evolving. It demands people who can take a 'big picture' view, something which I have found comes naturally to me. Although my first degree was in mechanical engineering, I came to systems engineering through the application of concurrent engineering in a manufacturing environment and have never looked back. I see this Doctorate as a way both to apply my knowledge and experience to today's complex problems, and to gain a more formal education in a rapidly developing subject. I'm enjoying it, despite the challenges!"

- Samantha is currently President-elect of the International Council on Systems Engineering (INCOSE). Her course at the Systems Engineering Doctorate Centre (SEDC) at Loughborough University is Government-funded through the Engineering and Physical Sciences Research Council (EPSRC)

For more information see:

<http://www.incoe.org>
<http://www.lboro.ac.uk/departments/el/sedc/>
<http://www.epsr.ac.uk>

Doctorate is the day job

Mandeep Khella first graduated in 2002, but has embarked on a full-time four year doctorate level programme of research, while still being employed by BAE Systems.

How is that possible? Based at the SEIC, the research within his group has always been focused on supportability and more specifically Through Life Systems Health Management for complex assets such as military fast jets and UAVs. Already having a suitable research programme and a company to support the research, it made sense for Mandeep to apply for the EngD programme at Loughborough University and effectively the day job has become the EngD.

A year and a half on, with one exam and three courseworks under his belt, he is preparing for the beginning of another semester. He said: "I hope to achieve several objectives, the prime goal being to develop a detailed understanding of systems engineer principles and gain experience in their application to real world issues. Systems engineering is seen as a multi-disciplinary skill set vital to dealing with emerging engineering challenges.

"Within my group, research has been progressing to help address a variety of through life challenges through the Intelligent Fault Diagnostic Project, which is developing a suite of tools that enable system diagnostic models to be produced and embedded in a Bayesian Belief diagnostic engine. The project is a collaborative venture between MAS (Warton), ATC (Filton) and the SEIC.

"The tools have been developed and evaluated on an experimental fuel rig at the SEIC and are now being evaluated under the Tornado ATTAC programme. Further tool developments on other air platforms are currently being considered, as well as potential application into Land Systems and Submarines."



Research

Innovation in systems engineering

The Systems Engineering for Through Life Capability Management working group helps formulate decisions on research and helps to identify and implement best practice.

Every Business fosters elements of research, but the Systems Engineering Innovation Centre (SEIC) is a pioneering £60 million collaboration between industry, education and regional authority. Developed in partnership between BAE Systems, Loughborough University and the East Midlands Development Agency, it spearheads research and training in all aspects relating to the development and delivery of systems, products or services which are characterised by complexity, novelty or risk.

The centre aims to provide business with a competitive advantage by improving systems engineering skills, and for the first time the SEIC pulls researchers and engineering under the same roof as academic peers. By 2010 the SEIC will be one of Europe's top 20 centres of excellence and a national source of reference and expertise.

In response to the changes in the world of defence and homeland security, SEIC is creating and implementing advanced technologies and systems, enabling customers to maintain operational and strategic advantage in the battlespace. Research programmes are focused on areas of key importance to future defence operations such as Network Enabled Capability and Intelligent Autonomous Systems.

Systems Engineering – for the planet!

That's the theme for the 2008 INCOSI International Symposium, held in the Netherlands in June. The aim is to hear how systems engineering can help form solutions that address social, economic, technological and political concerns. Systems engineering really is all around us!

For more information see:
<http://www.incose.org/symp2008>

Showcase

The SEIC recently hosted a showcase event at Loughborough University demonstrating the range of research undertaken in systems engineering. It was chaired by Group HR Director Alastair Imrie and Professor Shirley Pearce, the University's Vice Chancellor.

Alastair Imrie said that systems engineering is a key element of BAE Systems' engineering and technology capability, which features both in the Defence Technology Strategy and in the context of support and Through Life Capability – not just product design.

TRAIDE off

Members of the Systems Engineering Innovation Centre (SEIC) have been working with colleagues in Strategic Capability Solutions and MOD to explore the challenges associated with Through Life Capability Management and how they can be addressed.

A pioneering project, it involves visualisations and decision aids known as TRAIDE (TLCM Robust Acquisition integrated Decision Environment). The aim has been to develop an inclusive approach so that 'best of breed' solutions will emerge. The only way industry and MOD will be able to implement TLCM effectively will be to work together and TRAIDE is focused on providing information management as a key enabler to TLCM and evidenced information for informed decision making. It connects directly to MOD's Capability Planning Process.



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engineering/ukrow_engineering_council/basic_syst_eng.htm](http://connectus.intranet.baesystems.com/corporate_plc_(know_how)/engineering/ukrow_engineering_council/basic_syst_eng.htm)

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