Supersized Systems
Our main feature includes articles on a diverse selection of systems, but in their own field, each is supersized.

Chapter Updates
Check out our reports from November’s ASEC, as well as our regular PD updates. We are also pleased to announce our new offer on the Systems Engineering Competency Framework.
differentiate in 2018

become distinct in the process of growth

TECHNICAL PROBLEM SOLVING
19.03.18

FUNDAMENTALS OF SYSTEMS SAFETY
09.04.18 - 10.04.18

ACOUSTICS SYSTEMS ENGINEERING
04.06.18 - 05.06.18

QUALITY ON TIME
06.06.18 - 07.06.18

DESIGN THINKING & LEAN INNOVATION
18.06.18 - 20.06.18

CRADLE - TO - GRAVE: EQUIPMENT LIFE CYCLE ANALYSIS
27.08.18

FOR ALL 2018 COURSES: www.se-training.net

10% OFF COURSE FEES FOR INCOSE, IET & IEEE MEMBERS

LONDON - ZÜRICH FLIGHTS AS SHORT AS 1.5 HOURS
Regulars

5  President's Corner
10 Professional Development Update
14 I am a Systems Engineer and I Do...
16 I am Volunteer and I Do...

Features

6  ASEC 2017 Report TANYA GALLIARA
8  ASEC 2017: View From an Outsider ROSE DIXON
13 EMEA Sector Systems Engineering Conference

Supersized Systems Feature

18 Using 21st Century Systems Engineering to Monitor a 19th Century Plant JON WILLIS, MIKE RODD AND JON HOLT
20 The Enterprise Revolution... JOHN LOMAX
25 Supersized Systems; An Interview With Dr Larry Kennedy DR LARRY KENNEDY

Society News

9  Training Day 2018 TANYA GALLIARA
11 INCOSE UK Membership Survey
12 Systems Engineering Competency Framework Price Cut
16 Early Careers Forum OMER ELROUBI
30 INCOSE UK Events Calendar
Hello and welcome to this - slightly delayed - Winter edition of Preview magazine.

We have lots of content for you this issue; our regular content includes our ‘I am a...’ articles, with Sam Williams from DE&S completing our Systems Engineer feature [page 14], and Omer Elroubi from QinetiQ writing about his volunteering experience [page 16].

You can find our usual professional development update on page 10, which includes details on this year’s paper-based SEP exam.

INCOSE UK’s incoming Events Director, Tanya Galliara, reports back on her first impressions of ASEC in the role following her appointment in November. She also includes some details on the direction that this year’s events will be taking - read her report on page 6. We are also delighted to include a report from Rose Dixon, who was invited to ASEC so that she could attend the inaugural M’Pherson Lecture, as a family representative [page 8].

Preceding the staged release of the version 4.0 Systems Engineering Competency Framework, we are happy to announce a price cut for the current INCOSE UK Framework. Soft copies remain free to download for all Chapter members, but you can now pick up your hard copy for a discount - find out more on page 12.

This year’s INCOSE EMEA Sector Systems Engineering Conference will be taking place in Berlin this November, and the call for submissions is currently open. Find out full details regarding this on page 13.

Finally, you can read our main ‘Supersized Systems’ feature from page 18 onwards.

We have a range of subjects; the 21st century monitoring of a 19th century plant, an exploration of Enterprise Systems Engineering and an interview with Dr Larry Kennedy, who worked on the Apollo space programme in the late 1960s. A big thanks to all of our contributors for this issue and we hope that our members enjoy the feature.

Our next issue of Preview will released at the end of April and there will be an ePreview to come in the next few weeks - make sure to keep your eyes peeled for more details on this year’s events!
As we are already well in to 2018, there are lots of developments underway that I would like to share with you.

Last year’s Annual Systems Engineering Conference was a great success. It was very encouraging to see delegate numbers increase sharply from the previous year, and the feedback that we received was almost universally positive. The quality of the sessions on offer goes from strength to strength each year, and I would like to thank the technical team for the work that they put in to help achieve this.

I would also like to acknowledge all of the work put in by our outgoing Events Director, Ian Gibson, whose efforts have gone a long way towards making ASEC into the event that it is today. At ASEC 2017 we welcomed Tanya Galliara to the INCOSE UK Council as the incoming Events Director and I look forward to working with her, and seeing what exciting contributions she will bring to the role.

Looking forward to the coming year, there is lots of exciting developments on the horizon.

As many of you may already be aware, this year has been designated the Year of Engineering. It is a government initiative that aims to shake-up people’s ideas about engineering; inspiring the next generation of innovators, inventors and problem solvers by showing them what engineers actually do.

I am pleased to confirm that INCOSE UK has signed up to be a partner organisation to this initiative. We will be looking to put a focus on this throughout 2018, and will be attempting to help our members and UKAB companies to run STEM activities and promote engineering to the next generation of practitioners.

