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.
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.

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