

National Software Testing, Validation and Transformation Centre

Advanced Software Testing and TRAnsformation Centre - ASTTRA

Background and Critical Need Software is becoming more and more pervasive in the modern world, [1]. Increasingly, products and services are being delivered either on-line or through internet-based companies. Large amounts of money are spent on buying and commissioning IT systems for all types of organisations. Lack of adequate testing, including review, is a major obstacle to the success of digital enterprise. In established software companies – IBM etc. software testing and transformation is a major part of any project, many companies spend around 80% of the entire software development effort on testing and validation – making sure that the systems do what is required of them under all operational conditions and, more fundamentally, that they are the right system. Since software is now such a fundamental part of almost any activity, this is an enormous burden and responsibility. The numerous high profile failures in both public and private sector projects are evidence of the problems – recently there was a report (Times 21/12/11) on the Probation Service’s IT fiasco and this week the Olympics Ticketing system failed. These failures are a public demonstration of the problem of incompetent testing and validation. Inadequate testing is costing very large amounts of money, with estimates of up to 1% of gross domestic product in western economies such as the US and the UK (£15 billion in the UK). Despite this, very little is said about improving this major issue in the Government’s reports on the Public ICT Strategy.

The transformation of legacy software from old platforms to modern technology and the needs for better interoperability, required in a more integrated global world, is also a major demand on the industry and is, as yet, a poorly understood area with a multitude of practical problems. Without progress in these areas the promise of a digital-driven economic recovery will be compromised. Although there has been significant progress in research in these areas its take-up in industry is patchy - *particularly amongst SMEs*, who typically spend much less effort on testing. Globally, the opportunities are enormous as all countries face these issues and there are no national testing centres in existence. Unfortunately it is not sufficient to think about the technology in isolation from its operational context. Human and organisational factors are major considerations that need to be addressed. For example, there are numerous examples of Public Administrations (PA) that have failed to manage transformations from propriety systems to open source-based systems. The resistance to changing working practices and introducing new desktop into PAs has to be managed incredibly carefully if it is going to succeed.

The Sheffield City Region Local Enterprise Partnership has developed a strategy for developing the digital economy in the region involving large scale data centres, collaboration networks and a program for transforming public sector IT. This strategy has received widespread support from industry, public sector and UK Government.

The Opportunity Modern research into testing, security, human factors and change management in organisations means that this does not need to be the situation. There is a need for a mechanism for transferring appropriate research into the industrial sphere in a cost-effective and productive way that addresses the real problems of industry rather than esoteric research questions. This proposal is about establishing such an industry facing facility. The lead HEI is the University of Sheffield which has substantial experience in translating their research achievements into industry and the public sector. The Computer Science Department is arguably the largest source of expertise in software testing in any university in the UK and has worked collaboratively with Daimler-Benz (Mercedes Cars), IBM, ARM on different aspects of testing and design. For example, over 10 years we have developed an advanced test methodology for safety critical compute applications such as engine monitoring and braking systems which is now used in the production process at Mercedes. In all cases there is a clear track record in full collaboration between research and industry.

The University's Institute of Work Psychology has an international reputation in the field of change management and organisational behaviour. This will be strengthened by the addition of Sheffield Hallam University as a major partner, which has a leading human factors testing centre. Together there is the opportunity to build on this expertise to transform the development and introduction of effective IT systems into both public and private sector sectors and to reduce the large scale waste that currently occurs.

The Sheffield City Region Local Enterprise Partnership has developed a digital strategy for economic growth in the region. This includes proposals for Large-scale Data (cloud) Centres, Collaboration Networks (Techcity Sheffield) and a Public Sector IT Transformation strategy. ASTTRA is one of the cornerstones of the strategy's TechCity proposal in this region. It brings together expertise in both IT Transformation but also quality and reliability.

