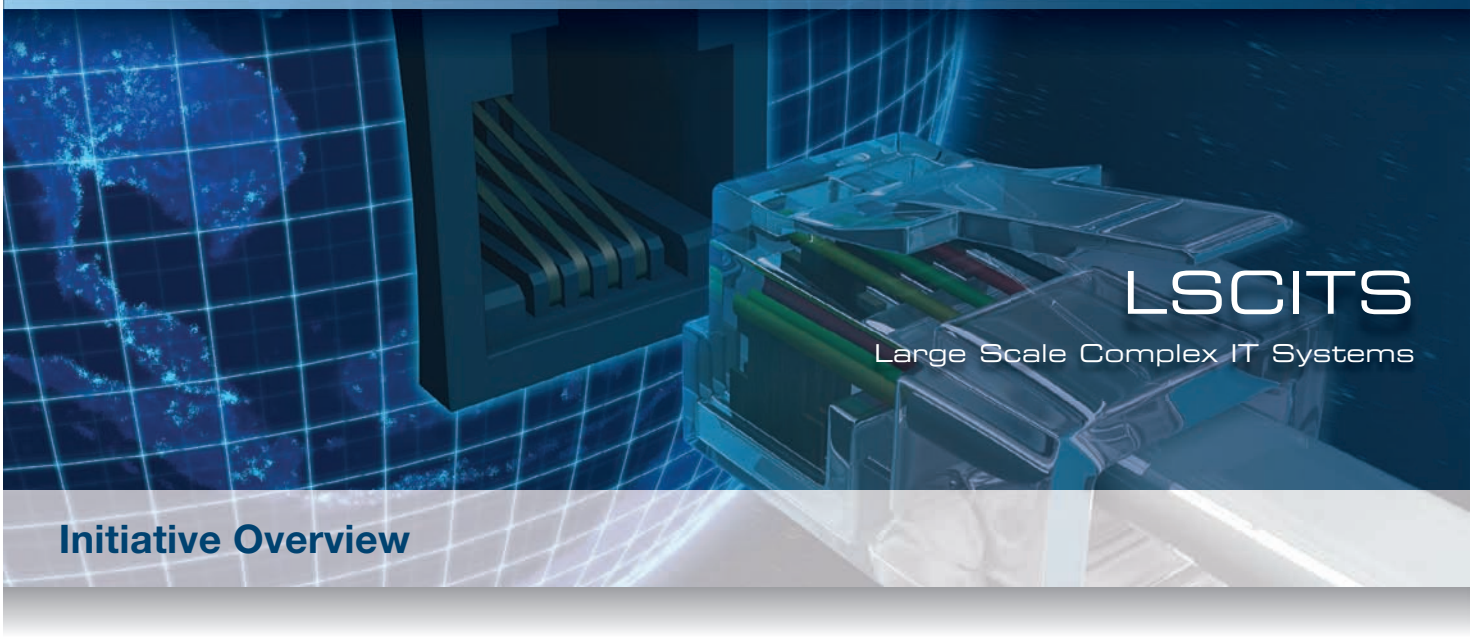


LSCITS

Large Scale Complex IT Systems

Initiative Overview

An Urgent and Growing Problem

Leading British academics and industrial practitioners have established a national strategic coordinated research and training initiative focusing on the science and engineering of Large-Scale Complex Information Technology Systems (LSCITS). Funds of approx £10m have already been committed by the EPSRC, the main UK funding agency for computer systems research.

The motivation for the LSCITS Initiative is the on-going growth in the size and complexity of information technology (IT) systems. Our ability to develop, maintain and manage such systems is falling behind the growth in their complexity. There is a high risk that we will find ourselves reliant on IT systems that we don't fully understand and that we cannot effectively manage.

The roots of complexity in IT systems are their increasing size; the increasing involvement of many different organisations in their construction and use; and the increasing rate of business and social change that they have to accommodate. To manage and control complexity, we need better technical tools and methods of system development. We also need a better understanding of the human, social and organisational issues that affect the procurement, development, deployment and use of complex IT systems.

The Initiative will establish a coordinated international network of researchers in industry and academia with the skills and knowledge appropriate to dealing with the problems of current and future LSCITS across their life-cycles. The Initiative's Training Programme is intended to produce the next generation of systems engineers and technology innovation leaders.

Both the LSCITS Training Programme and the LSCITS Research Programme will bring together academic researchers and industrial practitioners. This flyer gives an overview of the Initiative's general structure and approach. There are additional flyers giving more details of the LSCITS Training Programme and the Initiative's Research Programme.

Overall Aim

Our aims are to improve existing technical approaches to complex systems engineering and to develop new socio-technical approaches that help us understand the complex interactions between organisations, processes and systems. We will tackle the following problems:

System Understanding. The principal functional and non-functional properties of complex IT systems cannot be completely understood by our existing 'reductionist' approaches.

System Interactions. Systems interact with their operational environments in many different ways.

Systems and Organisations. Complex IT systems are specified, developed, used and maintained within organisations that may themselves be thought of as complex systems. The development, deployment, evolution and use of the IT systems is thus influenced by human, organisational, business, social and political factors.