In addition to supporting the Year of Engineering, we will also look to be highlighting Systems Engineering specifically as an emerging field.

We are currently planning to produce a special ‘Year of Engineering’ edition of Think Engineer. There is an opportunity for our UKAB members to get involved, with each company receiving a batch of branded books for them to give away as part of their STEM and outreach opportunities. The details of how to opt in to this have already been sent to our UKAB POCs, but if you have missed this and would like to receive more information, please email publications@incoseonline.org.uk. If you have any children (or grandchildren!) who are in KS2 and you would like to get them an educational gift, then why not pick them up a copy of Think Engineer? It is available from the INCOSE UK online store, with shipping available worldwide.

In June we will be running our annual Training Day, with this year’s event taking place at a new venue for us; the Marsh Farm Hotel, Royal Wootton Bassett. Due to circumstances outside of our control, we have had to make a change to the originally advertised venue, but we have managed to find somewhere that is only a few miles away! The booking system will be online shortly and we have a fantastic mix of courses available, with some options that are brand new for 2018. Keep an eye on the INCOSE UK website for details.

On the subject of professional development, I would also like to congratulate our latest CEngs’ David Ferguson and Ian Gibson, and new CEng transfer to INCOSE UK Franco Curtolo.

I also give my warm congratulations to latest ESEP Richard Beasley, and new ASEPs Jose Paul, Sarah Routley, Ian Ridpath, Matthew Harris, Neil Comerford, Marie Ertl, Michelle Stewart, Ian McNaughton and Salman Naqvi.

Finally, we are also on the cusp of being able to release more information about this year’s ASEC. There are some exciting new developments in the pipeline for this year’s flagship event and I look forward to being able to share them with you soon.

In the meantime, enjoy the issue!
We went all out at ASEC 2017 to Push the Boundaries of Systems Engineering (SE) knowledge. I particularly enjoyed our two inaugural M'Pherson and Arnold keynote lectures, delivered by Gordon Masterton and Paul Schreinemakers. It was also my privilege to observe and listen to Ian Gibson - my predecessor as Events Director - and his co-presenters, give their presentation on the MOD Acquisition Requirements & Acceptance Tube Map. For me, this is exactly the kind of novel thinking that means that systems engineers are shaping the future direction of the Engineering industry. I would also like to take this opportunity to recognise Ian’s contributions as Events Director towards really developing and making ASEC the ‘go to’ Systems Engineering event. I have very big boots to fill and look forward to working with Jon Holt, Emma-Jane Taylor and other members of the Events Team to really keep the momentum going for ASEC 2018.

The presentations from ASEC 2017 are now available on the INCOSE UK chapter website, and I would strongly encourage members to download these and take the opportunity to consider where they may be able to use some of the many good ideas presented. Not only did we have an excellent range of speakers, there were various tutorials taking place at ASEC 2017. Although I wasn’t able to drop in on all of these sessions, feedback from these sessions is that attendees found the content useful and would be able to take the material back to use in their workplaces. One session that I had really positive feedback about was the opportunity for attendees to attend a workshop on reviewing the material they had learnt about during the conference, and develop their thoughts and ideas on how they could apply what they learnt back in the workplace. I’d be interested in your feedback if you attended this session, to see if you managed to implement some of the ideas and thoughts developed during this.

I’d also like to bring to your attention that the Early Careers Forum (ECF) had their inaugural meeting at ASEC and I’d like to take the opportunity to congratulate Omer Elroubi on being elected to chair the ECF. The ECF is open to people of all - or no - technical backgrounds, who are starting or transitioning into a career in Systems Engineering. The current members are an enthusiastic and vocal bunch, and I am sure their voices are going to grow and become more strong as INCOSE UK develops through the next few years.

On this theme, the Systems Summit hosted by Jon Holt was a huge success, and the results and outcomes were presented to the UKAB and the INCOSE UK Council following ASEC 2017. We are going to be exploring the issues raised and I would like to thank the attendees who took part in this.
Of course, the conference wouldn’t be complete without the annual conference dinner. We had the opportunity to thank our two keynote lecturers and to also recognise the efforts of various members of the INCOSE UK team. In particular, I would like to thank the Dot-The-Eye team, headed up by Emma Jane Taylor. Their efforts were recognised as our unsung heroes, and having had the opportunity to spend time with them, both during my own CSEP application process and in finding my feet as Events Director, I would like to acknowledge personally the huge amount of effort they put in to helping us with providing support to the UK SE community. This was shown in the number of ASEP and CSEP individuals who were recognised at the dinner. Rhys Phillips was a fantastic after dinner speaker and some of the themes he explored in his talk will be picked up at ASEC 2018.

This year, we are picking up on the themes of ‘Year of Engineering’ and ‘Year of Women’ and will be promoting these as part of the activities we are arranging for the Training Day and ASEC 2018. You can read more about this year’s Training Day on page 9.

