Future Challenges in Software Engineering Workshop

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Report on Outputs and Next Steps

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1. Motivation and Objectives

In both the current and previous delivery plan period Software Engineering has been marked as an area for growth, as a proportion of the EPSRC portfolio. However, this has not occurred and this workshop was designed to better understand why this is the case and identify a series of actions that would enable us to realise the Software Engineering research area strategy. The workshop had the following objectives:

- Identify a number of challenges in Software Engineering and understand what is required to combat them
- Understand the UK Software Engineering community and identify methods to build it across academia and industry
- Help EPSRC realise the Grow strategy for the Software Engineering Research Area

2. Agenda

9.00	Arrival and Coffee
9.30	Welcome and Introductory Talk
10.00	Session 1: Identifying Future Challenges
11.45	Coffee
12:00	Session 2: Understanding the Image of Software Engineering
13:00	Lunch
14:00	Session 3: Roadmapping
16:00	Next Steps and Closing Remarks
16:30	Close

3. Pre-workshop exercises

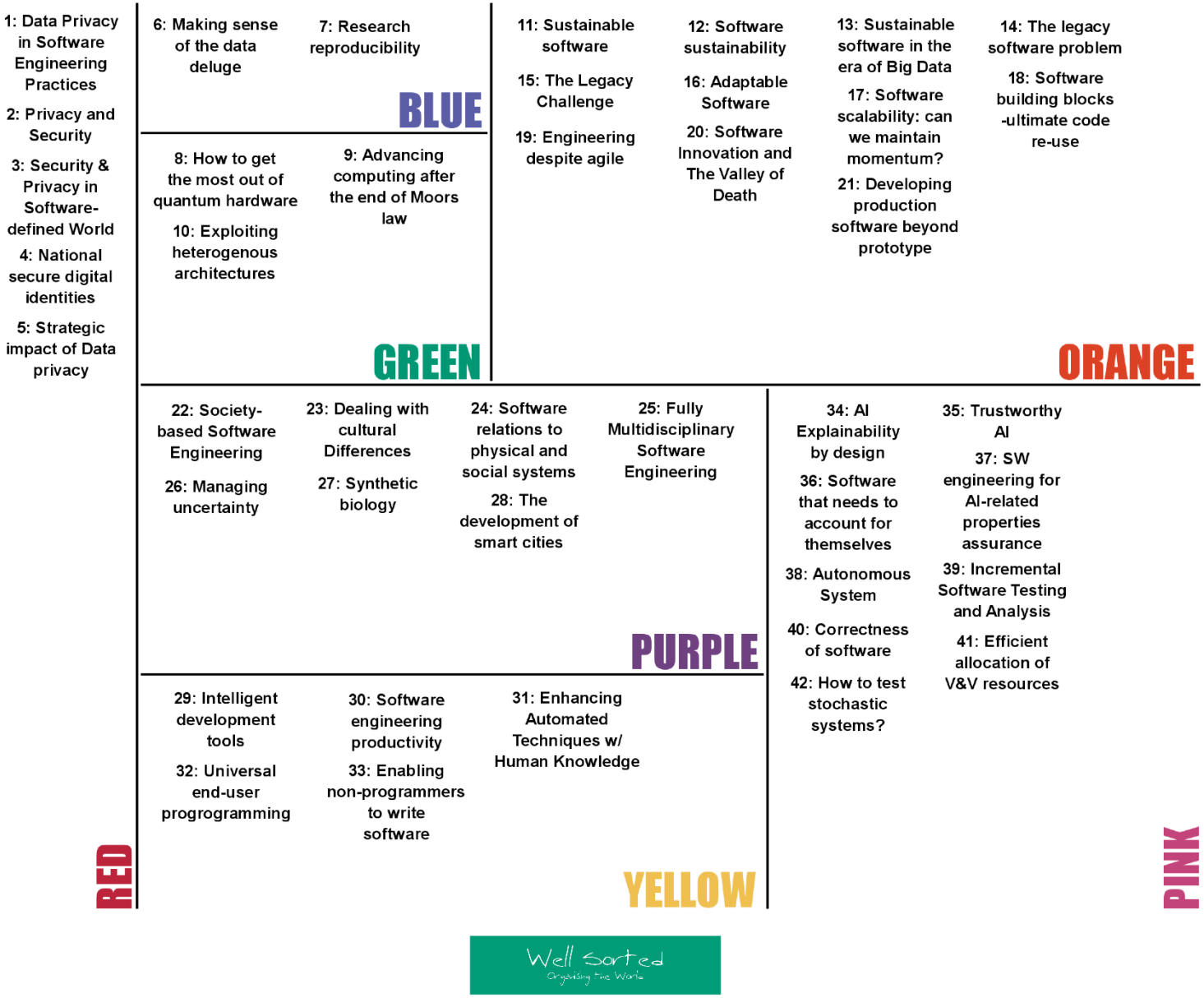
Prior to the workshop delegates were asked to complete an exercise using the "Well-Sorted" tool. Delegates were asked to provide two challenges in the area of Software Engineering and then sort the answers from all delegates into similar groups. The average of these sorts was then compiled and used to create the groups for the first Session of this workshop. The results of this exercise are shown below in Figure 1.