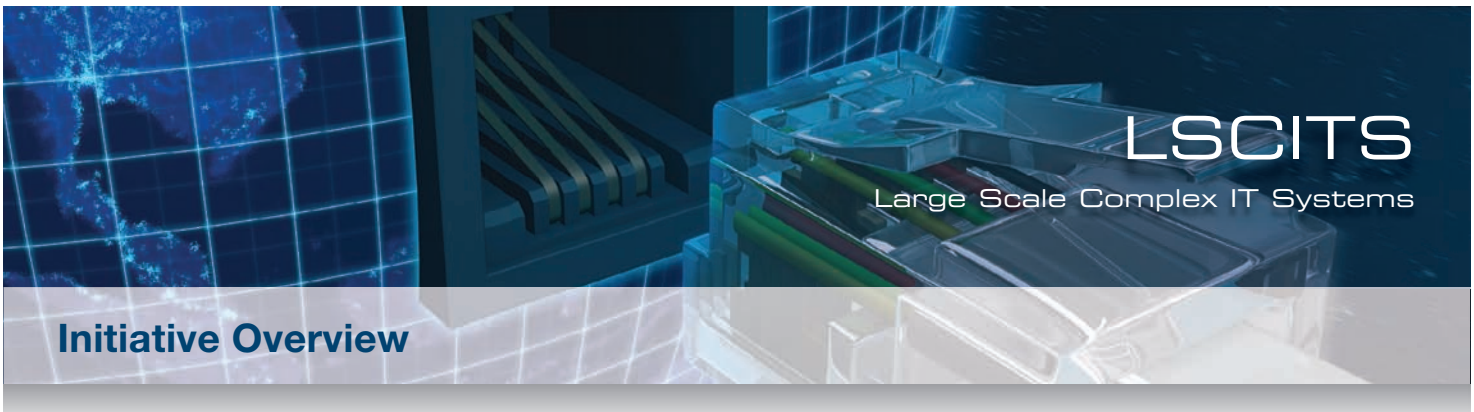
Conceptual Framework

The inherent tension between stability and change in LSCITS requires an approach to research that includes both of these perspectives.

Stability: The system's essential properties must be maintained, its key variables kept within the limits of system viability, and its goals must be kept in step with the goals of the organisation that it serves.

Change: Agile reaction and adaptation is desirable, reducing the time required to make appropriate changes in response to external pressures and perturbations, and to deploy these changes across organizations.

A key research question is then: how are essential large-scale complex IT system properties maintained in the face of change? There is no easy answer to this, but we must certainly reason at different levels. These include the detailed implementation level, the intermediate level of development and operational processes, and the higher level of organizational dynamics.



LSCITS

Large Scale Complex IT Systems

Initiative Overview

The LSCITS Consortium

A collaboration is required to tackle the problem because there is no single university in the UK which includes all of the expertise required to address issues of both stability and change.

The founding members of the LSCITS Consortium are each leading academics, internationally recognised for their research.

Dave Cliff (Initiative Director)
Professor of Computer Science
University of Bristol
dc@cs.bris.ac.uk

Justin Keen
Prof. of Health Politics & Info. Management
University of Leeds
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Marta Kwiatkowska
Professor of Computer Science
University of Oxford
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John McDermid FREng (Co-Director)
Professor of Software Engineering
University of York
john.mcdermid@cs.york.ac.uk

Ian Sommerville (Co-Director)
Professor of Computer Science
University of St Andrews
ifs@cs.st-andrews.ac.uk

A unified collaboration offers significant advantages:

- It allows each site to leverage expertise from the other sites.
- It enables us to integrate theory (Oxford, Leeds) and practice (York, St Andrews).
- It allows for the development of common perspectives on the LSCITS problem.
- It means that integration can be controlled - we are able to ensure that different streams of work remain compatible.
- It presents a single interface to industrial partners, funding agencies, and related projects.
- It provides a core of work that can be extended and complemented by new projects.

Industrial Partners

The Initiative is intended to be intimately coupled to the needs of industry, commerce, defence, and the public sector. The initial structure and content of the LSCITS Research Programme and of the LSCITS Training Programme are each the result of extensive consultation with researchers and practitioners in a wide variety of organisations. Over the lifetime of the Initiative, both programmes will be revised on the basis of feedback from ongoing consultation. It is expected that a range of companies and organisations will become involved as sponsors of research and training within the Initiative as it progresses. Approaches and offers of involvement from prospective additional industrial partners and sponsors are always welcome.

Management Steering Boards

The LSCITS International Scientific Advisory Board (ISAB) advises on the scientific quality of the Initiative's research activities from a worldwide perspective. It is composed of leading researchers in the science and engineering of LSCITS drawn from academic and industrial organisations around the globe. The ISAB includes members from Carnegie-Mellon University, Hewlett-Packard Labs, IBM Labs, MIT, and the universities of Toronto, Queensland, and Dortmund. The founding ISAB Chair is Professor Cliff Jones, of Newcastle University, UK.

The LSCITS National Stakeholder Board (NSB) exists to ensure that the LSCITS Initiative best meets the national need, and is integrated appropriately with related organisations, programmes and initiatives in the UK. Members of the NSB include representatives from companies such as BAE Systems, British Telecom, and Rolls-Royce; from UK public-sector organisations such as the Ministry of Defence, the Department of Health, and the EPSRC funding agency; and from directors of related UK initiatives such as the two UK Complexity Science doctoral training centres, and the UK's defence Software Systems Engineering Initiative (SSEI). The founding NSB Chair is Dr Mark Thomas of IBM UK.