The theme for this year’s ASEC is based around the Year of Engineering (https://www.yearofengineering.gov.uk/) and also the Year of Women in 2018. Picking up on themes from the Training Day, we are planning to run various STEM engagement activities with local community groups, to tie in with both the Year of Engineering and the Year of Women, and will be asking you to take an active part in supporting this as part of the ASEC activities planned for this year. I am personally really excited about being able to give back and reach out to the groups we hope to work with as I know from my own experience, that role models come in all forms and inspiration can come in many ways.

“The theme for this year’s ASEC is based around the Year of Engineering and also the Year of Women in 2018.

Picking up on themes from the Training Day, we are planning to run various STEM engagement activities with local community groups, to tie in with both”

We do have a venue planned for ASEC 2018, and are in the final stages of confirming it. However, I would very much like to highlight that our call for speakers, posters and tutorials will be coming out soon and I would encourage you call to consider submitting a paper, tutorial or poster.

As always, any questions, thoughts, comments or feedback, please let me know at events-director@incoseonline.org.uk, or the Events team know at events@incoseonline.org.uk.

Continued overleaf...
For a complete outsider, what did I make of the INCOSE UK annual conference? To be invited at all speaks well of the inclusiveness of SE. As family of Philip M’Pherson, I was invited to attend the inaugural eponymous lecture and, on arrival, I knew only that ASEC was one of the few gatherings where he always felt at home, where he could speak as he found, and in language that would be understood. Certainly, I was made welcome and given a sense that INCOSE UK is friendly and unstuffy - something of a family itself. No doubt it has squabbles, but as a tribe it seems to hang together well, accommodating its own diversity in a kind and generous way.

As a professional body, INCOSE UK has the vigour of relative youth and seems delightfully free from the sclerosis suffered by older institutions. One factor in this is probably the general ‘no-nonsense’, ‘down-to-earth’ attitude I picked up, typical of engineers, which must help to avoid (or at least reduce) political infighting. Another may be a constitution that keeps the committees topped up with new blood. It was also refreshing to find the presence of an able and enabling secretariat, i.e. the absence of a remote head-quarters administration that can be so stifling.

Listening in to presentations, the focus that came across is that of an industry body, with all its messy real-world problems. Clearly there is genuine openness and interest in shared learning from case studies and in developing best practice. It was good to see the relatively inexperienced being given a platform to test themselves out along with established gurus. I would have liked to have heard more from seniors in the audience by way of searching questions to probe weaknesses and sloppy thinking - but that may not be a fair quibble as my sample was small. There seemed to be little on more theoretical work, and just a scatter of delegates from academe. I found myself wondering if there is (or needs to be) a home for Systems Science if this is largely eclipsed in the SE forum.

“In some ways I felt that INCOSE UK is coming of age: old enough now to recognise founding fathers for the first time (losing its parents), and bent on providing paths for the next generation of SEs (bringing up the kids)”

The emphasis on looking ahead struck me as encouragingly strong, living up to the conference theme of ‘Pushing the Boundaries’. The ways in which SE can extend beyond its current reach to achieve greater sway and wider application is a long-term issue. How many organisations currently have a ‘Systems Director’ at board level, for instance? That could take a generation or more to become the norm. However urgent the need, there are seldom shortcuts to bring about such organisational change. How excellent that this is being taken seriously and recognised as too important to be left to ‘mañana’.

In some ways I felt that INCOSE UK is coming of age: old enough now to recognise founding fathers for the first time (losing its parents), and bent on providing paths for the next generation of SEs (bringing up the kids). The emphasis on looking ahead struck me as encouragingly strong, living up to the conference theme of ‘Pushing the Boundaries’. The ways in which SE can extend beyond its current reach to achieve greater sway and wider application is a long-term issue. How many organisations currently have a ‘Systems Director’ at board level, for instance? That could take a generation or more to become the norm. However urgent the need, there are seldom shortcuts to bring about such organisational change. How excellent that this is being taken seriously and recognised as too important to be left to ‘mañana’.

INCOSE UK looks well placed to build on its lead, to maintain the continuity needed to strengthen professional practice, and to bring the best brains to bear on expanding its sphere of influence. For a guest and a stranger, ASEC 2017 was a stimulating event and the first M’Pherson Lecture a heart-warming occasion. It was a pleasure to be among you and the honour was all mine. Thank you and well done.
INCOSE UK Training Day 2018

Words: Tanya Galliara, INCOSE UK Events Director

INCOSE UK are pleased to announce that the Training Day will be open for registration from Monday 5th March 2018.

Please note that the venue for this year’s event has changed. It was originally intended for this to take place at Lydiard House, but due to reasons outside of our control, the new venue will be the Marsh Farm Hotel, Royal Wootton Bassett.

The Training Day provides an opportunity for INCOSE members to explore new topics and extend their knowledge of Systems Engineering practice. The aim is for each session to cover either an introduction to a subject (e.g. requirements for MBSE) or a more detailed insight into a specific topic (e.g. running a successful Requirements Review).