The University of Sheffield is among the top 10 in the Russell Group, the association of leading UK research-intensive universities. A hundred years ago the founding motto of the University was *Rerum Cognoscere Causas*, meaning "To discover the causes of things". A century later the knowledge landscape has shifted dramatically. Our research ethos continues to uphold the ideals of discovery whilst acknowledging new ways of acquiring, investigating, developing and applying knowledge. Our researchers work to solve problems that matter to make an impact on the wider world. In this way our research continues to benefit the UK economy and its social and cultural life, the University's state-of-the-art facilities, training and research support systems empower our researchers to undertake their best work. Over the last decade, we have invested £170 million in research capital infrastructure, largely due to our outstanding success in securing HEFCE, JIF and SRIF funding. Our role in world-wide networks and strategic partnerships extends our global reach and enhances our input to regional and national activities.

The Advanced Manufacturing Research Centre, located in the Sheffield Advanced Manufacturing Park is a world leading establishment that has helped to transform the way complex artefacts are manufactured from the latest materials in companies large and small – including Boeing, Rolls-Royce, BAE Systems etc. New factories are being established alongside the Centre to exploit its expertise and a new Nuclear AMRC is being built. This successful model with strong industrial involvement is the inspiration for the ASTTRA Centre.

Sheffield Hallam University (SHU) is institutionally committed to maximizing innovative capability through the integration of research and knowledge transfer, through the support of symbiosis between research and knowledge transfer, with fundamental research and academically driven applied research leading to customer specified research. A corporate framework supports co-ordinated engagement in innovative multi-disciplinary research. Multidisciplinary research and knowledge transfer is a high priority; this is supported by cross-faculty and cross-institutional research collaboration supported through a total of seven full-time Knowledge Transfer Champion roles - two within the University's Culture, Communication and Computing Research Institute (C3RI). The research institute's Knowledge Transfer team includes a fulltime business development manager and administrator and is committed to supporting research staff applying their skills and research to create impact through enhancing cultural, economic, and social wealth.

Barnsley Metropolitan Council is a sector leader in modern applications of ICT to public service. Their Living Lab is an important mechanism for not only user testing e-services etc. but also the facilitation of citizens in the creation and design of new e-services.

Partners and sponsors The University of Sheffield, Sheffield Hallam University, Sheffield City Corporation, Barnsley Metropolitan Council, and ARM are currently the main sponsors and potential further partners including HP, Mercedes-Benz, Accenture, IBM, Capita, Fujitsu, Motorola etc. Other potential academic partners are UCL, Imperial, York, Hull, Kingston, Brunel and Strathclyde.

The Strategic Case Software testing is a major part of the software development lifecycle and a major cost and effort bottleneck. The larger software companies – IBM, Microsoft, etc. estimate that a typical project involves 80% of cost and effort on testing and related activities. Smaller companies tend to spend less on testing and the consequential problems of poor quality and ‘buggy’ software result in serious problems and delays – research into the ongoing problem of late delivery of software points to a major effect of having to divert staff onto fixing bugs in previously delivered systems. The issue of security in terms of IT systems is a vital one and the need for rigorous and effective security testing has never been greater. However, we cannot ignore the role of the users in such systems and many weaknesses in secure systems are to be found amongst the behaviour of individuals. Thus security testing needs to be a holistic endeavour that does not ignore non-technical issues.

Software transformation involves re-engineering existing systems – often legacy applications – to meet new standards or migrate to new technology platforms. Many organisations have bought or commissioned proprietary systems and are dependent on a small number of commercial suppliers for their IT needs. This ‘lock in’ affects both public and private sectors and is a major constraint on developing smarter citizen/consumer centric applications and services and on the move to a cloud-based future. Increasingly, organisations are connecting to their citizens/consumers through multiple platforms – broadband, smart phones etc. The model for the future involves greater interoperability between these platforms and between collaborating organisations in both the public and private sectors. There are enormous obstacles to doing this effectively because of the proliferation of propriety standards and systems – which are often incompatible. To deal with these problems organisations need to re-engineer their systems, transforming their software into open standard based applications on multiple platforms. This needs to be done whilst preserving or even enhancing their integrity and usability. The roles of the individuals using the systems must also be considered and the management of change, the involvement of users and the organisational culture have to be first class components of the process.