UK Government Funding

The Engineering and Physical Sciences Research Council, the primary funding agency for computer science in the UK, has reserved funds of approx £10m for the LSCITS Initiative over the period 2007-2012.

EPSRC Engineering and Physical Sciences Research Council

LSCITS

Large Scale Complex IT Systems

Research Programme

Phase One of the LSCITS Research Programme runs for five years from October 2007, primarily funded by a grant of £5.6m from the UK's Engineering and Physical Sciences Research Council (EPSRC). The founding members of the LSCITS Consortium will work closely with industrial researchers and practitioners, and with workers in related research initiatives. The initial research programme involves an integrated programme of work-packages that span a "stack" of complementary approaches to current and future challenges in the science and engineering of LSCITS.

A Systems-of-Systems Approach

The complexity that is inherent in large-scale systems stems from a variety of causes. These systems are often designed to address problems which, by their very nature, cannot be completely defined: they have to meet the (rapidly changing) needs of diverse stakeholders; they must integrate with a range of other legacy systems, processes and policies; they may be critical systems that have to deliver both a high level of performance and dependability; and they are profoundly affected by political influences in the organisations developing and procuring the system, and in the broader system's environment.

While it would be simplistic to suggest that we can solve all of the problems, we believe that we can make significant progress by altering our perspective on the engineering of LSCITS. Rather than considering this to be a problem of specifying, developing, deploying and operating a large-scale system, we believe that we should look at the problem as being a system-of-systems problem. By examining the relationships between the different systems that make up and interact with each other, and the systems involved in procuring, deploying and operating IT systems, we believe that we can make headway in tackling the issue of complexity.

The LSCITS Stack

By considering the challenges of LSCITS engineering as a system-of-systems (SoS) problem, it becomes clear that there cannot be a single 'magic bullet' that will solve all the problems of LSCITS engineering. We need to understand and design, in parallel, radically different types of system: from systems of organisational change (which may operate on a timescale of years), to real-time control systems operating at millisecond timescales. We need to improve existing 'reductionist' approaches to systems engineering and combine these with socio-technical approaches that take into account human, social and organisational issues and how they affect the system design.

We will therefore work on a coherent integrated "stack" of techniques and approaches, some of which are already in existence, that can address the problems inherent in different types of system. We refer to this as the LSCITS Stack, as illustrated in Figure 1.

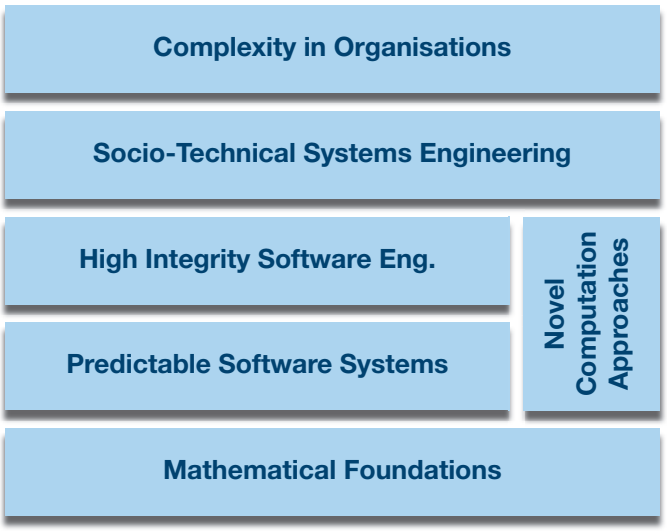
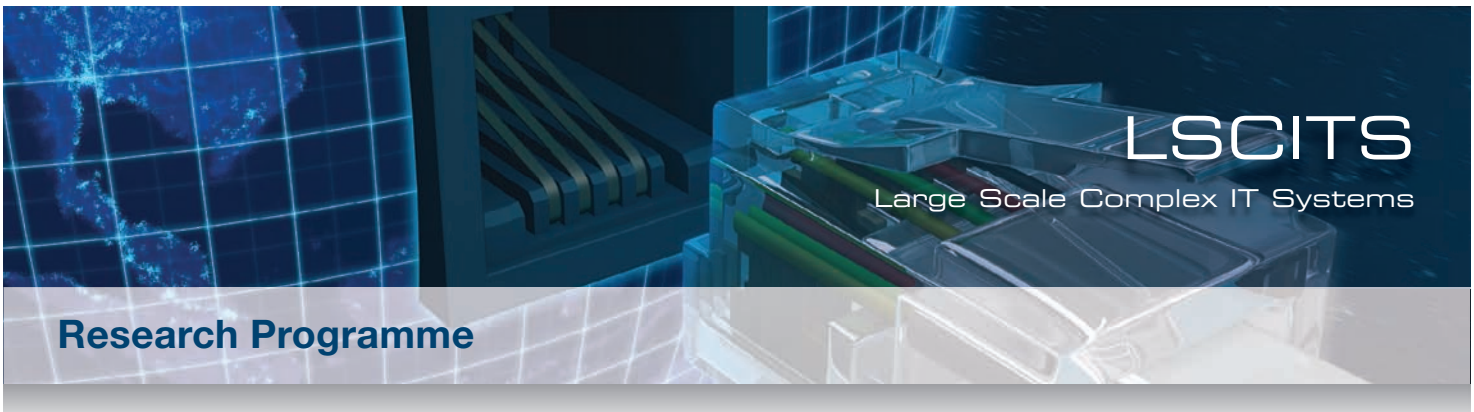


Figure 1: The LSCITS Stack



Research Programme

The Stack Explained

At the base of the stack is the foundational mathematics of nonlinear systems and of network science. The EPSRC has recently committed £8m to two Doctoral Training Centres (DTCs) for Capacity Building in Complexity Science (CBiCS). The two centres concentrate on the mathematical foundations of complex systems. Directors of these centres are involved in the LSCITS steering committees, and it is expected that some of the CBiCS PhD projects will be of direct relevance to Mathematical Foundations component of the LSCITS Stack. For this reason, the LSCITS Initiative's initial research programme concentrates on the remaining components of the Stack.