Delegates were also asked to speak to their colleagues outside of Software Engineering to answer the following two questions:

- How would you define Software Engineering?
- How important is Software Engineering research? Please provide reasons for your answer.

The answers to these questions were provided to the delegates for the second session and used to frame the discussion around the image of Software Engineering.

Figure 1: Result of the pre-workshop Well-Sorted exercise.



4. Outputs from Session 1 – Identifying Future Challenges

For the first session each table was tasked with looking at one of the coloured groupings from the Well-Sorted exercise. Delegates were first invited to discuss the commonalities within their cluster and identify if there were any outliers. Delegates were then asked to identify the bottlenecks or roadblocks within the cluster they were looking at and answer the following questions:

- Why have these challenges not been solved already?
- What needs to be done in terms of novel Software Engineering research to tackle this problem?

Below are brief summaries of each table's discussion about the coloured clusters. Note that due to the size of the Blue and Green groupings these were discussed on a single table.

Red Group

The Red cluster concerned the challenges of ensuring security and privacy in software development. The group discussed the challenges of privacy and security by design and how sometimes ensuring security "requires giving up some privacy". The complexities of verification of machine learning and other data driven systems was discussed and the implications this has for security. The table questioned where the security and privacy requirements come from and stated that there is still a need for robust software engineering methods for security by design systems.

Orange Group

The orange cluster primarily dealt with software sustainability and dealing with legacy software. The group defined the overall challenge as creating software that efficiently and effectively changes with needs and understanding how to sustain such software or replace when necessary. A major problem discussed by the table was how researchers don't often have access to *real* systems and that the links between academia and industry need to be stronger to improve sustainability of real world systems. The group also discussed some open research questions including whether cultural or organisational factors have a role on software sustainability, and what effect new hardware will have on this problem.

Yellow Group

The Yellow group defined their cluster as *Software Engineering for Domain Experts and the Commons,* effectively a range of techniques to democratise software engineering and enable non-experts in designing and writing software. The group discussed the difficulties in ensuring that these techniques would create systems that were both safe and secure. They

discussed how there are still needs for efficient, automatic software engineering methods i.e. tools that can automatically test, debug or even write code.

Purple Group

The purple table defined their cluster as *Society-Driven Software.* This cluster included the challenge of society managing and owning software, and also understanding the effect software can have on our lives. The group discussed the current challenge in software development across *two worlds,* the technical domain and the stakeholders or users of that software. The table discussed the need for better communication between these groups, to ensure that the users of software fully understand the importance of software in their everyday lives.

Pink Group

The pink table defined their cluster as *Complex Evolving Systems* and it concerned the software challenges associated with AI and autonomous systems. This includes research into the verification and validation of intelligent systems and of software that has to work in an unknown, unpredictable, stochastic environments. This includes autonomous vehicles, sensors and cyber physical systems. The group identified that this not only includes verification but also research into how we write software for these type of systems.

Blue/Green Group

The blue cluster concerned the emergence of new computer paradigms such as non Von-Neumann and quantum computers and the effect this would have on software engineering. The group's discussion was mostly focussed at a higher level than software and included the need for new architectures and programming languages to handle new computer hardware. Education was identified as a major roadblock and the need to teach programmers and software developers how to write for future computing systems.

The group briefly discussed the green cluster and identified the need for new software tools that can handle huge amounts of data.