The theme for this year’s Training Day is based around the Year of Engineering. We want people to be inspired by what they are doing in their work, whether they are new to Systems Engineering or have many years’ experience. We would like to invite you along to take part in a tutorial session and share your experiences. We have taken a ‘Back to Basics’ approach with the tutorials on offer this year, to encourage discussion of the fundamental principles we apply on a day to day basis.

As usual, we have a variety of interesting and some new presenters for you. These include the opportunity to visit the oldest working Steam Beam Engine in the world at Crofton and use this as a live example for MBSE modelling practice. We are also welcoming several new speakers, who will be presenting fresh perspectives on familiar topics. Back by popular demand, there will be the opportunity to sit the INCOSE ASEP exam. As part of this, attendees will have the opportunity to attend a morning session on a new way to learn the IPO diagrams, before taking the exam in the afternoon.

The full list of presenters and sessions will be available on the INCOSE UK website from Monday 5th March. For any other questions about the Training Day, please contact the Events team at events@incoseonline.org.uk.

“Back by popular demand [this year] there will be the opportunity to sit the INCOSE ASEP exam”

Venue Change

This year’s Training Day will now be taking place at:

Marsh Farm Hotel
Royal Wootton Bassett
Professional Development Update

Words: Lynn Davis, Professional Development & Membership Manager, INCOSE UK

Certification

UK Chapter Applications

The number of INCOSE members applying for SEP through the UK online system continues to grow with interest in ASEP showing a significant uplift in early 2018.

Below are numbers of members achieving SEP Certification through the UK online system along with total number of UK Chapter members who are certified.

With plans for the INCOSE UK Training Day well underway, we will again be offering the opportunity to participate in the paper version of the certification examination. The event will be held at Marsh Farm Hotel from 2pm on 6th June 2018. Booking of the exam will be available when the Training Day 2018 booking goes live. In a marked change to last year it is no longer required to apply for ASEP in advance of the exam or even to be a member as INCOSE guidelines state that successful applicants can take out membership and apply for ASEP after receiving their results.

All those with current ASEP or CSEP applications have already been contacted in connection with this opportunity. If you are interested in receiving more information or would like to discuss your option please contact the Professional Development team on profdev@incoseonline.org.uk or 01460 298217.

<table>
<thead>
<tr>
<th>Level of SEP</th>
<th>UK accredited</th>
<th>Total UK (from INCOSE Central records)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASEP</td>
<td>24</td>
<td>38</td>
</tr>
<tr>
<td>CSEP</td>
<td>21</td>
<td>59</td>
</tr>
<tr>
<td>ESEP</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

Certification Exam Opportunity

be held at Marsh Farm Hotel from 2pm on 6th June 2018. Booking of the exam will be available when the Training Day 2018 booking goes live. In a marked change to last year it is no longer required to apply for ASEP in advance of the exam or even to be a member as INCOSE guidelines state that successful applicants can take out membership and apply for ASEP after receiving their results.

We also send our congratulations to our new ASEPs; Jose Paul, Sarah Routley, Ian Ridpath, Matthew Harris, Neil Comerford, Marie Ertl, Michelle Stewart, Ian McNaughton and Salman Naqvi.

New UK ESEP

It is great to start a new year with positive news and this year we welcomed a new ESEP in early January 2018.

After months of perfecting his application Richard Beasley was awarded ESEP by the INCOSE UK review team. Fortuitous timing meant that Richard was able to receive his award at the INCOSE IW event later that month and enjoyed well deserved congratulations from the wider INCOSE community.

Professional Registration

New Systems Engineering Guidance

INCOSE UK has now published domain specific guidance for systems engineers preparing an application for professional registration. The guidance links specific guidance to each area of the UK-SPEC, assisting systems engineers in documenting their experience. It is available to all members beginning the professional registration process via the INCOSE UK website and is also available to buy as a hard copy in the INCOSE UK online store.

New CEngs

November 2017 saw two INCOSE UK members attaining CEng through the INCOSE UK registration pathway with the SEE. Congratulations to Ian Gibson and David Ferguson.
Professional Registration Transfers

In December 2017 the SEE approval committee approved an INCOSE UK member who wished to transfer their professional registration to INCOSE UK. Franco Curtolo has transferred his CEng from the Nuclear Institute.

If you are currently registered through another engineering institution but find that your main work domain is Systems Engineering it may make sense to consider a transfer.

Professional registration Approval Meetings

Following administrative checks by INCOSE UK, the first step for INCOSE UK members to gain EngTech, IEng or CEng with INCOSE UK is submission to the SEE approval committee. This group meet on agreed dates throughout the year to review applications and transfers. The dates for 2018 are as follows:

- **Wednesday 14th March 2018**;
- **Wednesday 13th June 2018**;
- **Wednesday 12th September 2018**;
- **Wednesday 5th December 2018**.