Predictable software systems (PSS) involves algorithmic methods for software construction and proof of correctness, based heavily on rigorous mathematics and formal logic, and also on the use of advanced simulation techniques. The focus is on developing techniques to evaluate the dependability and performance of adaptive software systems.

The PSS strand is undertaking foundational research, and the challenge will be to scale the technology to large-scale systems. The High Integrity Software Engineering (HISE) strand will be engaged in complementary research activities, taking an engineering approach to problems of safety-critical large-scale systems. Research activities will include adapting agile processes to safety critical software development, and approaches to certifying autonomous systems. The HISE activities will draw on the results of the PSS strand, as they mature.

In parallel to the techniques developed within PSS and HISE, the past two decades have seen the growing maturity of decentralised and massively parallel autonomic (or "self-star") approaches to managing LSCITS: such novel computational approaches (NCA) are also accommodated within the Stack.

To address the challenges of current and future LSCITS, there is a need to move beyond the confines of traditional software engineering, to incorporate approaches and findings from sociology, psychology, and management theory, so as to integrate operational and organisational factors into the software engineering process. The Stack component labelled Socio-Technical Systems Engineering (STSE) seeks to do exactly that.

Finally, because LSCITS are frequently created (sometimes inadvertently) to serve large organisations or groups of organisations that are transitioning to electronic documents and automated workflows, there is a general lack of appropriate tools and methods for describing and reasoning about complexity in organisations, whether those organisations are private-sector or public-sector. Addressing this is the role of the Complexity in Organisations (CiO) component.

Integration

There are cross-cutting issues that affect all levels in the LSCITS Stack: the need to accommodate change, to maximise agility, and to deal appropriately with various forms of requirements. For example, from PSS we know that formal specification can help define and refine requirements; from HISE we know that testability requirements determine levels of certification and trust; STSE teaches us that requirements also reach out to affect deployment and operational management of systems, and findings in CiO increasingly reveal the impact of organisational influences and constraints. But there is a difficult balance to achieve between integration and exploitation. Industry often finds it easier to exploit point solutions to identified problems, rather than to adopt a new integrated approach. For this reason, while the results at each level in the Stack will be loosely integrated, we do not plan to deliver an integrated LSCITS "package". Rather, our integrated results will be process-based. There will be easy movement between the processes that address issues at different levels in the Stack. Prof. Ian Sommerville, one of the Initiative's co-directors, is managing integration across the Initiative, identifying new integration opportunities and ensuring that the work at the different sites does not diverge.

Set-aside funds

Approximately £1.25m of the EPSRC's allocation for the LSCITS Initiative's research programme has been "set aside", for allocation to work-packages to be specified later in the Initiative. Proposals for the projects funded from the set-aside will be peer-reviewed and decisions made so that additional work-packages can start in 2009. In allocating the set-aside funds, the LSCITS Consortium may add new academic and industrial partners. Inquiries from interested parties are welcome any time.

For further details see the website at: www.lscits.org
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LSCITS

Large Scale Complex IT Systems

Training Programme

The LSCITS Training Programme is centred on the delivery of an innovative, custom-designed, world-class Engineering Doctorate (EngD). The EngD is a full doctoral-level qualification that is much more industrially focused than the traditional academic PhD. The first phase of the LSCITS EngD is planned to launch in October 2008, and is intended to graduate at least 40 students over the period 2012-2015. The degree will be based at the University of York, with major additional teaching and supervision from senior faculty at the Universities of Bristol, Leeds, Oxford, and St Andrews. The UK's Engineering & Physical Sciences Research Council (EPSRC) has reserved funds of £4m to support this EngD. Additional support, in cash or in kind, will come from industrial sponsors. Inquiries from new sponsors are always welcome.

EngD or PhD?

While a traditional PhD education is an excellent grounding for someone intent on pursing a career as an academic researcher based in a university, it has been recognised for some time that an equivalent qualification with a different emphasis would better serve the requirements of business, industry, and other non-academic organisations where the need for enterprising and commercially successful research and innovation plays a key role. The UK's Engineering Doctorate (EngD) programme was set up more than a decade ago to meet this need. Various British universities now house a total of over 20 EngD centres. Each centre is focused on a particular problem-domain or theme, and several involve partnerships between multiple collaborating universities and industrial partners.