Research and development in software testing is something of a ‘Cinderella’ subject with few of the major universities active in the field. In the UK the two big players are UCL and Sheffield – with individuals active in Brunel, Hull and Strathclyde. Sheffield’s Verification and Testing Research Group in the Department of Computer Science is a world leading player in software testing – covering a broader area than UCL and including research into software transformation and re-engineering.

As part of the strategy for the Creative and Digital Industries, the Local Enterprise Partnership in the Sheffield City Region has identified three main areas of activity. One is the creation of a major public cloud facility in Sheffield, another is the development of collaboration centres and hubs where developers and companies from all the industries active in Sheffield can work together to develop smarter, cheaper, more effective applications for their business and a third focus is on transforming public sector ICT provision.

Within this strategy there is an opportunity to exploit the expertise of the University of Sheffield – and also, potentially, Sheffield Hallam University – by creating an industry led centre where the most effective advances in software testing and transformation technology can be applied for the benefit of local industries.

The Software Testing and Transformation Research Centre would be part of the University’s contribution to the Sheffield City Region Local Enterprise Partnership’s strategy for re-invigorating the region’s economy; through the setting up of large scale data centres, the establishment of the TechCity Sheffield Science Park and the transformation of public sector ICT infrastructures. The Centre is proposed as a joint venture between several academic and industrial partners and will be located within TechCity. This fits in with both the plan to make TechCity the focus for all kinds of collaborations between all kinds of digital enterprises and the need to be adjacent to the data

centres – in many cases test sets are extremely large, so being located alongside a data centre is an advantage. There are many challenges in the new world of apps and mobile devices, in system integration and interoperability, use of open source solutions and open data standards – all key elements of the UK ICT strategy – and the need for reliable certification of some of these will grow. Ubiquitous monitoring devices, miniature sensors and health related applications all need to be trustworthy and the understanding of how this can be achieved is still a research field.

There are no research centres of this type in software testing in the world and this provides an opportunity to take a leading role in this vital area. The breadth of expertise is another unique factor.

The Economic Case This is a unique basis on which to build a game-changing Advanced Research Centre in Sheffield – inspired by the AMRC - in software testing and transformation.

Recent projects with industry include:

- A 10 year relationship with Daimler-Benz (Mercedes Cars) for the development of software testing technology for testing automotive software. Increasing levels of computing are found in modern cars and the testing of the more critical systems – engine monitoring, braking systems etc. is highly challenging. Sheffield contributed software to make this highly effective and efficient.
- ARM – designers of mobile chips – we collaborated with them on their AMBA system. Using their designs we developed smart software testing systems and compared them with their existing approach. The Sheffield technology found 3 times as many bugs and test sets typically took 10 minutes to run in contrast to ARM's which needed 20 hours.
- IBM – we have collaborated with them on the introduction of agile test-driven development processes.
- ZooDigital – we have worked with them on the testing of consumer games.
- A large number of projects in the company epiGenesys applying the latest testing tools in an agile development environment

There are a number of other local companies interested in collaborating with us such as WANDISCO etc.

The establishment of the Centre will boost the productivity of the UK's software development and enhance the quality of the systems delivered to customers because of the effective transfer of best practice and proven research methods into the industry.

The development of better transformational procedures for standardising databases and renovating legacy systems is likely to save considerable sums of money and make the provision of enhanced public sector systems more viable and sustainable. The focus on transformation to open cloud environments is extremely timely.

Providing advice on the human aspects of IT transformation will also make a major contribution to the success of such projects.

The Research Case There are many key research questions that are still a subject of vital importance but much is known and can be applied. Through all of these there are two critical themes – the technical and the social. We now realise that software, generally, is only part of a socio-technical system and its value is dependent on a clear, consistent and holistic understanding of its context. The human and organisational context is vital, implementing a technical solution may not always work if these aspects are neglected. There are many examples where perfectly sound software fails to be adopted into an organisation because it fails to meet the objectives of the users or the management.