Applications should reach INCOSE UK via the application upload and payment system a minimum of two weeks before the meeting is due to allow sufficient time for checks to be carried out.

If you are interested in finding out more about the process please contact Lynn Davis on 01460 298217 or via profdev@incoseonline.org.uk.

Early Careers Forum (ECF)

Following the official launch of the Early Careers Forum section on the INCOSE UK website the ECF Chair, Omer Elroubi, would like to encourage anyone with an interest to sign up and get involved!

Now that the ECF has officially launched, this is an excellent opportunity to get involved at an early stage and help drive it forward in to unknown territory. We will be looking to make progress on our aims and objectives and grow the forum; integrating it with other local and working groups where possible.

We also intend to set up a number of meetings and events throughout 2018 including a joint meeting with the UKAB and INCOSE UK in April this year. So if you're interested, please get in touch. We very much look forward to working together as part of an exciting new generation of Systems Engineering.

You can receive updates on the ECF by registering your interest via the INCOSE UK website. If you have any queries, you can contact Omer directly at ecfchair@incoseonline.org.uk.

INCOSE UK Membership Survey

Our Q1 2018 membership survey is now available online, and is focused to cover the area of engagement. We would like to hear from you about what resources you use and how you engage with the Society.

The survey is very short and should only take a few minutes of your time. If you would be happy to share your thoughts with us then we would be most appreciative - you can access the survey here.
Competency Framework Price Cut

While soft copy PDFs of the Framework remain free to all INCOSE UK members, you can now obtain a hard copy of this document for the reduced price of £30

Work is currently underway to update the existing INCOSE UK Competency Framework document, and it is expected that an early-release of version 4.0 will be available for INCOSE members to purchase later in 2018, with the annex to follow in 2019.

Prior to this release, the current Framework remains a comprehensive and up-to-date document and is an excellent reference for any practising systems engineer. If you have previously held off from purchasing a hard copy of this, now is the perfect opportunity.

This offer will remain active until current stocks are depleted. There will be no reorders made, so make sure that you don’t miss out by purchasing your copy now!

Both your complimentary soft copy, plus reduced hard copies, are available via the INCOSE UK online store here. Please don’t forget to log in using your INCOSE UK membership number and password, to receive your member discounts.

QINETIQ

Work with some of the world’s leading masterminds in Cyber and Systems Engineering.

Join QinetiQ and make the ‘Art of the Possible’ part of your future.

Find out more: QinetiQ.com/CITcareers
Mark your calendar for the bi-annual EMEA Systems Engineering conference, EMEASEC, in 2018. It is the premier conference of Systems Engineering and related disciplines in Europe, Middle-East and Africa (EMEA). The conference gives industry, organisations, educators, researchers, and government the opportunity to showcase cutting edge practice and research. EMEASEC 2018 also provides the opportunity to network with professionals from many domains in EMEA and Germany.

The conference will start with a tutorial day on Monday 5th of November. This is followed by the 2 days EMEASEC 2018 / TdSE 2018 conference with paper presentations and other exiting topics. On Thursday 8th of November we will offer some technical tours.

The EMEASEC 2018 conference is combined with the German Systems Engineering Conference, ‘TdSE 2018’.

Please submit papers and tutorials that fall within the practice of Systems Engineering and associated disciplines until 25th of May 2018. The theme of the conference, ‘Systems Engineering - Connecting the World’, focuses the application of systems thinking and Systems Engineering principles and processes on complex problems, such as the Internet of things, Industry 4.0, Digitalisation, Sustainability, Connected Home, Connected drive and Autonomous systems, with further proposals welcome.

Submission types are defined:
- Research papers, following the rules and requirements for a professional research paper
- Industrial papers are reports from practical Systems Engineering application providing lessons learned, tips and tricks and other valuable benefits for the participants where an easier review process is conducted
- Tutorials from educators and experienced systems engineers.

You can learn more about EMEASEC 2018 here and find out about TdSE 2018 here.

When
Monday 5 - Wednesday 7 November, 2018

Where
Berlin: Mercure Hotel
Stephanstraße 41
10559 Berlin
GERMANY

Theme
Systems Engineering - Connecting the World

Website
https://www.incose.org/emeasec2018
I Am a Systems Engineer and I Do...

Sam Williams from DE&S discusses how she started her career in Systems Engineering, and her advice for those who are just starting out themselves.

**Why did you choose to be a systems engineer?**

Like quite a few people I suspect, the label of 'systems engineer' only came many years after I'd been 'systems thinking' and 'systems doing' in many varied engineering roles.