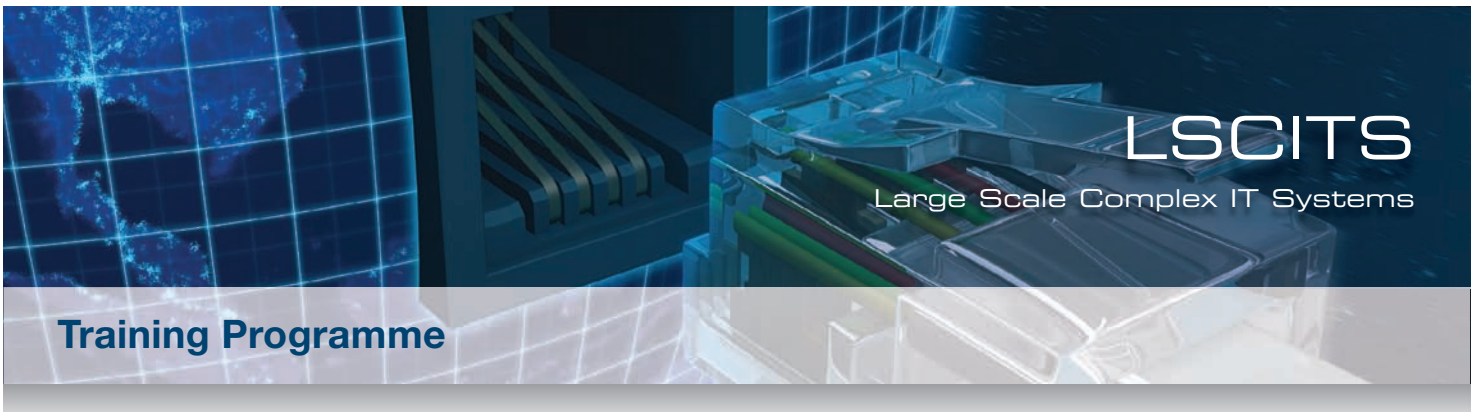
EngD students, known as Research Engineers (REs), are required to pass a number of taught courses (similar in style and content to those found on master of science, or master of business administration, degree courses), and then to pursue independent research leading to the submission of a doctoral thesis. The thesis should be single coherent document, but may be based on a portfolio of related research studies.

Industrial Involvement

All Research Engineers (REs) studying for an EngD are expected to work closely with a sponsoring institution. For many REs, the sponsoring institution will be their employer, who releases the RE to attend the EngD's taught courses and who helps specify the scope of (and topics explored in) the RE's independent research activities. For other REs, the sponsoring institution is likely to have suggested a desired research topic or theme, provided some funds to support the RE, and agreed to hosting the student for extended periods of time. Many such REs will receive their primary funding (stipend and fees) from EPSRC studentships. Typical sponsoring institutions could be: a private-sector company at any stage of maturity from start-up to global multinational; or a public-sector entity such as a government agency, a state-funded healthcare provider, or a division of the armed forces or emergency services. For ease of reference, any such sponsoring institution is referred to here as an "industrial sponsor".

What's in it for the Industrial Sponsor?

In an extensive independent survey conducted for EPSRC by Strategic Marketing Associates (SMA's "Review of the Engineering Doctorate Scheme: Stakeholder Survey", Mar. 2006: available from the EPSRC), previous industrial sponsors listed various reasons for getting involved in an EngD. These included: a means for directly connecting with and becoming involved in university research; a cost-effective method of getting research done (of particular value to SMEs); the attraction of working with the RE as a commercially-oriented recruit; the opportunity to "grow your own" researchers in light of recruitment difficulties; and the attractive prospect of treating the interaction between the sponsor and the RE as a form of four-year job interview. The same report states that, for industrial sponsors, a major distinction of the EngD in comparison to a PhD is the advantage that the RE will be based for much of the time at the company and hence will be available to work on a project on a full-time basis. Nevertheless, given the four-year time-scale for an EngD, it is seen as best suited to a project that addresses an underlying problem (e.g. strategic or pre-competitive research) rather than a current immediate tactical need.



LSCITS

Large Scale Complex IT Systems

Training Programme

What's in it for the Student?

All EngD programmes are explicitly intended to equip their Research Engineers (REs) for senior roles in industry and commerce. (Nevertheless, an EngD would also be a valuable route into academic research.) They do this by providing high-quality collaborations between the universities and a range of companies, and immersing the REs in leading-edge research in a commercial context. In contrast to the traditional UK 3-year academic PhD, EngD courses last for four years, carry a higher annual stipend, and require that 70% or more of the RE's time is spent on a project for the sponsoring organisation, with at least 25% of that time spent on-site at the sponsor.

A March 2007 review of the UK's EngD programmes found that, when compared to a standard PhD, in most cases the number of publications from EngD REs was higher, while both the completion rates and the academic standards of the final theses were directly comparable.

While most EngDs do accept REs with no prior industrial experience, historically over 50% of all REs have spent between 1 and 5 years in industry prior to enrolling, and 20% have more than 6 years industrial experience at enrolment. SMA's March 2006 survey of the UK EngD Programme found that the strong industrial connection is one of the main reasons for choosing to do an EngD; it states: "one third of all REs had not considered doing a PhD but were attracted to the EngD because of the chance to work in a real industry environment."

LSCITS EngD Aims

The LSCITS EngD offers its REs a unique opportunity to become members of a new generation of specialised engineers and scientists, who – by their interaction with, and active participation in, the LSCITS Research Programme – will become members of a wider national and international community of researchers and practitioners dedicated to meeting the challenges inherent in dealing with current and future large-scale complex IT systems and systems-of-systems.