A key factor in any approach where new systems and processes are to be introduced into a working environment is the consideration of key issues BEFORE effort is expended on detailed design and coding. Thus:

1. the operational, managerial and user contexts must be explored thoroughly and stakeholder buy-in must be obtained – otherwise there may be obstruction, incomplete adoption or other failures as a result.
2. the main security issues have to be identified at the beginning and these will involve people issues as well as technical ones
3. the testing strategy must be identified – what behaviour, performance, usability, maintainability etc. is required for the system to be acceptable

None of these aspects – organisational, security and performance can be achieved effectively if they are issues considered *after* the main design decisions have been made. These issues are fundamental and not *add-ons* that can be dealt with once a project is well under way!

To address these issues it is necessary to bring together a variety of skills and experiences that will provide a multi-disciplinary approach that is driven by application need rather than research theory.

Further information about the research background is in the Technical annex.

The Commercial Case The aim is to position the centre as a focus for advice about software testing in general. There is no independent authority that can provide evaluation and advice on software testing techniques and technology. A comparative analysis of the benefits and disadvantages of different testing tools and environments, based on industrial trials is urgently needed.

The Centre will develop a wide range of computational environments and place these in the core of the cloud-based environment implemented at the centre. The philosophy is to create an approach, labelled *Testing as a Service (Taas)* to go alongside other Cloud services – Software as a Service (SaaS), Platform as a Service (PaaS) etc. In this way software development companies and organisations will not need to provide their own testing infrastructure and the expertise to run it but will buy the service when needed.

There will be a number of cloud and web-based services along the following lines:

1. An open testing environment based on open source test tools and test management facilities that will be available to all research groups in the UK. There will be standardised interface that will allow researchers to submit code – unit, system, interface etc. to be tested on the Centre's equipment often using automated testing tools based on evolutionary algorithms or specification learning and self testing software such as JWalk. The customers will receive the test sets and test results.
2. A mechanism for specific test environments to be installed at cost price to allow for specific test regimes to be run.
3. A consultancy unit that will provide advice, training and development on a variety of test-related topics such as test-driven agile development, user testing, etc.
4. A facility for testing *apps* and to provide a certification service at cost price.
5. Research tools for software transformation from legacy code including: specification discovery, database migration, regression testing and system integration testing.
6. Sponsors of the Centre will be able to bid for specific research projects on matters of interest, these proposals will be evaluated by the Scientific Board of the centre and the most appropriate ones will be carried out.
7. A Games testing lab will be created to develop new technology to test games.
8. Commercial software testing will be carried out at normal commercial rates.

The position of the Sheffield Region having established an ambitious but realistic digital strategy aligned with threads such as the large-scale cloud data centre, the transformation of public sector services and the collaboration network in TechCity means that there will be strong uptake of the services and facilities in the Centre.

Our strong research base in software testing and our track record in transferring research into industry, (e.g. Mercedes) provide a unique opportunity to make a big impact in these emerging areas of the software industry.

One benefit for sponsors is that the Centre will be able to undertake rapid research and development work. One issue we have faced with, for example McLaren Racing, is that our normal basis for research is through PhD and postdoctoral researchers who generally operate on a 3 year timescale. By having a pool of researchers constantly available we will be able to take on short more urgent projects in a practical and cost effective way.

The Financial Case The on-going funding from corporate sponsors will be crucial. The proposal is, based on AMRC model, is that large companies will subscribe at £200k per year (Gold rate) and smaller companies at £35k per year (Silver rate).

These contributions provide the following benefits:

Gold sponsors will have a place on the Projects Board and will be able to propose projects and developments. Silver sponsors will be able to propose projects which will then be considered by the Board. In both cases the results of the projects will be shared between the Centre and the company sponsor in terms of IP and other benefits.