I trained as an electronic/electrical engineer as part of a four-year Telecommunications Craft Apprenticeship in the dockyard. From this, I went on to be a Telecommunications Maintenance Engineer, a Combat Systems Installation Engineer, a major warship Platform Upgrade and Upkeep Installation Manager, a Weapons Systems Trials and Commissioning Officer, an ILS Manager for new defence sonar systems, an MoD-wide Acquisition Transformation Change Manager, a Systems of Systems Architect, a Capability Engineer and a Systems Engineering policy author, among others. All of which required me to apply systems thinking and systems science to help understand and solve real world business problems; that's my expansive definition of Systems Engineering.

"I never grew up with the notion that I wanted to be an engineer... I did however, grow up with a desire to understand why things were the way they were"

I never grew up with the notion that I wanted to be a systems engineer, or even an engineer for that matter. I did however, grow up with a perpetual curiosity, and a desire to understand why things were the way they were. I saw connections and patterns everywhere, had a vivid imagination of how things could be different, and a somewhat reckless sense of discovery to try new things.

This has led me on a 25-year journey backwards through the defence lifecycle, starting from the nuts and bolts of service equipment support, through to now at the fuzzy front end of complex Capability Engineering and Organisational transformation.

Perhaps the question should be why have I stayed in Defence (as a Systems Engineer) for 25 years? It's because every day I can see the need to improve as an organisation in how we understand and deal with complexity, uncertainty and change. Applying systems thinking and doing in defence gives me rich opportunities to tackle those messy complex problems and make a difference. There's never the excuse of a dull moment as a systems engineer in defence, there's always challenging problems, room for improvement, and opportunities for learning somewhere if you choose to seek it out.

**Education / qualifications to become a systems engineer?**

As an engineer, I have general engineering education and qualifications, 4-year Indentured Craft Apprenticeship, a HNC in Electrical/Electronic engineering, IEE qualified Electrician, Post Graduate Certificate in Supportability Engineering (ILS), Post Graduate Diploma in Systems Engineering. I'm a IET Chartered Engineer, and an INCOSE ASEP and CSEP.

I do not have a first degree, and have not quite finished two part-time MSc’s through my career so far. (third time lucky perhaps?)

For me, Systems Engineering is a team sport; we don’t do Systems Engineering in isolation for the sake of it. Systems Engineering helps support a wider business need, therefore it needs to be applied in concert with all other parts of business to be useful and successful. Doing that well requires lots of soft and business skills, of which I have acquired a few of the years (portfolio, programme and project management, change management, negotiation, facilitation, emotional intelligence, to name a few).

Systems Engineering is also a practise and an art, it is the creative application of systems science to tackle real world problems... That requires real application, trial and error, reflection, continuous development, a sense of adventure, and, in most cases, opportunities to put it into action for real more than once or twice. Often it is from our scars and failures we learn and grow the most as systems engineers! So I've more learning to do. In order to support my current work in complex Defence Capability Coherence, I'm informally educating myself in behavioural psychology, decision science, eastern philosophy, and complex adaptive systems.

Finally, two other key qualifications spring to mind: having the skin of the rhino to cope with the impact of critical challenge, and endurance to keep going in face of failure, adversity and sometimes isolation. I'm continuously working on those ones!
What is it about Systems Engineering that you find so compelling?

Ahhhh great question! Interestingly, the choice of words presumes as system engineers we are compelled to be systems engineers and do Systems Engineering? That would be a fair description in my case!

"We are what we repeatedly do" Aristotle said (I think!). I can't help noticing connections and patterns that others in the team generally do not; I'm hopeless at detail most of the time. I search for the similarities in things that look different and differences in the things that look similar. I am compelled to ask 'why', to question assumptions, and explore the 'what ifs'. I often say 'I don't get it'... I am compelled to understand why I don't get it... often asking for people to "explain it to me like a 3-year-old". I always look for how it can be improved, or indeed made worse.

Systems Engineering offers lots of opportunities for exploring messy 'why' and 'I don't get it' situations; that interests me. My particular area of Systems Engineering is often very people-centric and stakeholder focussed activity based. As a compulsive 'people watcher', I find that aspect very interesting too.

I also have a belief that the pursuit of better understanding of problems - particularly complex, messy ones - will help improve our ability to implement better solutions and therefore add value, make a difference, and contribute to the greater good.

Applying Systems Engineering in complex defence problems situations satisfies a compulsion to contribute in a unique and fun way.

Systems Engineering is such a broad church and there are lots of ways to add value across the spectrum: from fuzzy front-end organisational-level problem structuring activities, to more traditional product focussed problem solving and integration activities. I enjoy the challenge of putting together diverse system approaches, methods, and techniques in different ways to help tackle complexity in defence. There is always lots of variety, lots of challenge,

What advice would you give a systems engineer just starting out in their career?

Have fun and actively seek out the ambiguity. The field of Systems Engineering is so broad (and evolving) that there are many areas to work in. I would recommend not to treat it as a destination career, perhaps more like an intriguing and rewarding journey. My advice would be find something within Systems Engineering that resonates with you (or conversely jars with you) and start from there; keep an active open mind to potential new opportunities and remember to challenge your own mindset and assumptions from time to time. "Rule 1 is not to fool yourself and you are the easiest person to fool!"