Our primary aim is that graduates of the LSCITS EngD will have a good understanding of relevant issues and methods across all components of the LSCITS Stack (described in more detail in the related LSCITS Research Programme flyer), and of how the different components of the Stack interrelate, interface, and integrate. The EngD REs, and also the LSCITS PhD students and postdoctoral researchers working directly on the Initiative's Research Programme, will collectively aim to deliver intellectual tools (and software) that will allow us to improve our understanding of how to analyse and design, and deploy and manage, current and future LSCITS.

LSCITS EngD Course Structure

The LSCITS EngD requires REs to successfully complete a number of core taught modules, and also a sufficient number of optional taught modules. REs who accrue sufficient course credits from their taught modules may progress to pursue their individual research studies, leading to submission of their thesis.

The LSCITS EngD core modules are:

- Systems Engineering for LSCITS
- Empirical Methods for LSCITS
- Predictable Software Systems
- High-Integrity Systems Engineering
- Socio-Technical Systems
- Technology Innovation

For further details see the website at: www.lscits.org

Note: This document describes a planned LSCITS EngD at York. Final approval from the relevant University of York authorities is being sought, and is expected to be granted by the end of 2007. First intake will be in October 2008.

The LSCITS EngD Centre at York

Faculty at the University of York have worked closely with other members of the LSCITS Consortium, and with various potential industrial sponsors, to design the LSCITS EngD. The EngD is an entirely new degree course, based in York's Department of Computer Science (rated '6*' and 'excellent' in independent reviews of its research and teaching) but with significant additional involvement from the York Management School and from the partner sites of the LSCITS consortium. The York LSCITS EngD Centre Director is Dr Gerald Luettgen, Senior Lecturer in Computer Science.

For further details see the website at: www.lscits.org
Email: EngDInquiry@lscits.org

LSCITS Undergraduate Intern Scheme

A paid undergraduate intern scheme will also operate as part of the LSCITS Initiative over 2008-2012.

For further details see the website at: www.lscits.org
Email: InternInquiry@lscits.org

EPSRC Engineering and Physical Sciences Research Council

LSCITS

Large Scale Complex IT Systems

EngD: Core Taught Modules

The LSCITS Engineering Doctorate (EngD) Programme at the University of York requires REs to successfully complete a number of core taught modules, designed and delivered by senior faculty from the LSCITS Consortium universities of Bristol, Leeds, Oxford, St Andrews and York. Although based in the York Department of Computer Science, the EngD also involves modules designed and delivered by the York Management School. This flyer gives summary details of each of the EngD core modules, and then briefly introduces the remaining components of the EngD.

The Engineering and Physical Sciences Research Council, the main funding agency for Computer Science in the UK, has reserved £4m to support the LSCITS EngD. In addition to covering set-up and running costs, the EPSRC funds are intended to provide for 30 fully-funded LSCITS EngD studentships over the four intake years 2008-2011.

1. Systems Engineering for LSCITS

This, the first module on the course, is an intensive one-week course intended to provide both a technical "flying start" and also some initial team-building among the REs. The module is intended to provide an overview of some of the key issues in developing and assuring large scale complex IT systems, especially covering requirements and architecture: the key elements of a Systems Engineering approach. It will also give a brief overview of other core modules, and it includes some orientation content to help familiarise the REs with the various academic facilities available at York. Sample texts include:

G. Kotonya & I. Sommerville (1998). *Requirements Engineering Processes and Techniques*. John Wiley.

J. McDermid (1992). *Software Engineer's Reference Book.* Butterworth Heineman.

I. Sommerville (2007). *Software Engineering (8th Edition).* Addison-Wesley.

2. Empirical Methods for LSCITS

As IT systems increase in scale and complexity, so there is a growing need for graduates with strong understanding of empirical techniques for analyzing and visualizing their structure and dynamics. Understanding and managing LSCITS requires well-developed skills for generating, summarising, comparing, and making informed decisions from multivariate data that may not be well modelled by standard distributions. This module aims to provide students with a broad but firm grounding in methods drawn from the literature on experiment design, data analysis, and visualisation; and furthermore to integrate this with recent findings from studies of the interplay between network topology, growth-history, and dynamics. Sample texts include:

J. Antony (2003). *Design of Experiments for Engineers and Scientists.* Butterworth-Heinemann.

J. Miller & S. Page (2007). *Complex Adaptive Systems.* Princeton University Press.

D. Watts (1999). *Small Worlds: the Dynamics of Networks between Order & Randomness.* Princeton University Press.

3. Predictable Software Systems

This module covers the main software systems modelling and verification techniques, and illustrates their usage with real-world examples studied and analysed with model-checking tools. The focus is on properties such as safety, dependability, resource usage, and performance. The content includes: reactive systems and their models; temporal logic; model checking and algorithms; modelling formalisms; verification of system properties; real-time model checking; probabilistic model checking; software verification; security and trust. Sample texts include:

B. Berard et al. (2001). *Systems and Software Verification: Model Checking. Techniques and Tools.* Springer.

E. Clarke, O. Grumberg & D. Peled (2000). *Model Checking*. MIT Press.

M. Huth & M. Ryan (2004). *Logic in Computer Science: Modelling and Reasoning About Systems.* CUP.

EngD: Core Taught Modules

4. High-Integrity Systems Engineering

This module provides an overview of the challenges in developing high-integrity software systems; and of current processes for accreditation of security-critical systems and for certification of safety-critical systems. It also provides an understanding of the growing diversity of high-integrity systems on which commerce, transport, healthcare, etc. increasingly depends. It introduces techniques for achieving and assuring high-integrity software, and the approaches to justifying their safety and security. On completion of this module, students will have a firm appreciation of the growing societal dependence on high-integrity systems, and they will understand the state of the art in developing high-integrity systems and the risk factors and approaches to managing key risks. Sample texts include:

J. Barnes (2003). *High Integrity Software: The SPARK Approach to Safety and Security.* Addison Wesley.

J. McDermid et al. (2004). *The Challenges of Complex IT Projects.* Royal Academy of Engineering and the British Computer Society. ISBN 1-903496-15-2.