This is a sustainable approach and the centre will be self-funding in the medium term. It will bid for resources from a variety of sources both industrial funding initiatives and research councils.

To enable this to happen in the longer term start-up funding is required. Once established, the centre will expand and undertake commercial activities alongside the core research and development transfer work.

The Social Case The Centre will play a large part in the LEP strategy to generate new business, new public sector systems and through this generate jobs and wealth for the region. Modern technology plays a vital role in developing communities and wealth. However, many people are excluded from this digital world. The interest in the Games testing Lab in the Centre will attract young unemployed people in disadvantaged communities who have an interest in games and who could be helped to develop skills and technology to support games testing and evaluation, and could be encouraged, through the TechCity Science Park environment to set up their own companies.

The Management Case An initial approach would be to set up the Centre and invite subscriptions from local industry and the public sector in order to finance collaborations and training activities in software testing – some of these would involve PhD students and PDRAs funded by the subscription model who could, with academics deliver training and consultancy. Other sources of funding would be sought – ERDF, RGF, EPSRC, EU etc.

The Centre could be involved in some of the testing activities in the development of the software platform for the Public Cloud. In particular, through our collaboration with the South-East European Research Centre, we have developed expertise in the quality assurance of service-oriented systems, through software testing, governance and monitoring.

A longer term aim is to position the centre as a focus for advice about software testing in general. There is no independent authority that can provide evaluation and advice on software testing techniques and technology. A comparative analysis of the benefits and disadvantages of different testing tools and environments, based on industrial trials is urgently needed.

The Director will be responsible for driving the scientific programme of the Centre and for overseeing the technical assets.

The Sales Manager will have responsibility for attracting sponsors and partners, for identifying funding sources and for marketing the Centre's capabilities throughout the commercial software sector.

2 technical support officers will be responsible for implementing and maintaining the equipment asset base and for delivering high quality ICT services to the Centre. One of these will be a more senior post with responsibilities for defining and delivering the Centre's IT strategy.

There will be a Board to oversee the Centre; this will consist of key players in the testing and transformation world, including academics and senior industry people. The Board will set Centre objectives, monitor progress and performance and provide strategic steers for the Centre.

There will be a project Board which will include representatives from all the sponsors. The role of this Board is to choose projects from those submitted by the sponsors and partners in accordance with the objectives and capabilities of the Centre. These projects will involve PhD students, post-doctoral researchers and support staff.

The commercial activities – such as external contracts will be undertaken by a team of qualified staff recruited as part of the commercial ventures identified by the Sales manager and centre Director.

Administrative and secretarial staff will support the Centre's activities and staff.

Requirements

Premises and infrastructure

Some high profile offices and training space located in the SCR Science Park is needed. The potential for making use of the Moorfoot building in the interim is worth exploring – it has recently been purchased by Sheffield City Council.

Initially, the computing infrastructure will be based within the Centre but greater use of the Public Cloud will be made when available.

Personnel

1. A director of the Centre – Dr. Phil McMinn (Currently a SL in the Department of Computer Science).
2. A critical appointment will be, following the AMRC's lead, an experienced Sales Manager with some knowledge of the software testing market.
3. 2 academic staff in software testing, transformation or public sector IT to allow for the secondment of existing staff to the centre.
4. 3 further experienced research staff with expertise in software testing and/or transformation.
5. 3 PhD studentship bursaries with fees
6. An administrator/secretary to manage the Centre.
7. Technical support for running the infrastructure – 2 posts.

Business plan

Start-up Costs

Premises -- currently these will be provided free by Sheffield City Council
 Staffing costs -- £600k per year
 Equipment and software -- £500k
 Running costs - £100k per year

Total annual running costs - £1.2m

Initially the start-up funding is needed for the 1st and possibly the 2nd year. After that it needs to be self-funded.