5. Outputs from Session 2: Understanding the Image of Software Engineering

Delegates were provided with a selection of answers from the questions described in section 3. The aim of this session was to understand the external view of software engineering and these answers were used to focus this discussion.

In the round table discussion that made up the bulk of this session the delegates discussed the need to rebrand the area. Delegates described software engineering as an "anti-buzz word" and highlighted the need for a new 21st century definition of the area that framed it

as research which tackles societal need. It was identified that any such rebranding would require a multi-disciplinary approach.

The rest of the discussion revolved around the nature of this rebranding. Whilst discussing the differences between software engineering and the rest of computer science, some delegates suggested the community should *embrace engineering* and the need for people who can build software rather than research in how to do it. Other delegates disagreed with this point highlighting that engineering implies a top-down approach and bottom up approaches are still very important in this area.

The delegates also discussed the important role of advocacy for software engineering and the need to communicate its impacts. This includes emphasising how key it is for other areas of EPS research and where those outputs end up e.g. in industry, in other fields. Some delegates were worried that focussing too much on the impacts of software engineering in other domains could reduce the field to a service for others. They stressed the point that any multidisciplinary working would have to involve true co-creation, with all parties working on problems that are novel and interesting for all involved.

6. Outputs from Session 3: Roadmapping

For the final session the delegates were asked to perform a road mapping exercise. This involved delegates taking it in turn to add cards to an evolving timeline. These cards could form one of the three following components that made up the overall roadmap:

- Major socio-technical events that made up the overall backbone of the timeline
- Software Engineering challenges required to realise the above events.
- Workpackags or concrete pieces of research required to tackle the above challenges.

Figure 2 shows a schematic of these timelines which was used to describe the activity to the delegates on the day. Figure 3 shows an example of one of the completed timelines created by one of the workshop groups.

Delegates stayed within the groups from the first session and were advised to use the outputs from that session to help with the building of their timeline. Below are brief summaries of each of the tables' timelines.