E. Hollnagel, D. Woods, & N. Leveson, editors (2006). *Resilience Engineering: Concepts and Precepts.* Ashgate.

5. Socio-Technical Systems

This module requires students to investigate and understand the relationship between LSCITS and organisations. Other EngD core modules start with technological complexity and work outwards toward production processes and governance. This module starts with organizations and shows how IT solutions are produced by complex organisational processes – and, in the case of start-ups, by broader social and economic processes. On completion of this module, students should be able to understand the social and organizational reasons why projects go well or badly; understand that it is essential to identify and study salient features of organizational processes; understand and be able to use social research methods to study the creation and use of LSICTS in an organization setting; and understand the issues and problems of setting up workplace fieldwork. Sample texts include:

A. Crabtree (2003). *Designing Collaborative Systems: A practical guide to ethnography.* Springer.

P. Dunleavy et al. (2006). *Digital Era Governance.* Oxford University Press.

D. Vaughan (1997). *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA.* University of Chicago Press.

6. Technology Innovation

The subtitle of this module is Strategy, Management, and Commercialisation. It aims to provide students with a firm grounding in the legal, managerial, and financial aspects of innovative technology research for knowledge transfer and wealth creation. This module is intended to provide a grounding in the current practices of industry and commerce, and current thinking and research in schools of business and management. It has been custom-designed for the LSCITS programme and the industry-focused careers expected of its EngD Research Engineers. Sample texts include:

H. Chesbrough (2003). *Open Innovation.* Harvard Business School Press.

C. Perrow (1999). *Normal Accidents: Living with High-Risk Technologies.* Princeton University Press.

S. Scotchmer (2006). *Innovations and Incentives.* MIT Press.

Optional Modules & Individual Project

The taught component of the LSCITS EngD also requires the student to complete a number of optional modules, and an individual project, usually within the first two years. In addition to the optional modules offered by York's Computer Science Department, optional modules may be studied at York Management School, and/or at the LSCITS Consortium partner universities. LSCITS staff from all the Consortium partner sites are available as advisors for the student's Individual Project.

The LSCITS EngD Centre at York

The LSCITS EngD is an entirely new degree course, based at the University of York's Department of Computer Science. The LSCITS EngD Centre Director is Dr Gerald Luettgen, a Senior Lecturer in Computer Science at York. The LSCITS Initiative's overall Training Director is Prof. John McDermid, Head of York's Department of Computer Science .

For further details see the website at: www.lscits.org
Email: EngDInquiry@lscits.org

THE UNIVERSITY of York

EPSRC Engineering and Physical Sciences Research Council

Note: This document describes a planned LSCITS EngD at York. Final approval from the relevant University of York authorities is being sought, and is expected to be granted by the end of 2007. First intake is expected to be in October 2008.

LSCITS

Large Scale Complex IT Systems

EngD: Options and Pathways

The LSCITS Engineering Doctorate (EngD) Programme at the University of York requires Research Engineers to successfully complete a number of optional (elective) taught modules. A wide range of optional modules are available, designed and delivered by senior faculty from the LSCITS Consortium universities of Bristol, Leeds, Oxford, St Andrews and York. This flyer explains the taught credit requirements of the EngD, lists the options available, and then gives three illustrative pathways through the EngD programme.

Taught Credit Requirements

Research Engineers (REs) pursuing the LSCITS Engineering Doctorate (EngD) programme are required to successfully complete the taught component of the programme, partly before and partly alongside the main doctoral research work. The taught component comprises modules worth 120 credits overall, consisting of the six compulsory core modules each worth ten credits, and then the student's choice of optional modules worth another 60 credits in total. Each student is also required to complete a compulsory individual project worth 60 credits, which serves as the literature review and research plan for the student's doctoral research activity.

Optional Modules

The optional modules are structured into two strands: (I) *Foundations, Systems and Software Engineering*; and (II) *Management, Commercial and Business Issues*. All LSCITS EngD students are required to take a minimum of 20 credits from Strand II. Further details of each module can be found in the Programme Specification for the LSCITS EngD, available upon request. All optional modules count for 10 credits, except those offered by The University of St Andrews, where all modules are worth 20 credits. The University of York offers LSCITS EngD modules both from its Department of Computer Science (CS) and also from its Management School (MS).