Year	1	2	3	4
Expenditure	£1.2m	£1m	£1.05m	£1.1m
Gold members	1	2	3	4
Silver members	1	4	6	8
Consultancy	£100k	£200k	£300k	£400k
Start-up income	£1.2	£1.2m	0	0
Grants	0	£200k	£400k	£500k
Total income	£1.535m	£2.150m	£1.520m	£2.0m
Balance	+£335k	+£1.150m	+£0.47m	+£0.9m

Timescales for expenditure: The Centre will have immediate access to space in the Moorfoot building, owned by the Sheffield City Council, including vacant server rooms and facilities for the immediate installation of a range of computer infrastructure including a server-based cloud infrastructure, a HPC facility and the necessary infrastructure. The longer term plan is to relocate in TechCity site alongside a data centre. The AMRC provides a good model. Profits from the Centre will be ploughed back into advanced R&D to accelerate leadership in the field of test and validation and shared equitably with the university via charitable donations. Initial appointments and setting up could be achieved in Q1 2012.

Institutional support: The University will be asked to support the foundation of the Centre through the appointment of staff: academic staff to release current staff, a sales manager to market the Centre and negotiate sponsorships and partnerships, and technical posts to manage the infrastructure. These are the subject of a more detailed proposal to the University. The project will also require access to the University's procurement, CICS, legal and other relevant specialised services.

Government support requested The establishment of the Centre is dependent on number of factors: funding for staff to provide the services; equipment for the testbeds – this would require the availability of devices including cloud-based environments for testing new public services, mobile devices and PCs, and High Performance Computers for testing scientific codes. Further partnerships with key industry players are another requirement since the more partners in the centre the more self-sustaining it can become.

Technical annex

The software testing research at Sheffield is internationally leading and as such is very well placed for dissemination. Work on state-machine based testing led to a prestigious line of research and has been applied in many practical projects in industry. Work on search-based testing [3] is based on algorithms inspired by nature, and capable of automatically generating test cases for a number of testing criteria, including automatic code coverage, functional and non-functional properties (such as worst case execution time) and stress testing. It has previously been applied in industry in

embedded systems at Daimler, and remains pertinent to this field of software engineering. Usually software testing involves a human as part of the loop in some respect, be it as an oracle to verify the correctness of tests, or by providing a specification that can perform this task automatically. Sheffield has expertise in both areas.

The problem of determining the desired correct system behaviour for a given input is called the Oracle Problem. Since manual testing is expensive and time consuming there has been a great deal of work on automation and part automation of Software Testing. Unfortunately, it is often impossible to fully automate the process of determining whether the system behaves correctly. This must be performed by a human, and the cost of the effort expended is referred to as the Human Oracle Cost. The EPSRC-funded RE COST project at Sheffield [3] seeks to generate test cases that minimise human evaluation time. It uses Search-Based Optimisation techniques to attack the Human Oracle Cost problem quantitatively and qualitatively. The quantitative approach will develop methods and algorithms to both reduce the number of test cases and the evaluation effort per test case. The qualitative approach will develop methods and algorithms that will reduce test case cognition time.

Over the last ten years, so-called “agile methods” have proven more effective than traditional software lifecycle methods in actually delivering working software systems. While these approaches emphasise frequent software testing as insurance against failure, they lack any principled means for selecting the right unit tests. On the other hand, formal specifications support the generation of functionally complete test sets. However, agile methods eschew any up-front formal specification, thinking that these constitute excess documentation, divorced from the code. The JWalk project [5] successfully adapted specification-based testing for agile software development, by inferring the test oracle from the software prototype during its development. As the software prototype evolves, the JWalk tool infers an algebraic and state-based specification for the software, with the help of human intervention to confirm certain test results. Using a combination of automatic analysis and human evaluation, the tool increases testing productivity by two orders of magnitude, compared to industry-standard developer-led testing.