Systems Engineering really is a team sport, so make time to span boundaries and build bridges with the other communities to understand and facilitate better collaboration; particularly with non-technical communities. Often, it is only the language that divides us, so learn to translate.

People in systems make them complex. So soft skills, collaboration, and communication are paramount!

Prioritise that for development; seek out opportunities to facilitate, negotiate, present, and teach where possible - it will help you improve, and it needs practice.

Systems Engineering is a practical experience and a creative activity: go and explore, discover, experiment, try, fail, reflect, learn as often as you can. Often it is our experiential scars that makes us who we are, and our experiences shape our perspectives and how we sense make. Take time to deliberately step into other perspectives to gain insight; learn that no-one has the 'god's eye view', and that the need for diversity of perspective is really important. Stay curious!

Biography

Sam Williams has spent the last 20+ years trying to understand and tackle complex problems in Defence. Having started as an Engineering apprentice in the 'In Service Equipment Support' environment, and gradually working backward through the CADMID lifecycle, she finds herself now exploring the Capability pre-concept space.

Sam is part of the Systems of Systems Approach team in the MoD. Her current work includes promoting the awareness and adoption of applied systems thinking and systems approaches in Defence. Always keen to find new ways of bringing systems thinking and doing to life in both the work and education context, she spends her time trying to bridge the gaps between different fields of knowledge and experience. Sam is a Chartered Engineer, an INCOSE CSEP and an active STEM ambassador.
As the interim Chair of the Early Careers Forum (ECF) over the last 6 months, I have had the pleasure of helping to define what the forum is and what it hopes to achieve.

As it is still in its infancy there has been a lot of work done to try to get it started. I have participated in INCOSE UK and UKAB joint meetings, as well as INCOSE UK Council meetings, where the views of the forum have been expressed and recommendations have been given to INCOSE UK on how they can support people in their early careers. I was also able to draft the Terms of Reference for the forum, which gave me and others involved a chance to shape the future of the ECF and have a real influence on its direction and purpose.

Following this we launched the forum at ASEC in November 2017, which was a fantastic experience and a great place to meet a lot of very enthusiastic systems engineers. My responsibilities now as the Chair of the ECF, are to ensure that the forum meets its terms of reference, aims and objectives. I will be preparing for meetings and events and liaising with early careers individuals to help promote the forum.

What originally inspired you to volunteer for INCOSE UK?

I first became involved with INCOSE UK in April of 2017, when I attended an early careers event held jointly with the UK Advisory Board (UKAB). The event brought together people with different expertise in different domains from all over the country, and a variety of different backgrounds.

As the day drew to a close I ended up presenting all the feedback from the event to the audience, and I was very keen and enthused about taking the early careers forum 'idea' further.

Getting to speak to those people and being engaged with a community of systems engineers outside of my job was captivating. I wanted to do it again and become more involved with more people from more places!

“It was then that I first felt like I wanted to be a part of the SE community at large, and volunteering felt like the right way to make that happen”

It was then that I first felt like I wanted to be a part of the SE community at large, and volunteering felt like the right way to make that happen. I'm also very passionate about supporting and developing people in their early careers and providing a voice for those who will inevitably become the future systems engineering leadership. I was invited to pass on the feedback and recommendations at the next INCOSE UK council meeting. At this point, I agreed to take on the interim role of ECF Chair to help make the ECF a reality.
What do you feel that you get out of volunteering?

“You get a different perspective on things from the different viewpoints of various people, and thus more insight to the way in which SE is practised in other domains and companies”

First and foremost, it is enjoyable and keeps things interesting. There is more to a career or profession than just your job, and volunteering has helped me to realise that and explore the vast amounts of other experiences to be had.

I've gained know-how in creating and launching something new from the bottom up, whilst developing an understanding of how INCOSE UK functions. I've been a part of spreading the message that SE is an important part of engineering and met a whole load of people that are far more intelligent than me in the process!

You get a different perspective on things from the different viewpoints of various people, and thus more insight to the way in which SE is practised in other domains and companies. Ultimately, it can give you a much more holistic view of the world and the discipline of Systems Engineering and its practitioners. At a personal level it can be an invaluable experience to take with you wherever you go, whether changing employer or even profession.

Specifically, being able to set the course for the future of the ECF and its members has been both fun and exciting.

Do you have any advice or feedback to offer anyone who is considering volunteering?

I'm sure almost everyone who has volunteered for something at least once will have said the same thing; just give it a go, try it out, and do it! There is little to lose and you are normally able to contribute as much or as little as you are able to, on your own terms with no obligations.

Don't be afraid of what you think you can or can't achieve and just look at it as an opportunity. It can be an opportunity for personal development, meeting new people, getting to know yourself better and what excites you or most importantly, an opportunity to make a difference and help others.