Optional Modules: Strand I

- Advanced Concurrency Tools (Oxford)
- Advanced Networks and Distributed Systems (St Andrews)
- Advanced Software Engineering (St Andrews)
- Concurrency and Distributed Systems (Oxford)
- Critical Systems Engineering (St Andrews)
- Design for Security (Oxford)
- Distributed Systems Architectures (St Andrews)
- Foundations of System Safety Engineering (York CS)
- Mathematics for Systems (Bristol)
- Mobile & Multimedia Systems (St Andrews)
- Performance Modelling (Oxford)
- Security Principles (Oxford)
- Software Architecture (St Andrews)
- Software Engineering Mathematics (Oxford)
- Software Implementation (York CS)
- Systems Engineering 1 (York CS)
- Systems Engineering 2 (York CS)
- Software Requirements and Architectures (York CS)
- Software Testing (Oxford)
- Software Testing for Safety Critical Systems (York CS)
- Web Services (Oxford)

Optional Modules: Strand II

- Advanced Systems Engineering (Bristol)
- Financial Management (York MS)
- Human Resource Management (York MS)
- Management of Risk and Quality (Oxford)
- Process Quality and Improvement (Oxford)
- Software Development Management (Oxford)
- Safety Critical Project Management (York CS)
- Strategic Human Resource Management (York MS)
- Strategic Management & Organisational Change (York MS)
- Operations and Project Management (York MS)
- Organisational Analysis (York MS)

Notes: certain modules listed here have prerequisite modules elsewhere in the lists; some pairs of modules are mutually exclusive choices; some modules may not be offered in a particular year if demand is inadequate; course regulations and module availability are subject to change.

This is LSCITS Flyer number 5.

EngD: Options and Pathways

Pathway Examples

Fictional accounts of three possible case-history "pathways" through the LSCITS EngD are given here, to illustrate likely scenarios for Research Engineers.

Pathway 1: The BigCo Employee. Jane has worked for BigCo, a large engineering company, for seven years. She joined BigCo straight after leaving college with a Bachelor of Science degree in Physics, and works on developing new IT services and solutions for various key aspects of BigCo's business. Jane's managers are keen to retain her as an employee, and appreciate her need for career development, so they pay for her to take part in the LSCITS EngD while keeping her on payroll as a BigCo employee. In the first three years of her time on the EngD, Jane spends a total of twelve weeks attending one-week taught modules: an average of one week every three months (the rest of the time, Jane remains at her BigCo office). After studying the core modules taught at York, Jane finds that she is most motivated by issues in software engineering, and so she completes her EngD tuition by choosing the Oxford *Software Development Management* and *Process Quality and Improvement* modules; the St Andrews *Software Architecture* double module; and the York modules *Systems Engineering 1* and *Software Implementation*. Jane pursues all her doctoral research on-site at BigCo, developing valuable new tools and practices for BigCo. After her EngD studies are concluded, Jane remains with BigCo and increasingly finds herself in leadership roles within the company. In a quite remarkable coincidence, Jane's brother John also successfully completed the LSCITS EngD, having previously worked for several years as a government employee. Like Jane, John stayed on salary throughout his EngD studies, and remained with his public-sector organisation after he graduated from the EngD.

Pathway 2: The Continuing Student. Anil has greatly enjoyed his undergraduate degree in Computer Science. He is keen to study for a doctoral-level degree, but has little interest in pursuing an academic research career, and so would like an alternative to a traditional academic PhD programme. Anil's ultimate aim is to work in a management position in a company where technology innovation plays an important role. Attracted by the industrial focus of the LSCITS EngD, Anil successfully applies for an EPSRC-funded LSCITS EngD studentship, working with an industrial sponsor called SME.com, a medium-sized software systems consultancy company. Anil is able to take all the core modules in his first year on the EngD, and he elects to concentrate in his second year on non-technical optional modules, taking four courses offered by York Management School: *Strategic Management and Organisational Change; Operations and Project Management; Organisational Analysis;* and *Human Resource Management*. He also takes the Oxford *Software Development Management* module and the Bristol *Advanced Systems Engineering* module. For his doctoral research, he spends almost all of his time working alongside a team at SME.com, and interacting with SME's clients. Anil's doctoral research project explores the interplay between social network dynamics in multi-organisation project teams and the design and maintenance of LSCITS. Anil's industrial collaborators at SME.com value his participation in their team, and when Anil graduates with an EngD after four years, they decide to offer him a position on their staff.

Pathway 3: A Change of Career. Siu-Ming studied Business Computing as an undergraduate and then moved straight into an MBA. For the last four years he has worked for a major management consultancy company, mainly on public-sector IT projects. For various reasons, he has decided that the time has come for a change of career path. He resigns from his old job to take up an EPSRC-funded studentship on the LSCITS EngD, and through his professional contacts he negotiates a new industrial sponsor: a major IT consultancy company involved in introducing advanced IT systems into public-funded provision of health and social care. After completing the six core modules, Siu-Ming selects the two Oxford modules *Process Quality and Improvement* and *Management of Risk and Quality*; the St Andrews module on *Critical Systems Engineering*, and the two York modules *Safety-Critical Project Management* and *Software Testing for Safety Critical Systems*. His doctoral thesis is a portfolio of related papers addressing issues in the adoption, use, and extension of high-integrity software engineering methods in large-scale health and social care IT applications. Upon completion of his thesis Siu-Ming and two fellow LSCITS EngD students establish a start-up company, offering specialised technology development and consultancy in safety-critical public-sector IT systems.

For further details see the website at: www.lscits.org
Email: EngDInquiry@lscits.org

THE UNIVERSITY of York

EPSRC Engineering and Physical Sciences Research Council

Note: This document describes a planned LSCITS EngD at York. Final approval from the relevant University of York authorities is being sought, and is expected to be granted by the end of 2007. First intake is expected to be in October 2008.