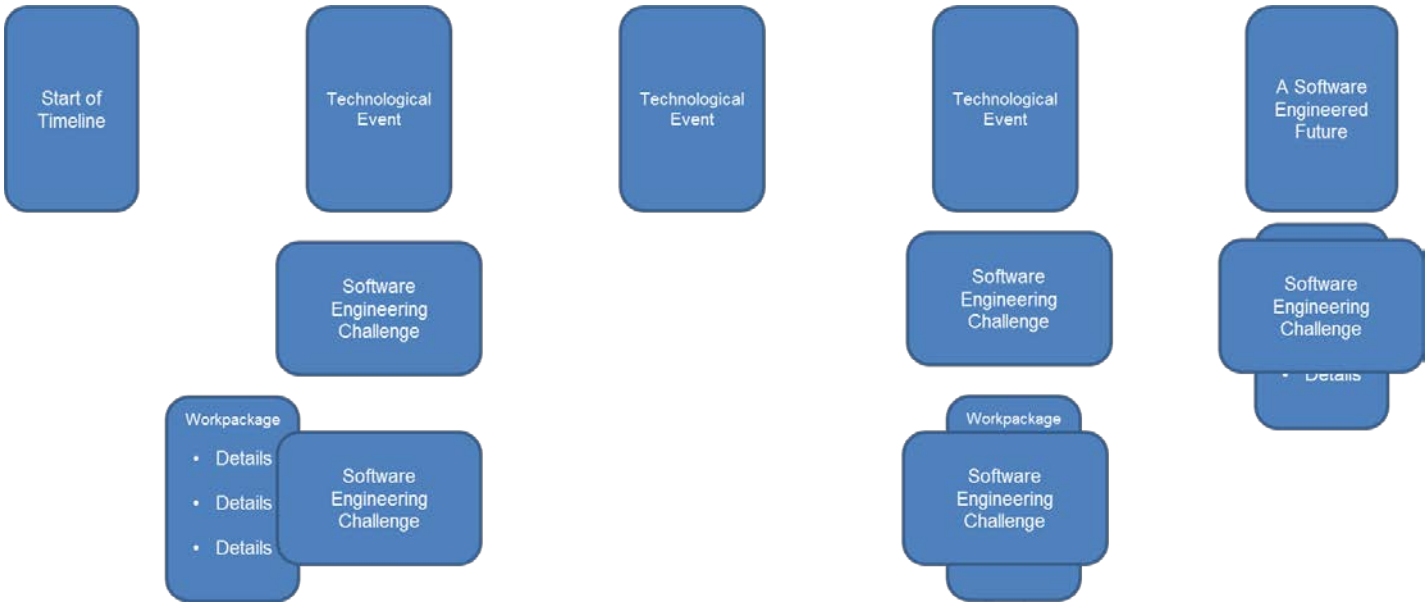


Figure 2: A schematic of the timeline exercise used for the third session at the workshop. Delegates were asked to take it in turns adding cards in order to collaboratively create a timeline. At the top level major technological events were added. Underneath these a second timeline of software challenges was added. Last of all, underneath these challenges delegates could add cards detailing specific research questions or workpackages.

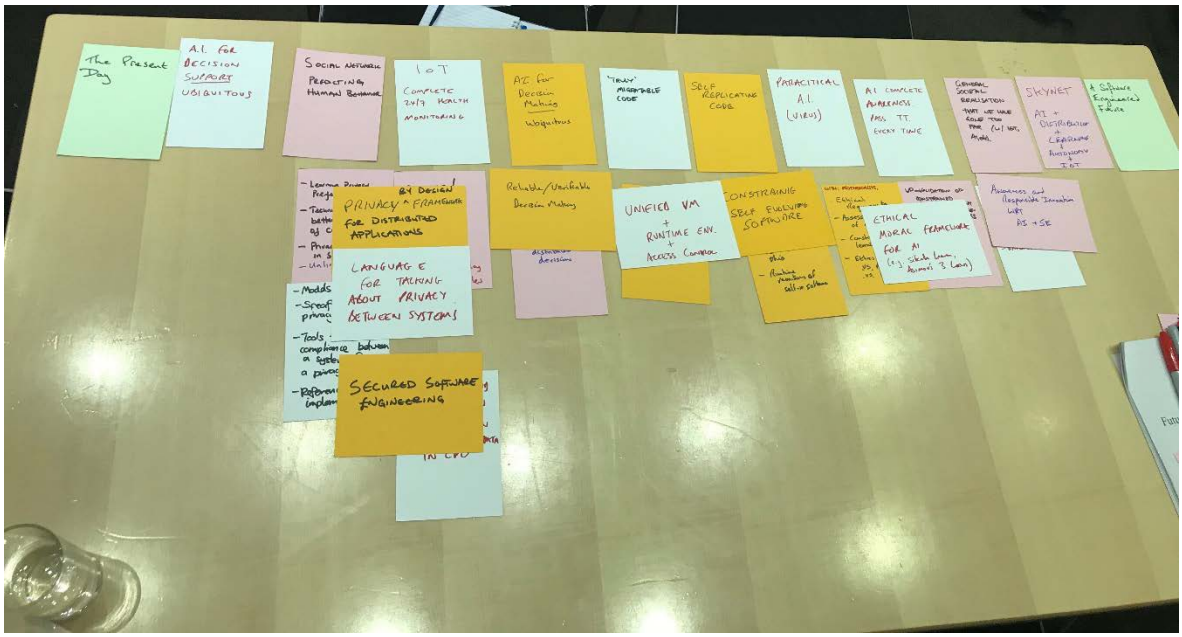


Figure 3: An example of one of the timelines created at the workshop. In practice some delegates chose to place challenges that cut across multiple technological events.

Red Group

This group's timeline tracked the progress of software for Industry 4.0 systems, through to smart cities and eventually software that can build itself. The table focussed on the socio-technical and human aspects, and on the democratising of software engineering whereby end-users could define the requirements of software which would then build itself. The group identified the longevity and disposability of such systems as a major challenge and said that work would be required to check the health of aging software.

Orange Group

The orange table focussed specifically on reliably programming for parallel systems. They identified a number of challenges in this area including the need for new mathematical notation. The group's timeline extended beyond programming to improvements on verification for larger systems and ultimately to AI systems that could learn from single examples rather than requiring large data sets.

Yellow Group

Rather than create a detailed timeline the yellow group zoomed in on two technological events. They explored the challenges present in non-conventional software engineering, namely programming for biological applications. For this they discussed the challenges in creating languages that can be translated into living organisms, and that this would require multidisciplinary working with biologists.