Sheffield has been at the centre of four EPSRC specification-mining approaches, three in grammar inference and one in evolutionary algorithms. Two approaches developed a human-centric automatic specification inference technique. This permits one to take a system running in a live environment (or a system running the few tests one would usually have) collect information about its behaviour and subsequently infer what a specification might be like. The process of inference, implemented in the open-source publically-available Statechum tool, makes a number of hypotheses during the construction of a specification. These hypotheses are verified by testing in a test environment [6]. Reference [7] shows how one may generate additional tests from the inferred model and these have been rather effective for the inference of parts of TCP/IP - the protocol on which the Internet is built. Where one cannot run a system in isolation, it is possible to infer a model without running any additional tests. The recently-completed competition [8] involving many people in the inference area has identified a new algorithm which appeared substantially more effective at inference. In both cases (inferred with additional tests) and inference where a model is built without running extra tests, the outcome is shown to a human developer who can offer a counter-example where he/she believes a model to be wrong and the tool will then restart the learning and present a new model. Recent work, [9], involves identification of differences between models, one may hence compare models inferred from different versions of the same system to see what has changed and may need re-testing. Unlike previous work, this approach works on non-deterministic models with unconnected parts. Just starting is a 6-month project on the inference of models of the behaviour of Autonomous Air Vehicles.

Experience in the transformation of information to open source in PAs has accrued in two EU projects COSPA [10] and OSEPA [11]. The role of individuals and organisations in ensuring the success of technology change is a key part of the latter project.

Much scientific software, especially the large codes, is known to be seriously affected by software bugs [12]. The reason is obvious, testing has been rudimentary and little of the work has been carried out by qualified software engineers. A core part of the remit of the Centre is to provide support and services to the scientific research community to remedy this dismal situation. Such scientific software is more and more important in policy analysis, particularly in environmental, economic and social research. Other grants include Automated Discovery of Emergent Misbehaviour looking at the testing of advanced simulation software used in medicine and biology.

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People

Professor Holcombe has substantial experience running large research projects and founded the software company epiGenesys. He was also Head of Department of Computer Science and Dean of the Faculty of Engineering at different times. He has a long history of research in agile software engineering and software testing. He is also the lead on a number of complex system simulation projects in biology, economics and social science. He has been active in open-source for public administration projects in Europe for the last 7 years. He is Chair of the Creative and Digital industries Board of the Sheffield City Region Local Enterprise Partnership (one of the bodies replacing the RDA Yorkshire Forward) and is heavily involved in the planning of the region's digital strategy with BIS, Treasury and Cabinet Office. ASTTRA is one of the cornerstones of the strategy's TechCity proposal in this region.

Prof John Derrick is head of the computer science department at Sheffield. He has undertaken a substantial amount of work on theoretical and methodological aspects of formal methods and their application, particularly to distributed systems. He has published over 130 journal and conference articles, edited a number of collected works, and several research monographs. He is Vice-Chair of IFIP Working Group 6.1 (Architectures and Protocols for Distributed Systems), on the steering and PCs for many international conferences (FMOODS, FORTE/PSTV, TESTCOM, Z, IFM, Model-Based Testing), and has edited a number of special issues of major journals (FACS, IEEE TSE, SoftSys etc). He recently held a Leverhulme Research Fellowship. He has extensive experience of management both of research projects and Univ. management, and is the coordinator of the FP7 project ProTest.

Professor Simeon Yates is the Director of the Cultural, Communication and Computing Research Institute (C3RI) at Sheffield Hallam University in the UK. This role includes Director of the Design Futures Center of Industrial Collaboration as well as over sight of the Art and Design, and the Communication and Computing Research Centres. Simeon has a background in social science (communication studies) as well as an interest and training in science (geology) and has previously worked at the Open University (UK) and at the University of Leeds (UK). His current broad research interests include: new media, language, culture and interpersonal interaction; scientific and technical communication; and discourse analysis - theory and methods.

Phil McMinn is Senior Lecturer in Software testing at the University of Sheffield. His expertise is in evolutionary testing of complex software and in search-based software engineering, generally. He has worked extensively with industry including Mercedes Cars, McLaren Racing, Motorola etc.

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