Separate to this the yellow table they focussed on the challenges in building trustworthy and trusted systems. They discussed the need to understand legal and social issues and how trust can be measured. They also discussed how you future proof a trustworthy systems specifically against cyberattacks. They identified the challenge in quickly changing code to deal with attacks whilst maintaining the functionality, and trustworthiness of the system.

Purple Group

This group's timeline covered a variety of major socio-technical events including the development of the internet of things, software that can be fully and safely configured by users, the deployment of autonomous vehicles and ultimately a world where over 80% jobs have been automated. In creating this timeline the group discussed a large number of associated software engineering challenges.

When discussing the internet of things the group emphasised the need for smart systems that still work when they lose access to the network. When discussing user configurable

software the group identified the challenge in ensuring these systems were robust and *self-healing*.

A common thread throughout this timeline was the steady improvement of smart systems. The group stated multiple times the need for privacy and security by design in the systems and, as with other groups, the importance of trust in such systems was identified.

Pink Group

As with other groups the pink table's timeline chronicled the progress in artificial intelligence. This group focussed on some of the potential negative aspects of AI such as social networks that can mimic human behaviour, self-replicating code and ultimately a dystopic vision of the future where AI has overtaken human intelligence.

The group focussed on the vital role software engineering has to play in preventing this future. This included the verification of autonomous systems and applying constraints to self-evolving software.

The importance of cross-disciplinary working was once again highlighted and the group discussed the need to work with social scientists on the ethical and legal aspects of intelligent software.

Blue/Green Group

The blue/green table's timeline contained many elements that other groups also discussed including, legacy software systems, autonomous vehicles, the internet of things and a future autonomous workforce. The end point of their timeline focussed on a future where the average life expectancy exceed 100 years and the impact software will have on an aging population.

The group discussed the use of machine learning systems to understand wellness and stress and the need for research into the impact of software on well-being, dignity, personal choices and fairness. Namely, as with other groups the blue/green table focussed on the human aspects of software engineering and the need for multi-disciplinary research in tackling this.

7. Conclusions and Next Steps

The workshop concluded with a roundtable discussion the events of the day and potential next steps. It was emphasised that the UK is currently internationally leading in software engineering and EPSRC has a role to ensure this is maintained. Several delegates discussed the need for greater industrial engagement, and what EPSRC can do to help facilitate this engagement and help researchers gain access to industrial scale software.

A reoccurring theme throughout the workshop was the huge effect software can have on our everyday lives. Delegates discussed the importance of ethics and ensuring software systems are developed responsibly. Some delegates questioned how much of software engineering research funding is about actually understanding the human element.

This led to a discussion on the need for multidisciplinary software engineering research and its associated challenges. Some delegates returned to an earlier discussion on the need for true co-creation, ensuring the software engineers are not treated *as a service* and that the multidisciplinary research is truly integrated.

The need for a rebrand of the area was mentioned again and that this would help highlight the importance of software engineering on people, help promote multidisciplinary research and improve the engagement with industry.

Delegate List

Anna	Angus-Smyth	EPSRC
Michael	Barclay	EPSRC
Balbir	Barn	Middlesex University
Nelly	Bencomo	Aston University
Achim	Brucker	The University of Sheffield
Michael	Butler	University of Southampton
Cristian	Cadar	Imperial College London
Nicholas	Chancellor	Durham University
Hana	Chockler	King's College London
Steve	Crouch	Software UK
Andreas	Dedner	University of Warwick
Jason	Morgan	EPSRC
Michael	Fisher	The University of Liverpool
Robert	Haines	The University of Manchester
Rob	Hierons	Brunel University London
Paul	Jackson	University of Edinburgh
Caroline	Jay	The University of Manchester
Catherine	Jones	STFC
Joanna	Leng	University of Leeds
Emmanuel	Letier	University College London
Ana	Martinez-Ubeda	EPSRC
Sofia	Meacham	Bournemouth University
Goksel	Misirli	Keele University
Bashar	Nuseibeh	Open University
Inah	Omoronyia	University of Glasgow
Federica	Sarro	University College London
Alan	Serrano	Brunel University London
Helen	Sharp	Open University
Martin	Shepperd	Brunel University London
Les	Sims	EPSRC
Laurence	Tratt	King's College London
Colin	Venters	University of Huddersfield
Anna	Walker	EPSRC
Christopher	Woods	University of Bristol
Steffen	Zchaler	King's College London
Andrea	Zisman	Open University