All in all, it will almost always be both stimulating and rewarding, and will certainly expand your horizons. Just give it a go, try it out, and do it!

Biography

Omer attended the University of Loughborough and completed a bachelors degree in Aeronautical Engineering. He is currently studying for his MSc in Systems Engineering for Defence Capability from Cranfield University.

After completing a placement as an Aircraft Maintenance Engineer, he went on to take a role at QinetiQ as a Systems Engineering Consultant, before moving in to the role of Lead Systems Engineering. He is now works in project teams and holds responsibility for the application of good Systems Engineering principles, and the coordination of all Technical/Engineering effort to deliver required solutions.
Crofton Pumping Station was built in 1807-9 as the primary source of water for the summit pound of the Kennet & Avon Canal linking Reading and Bristol, using coal-fired beam engines to pump water to the highest point of the canal. After initially opening in 1810 with a single engine, a second engine was installed in 1812 to increase capacity. The Grade I listed station was originally owned by the Kennet and Avon Canal Company, then by the Great Western Railway, followed by British Waterways. Replaced by electric pumps in 1959, it was abandoned until 1968, when it was purchased and restored to full working order by KACT volunteers, thereby preventing it from being scrapped. It still houses two steam-operated beam engines: the 1812 Boulton & Watt and an 1846 Harvey which replaced the earlier original engine. The 1812 engine is the oldest fully operational beam engine in the world.

However, the station now has urgent structural issues that need to be addressed in order to secure the long-term future of this site, which is one of the most important surviving (and uniquely fully operational) monuments of the Industrial Revolution.

The Georgian and Victorian beam engines are themselves in good working condition, but are fragile, especially as they run under full load conditions. Most historic engines such as these have long since failed. To maintain their long-term viability, their operators have to deal with issues typical of similar legacy systems, including:

- Understanding their internal operation in detail, given the lack of original design information
- Monitoring operation and predicting potential failures
- Retaining knowledge of operation for use in training and informing future generations of volunteers

All this has to be done within the restrictions involved in working with Grade I listed historic structures. To meet these objectives within the constraints of a heritage situation, a unique Mechatronics project has been initiated, working jointly with Bath University Mechanical Engineering Department and Scarecrow Consultants. As part of a Heritage Lottery funded project, this seeks to exploit modern industrial technology, in a heritage-acceptable fashion, to provide real-time data monitoring of the plant's internal operation. The aim is to allow operating and maintenance engineers, students, and visitors to observe how the various components of the pumping station are functioning in real time. It will provide a deeper understanding of the critical 208-year old station's operation and of the condition of its components, both for experts and for the more casual visitor.

Using 21st Century Systems Engineering to Monitor a 19th Century Plant

Jon Willis, Mike Rodd and Jon Holt presented a very popular presentation at ASEC 2017 on this topic, and there will be a course run at the Training Day that visits this site. Read on below for full details on this fascinating project.

- Displaying the operation at varying levels of interest to the wider audience
- Providing operational details of the plant for research and use by others facing similar problems
Following the experimental pilot work undertaken by Bath University engineering students, the key to taking this unique project forward to implementation has been the development of a complete set of requirements and system specifications for the mechatronics system.

Considerations in this process have included:

i. Fully utilizing the lessons and data obtained from the Bath work
ii. Capturing the extensive knowledge of (often ageing) local plant experts, including any who might still be rather dubious about the ultimate value of the project
iii. Appreciating the necessity for the system to be both fully "heritage compliant" and yet sufficiently rugged to operate in an extremely harsh, Grade I listed building environment
iv. Providing for adaptability to meet changing needs - for instance, the possible introduction of additional sensors; and
v. Ensuring that the installed system is capable of being maintained by local volunteers and unskilled staff.

"The aim [of the project] is to allow operating and maintenance engineers, students, and visitors to observe how the various components of the pumping station are functioning in real time. It will provide a deeper understanding of the critical 208-year old station's operation and of the condition of its components"

The specification methodology adopted was led by Scarecrow Consultants and involved a number of Crofton’s own steam experts. This work resulted in an agreed initial set of requirements as well as the system specification, which are now being developed and used as a basis for a commercial tender for the actual system. The systems modelling approach adopted was as described in "SysML for Software Engineering" [Holt & Perry 2013, IET]. All models were prepared using SysML version 1.3 and using the Sparx EA modelling tool.

Thus in extracting the requirements the stages involved:
1. Identify stakeholders and then;
2. Examining the requirements in the context of:
   a. The overall high-level system
   b. The needs of various users, including local visitors, plant operators, and also externally based interested parties
   c. Data to be captured - how and what?
   d. Data processing and display - how and where?
   e. Overall system control

Based on these requirements, an initial specification was developed. The key issues now are not only to determine the most urgently required sensors and how they can be appropriately introduced into the historic structure, but also to ensure that, as better knowledge of the plant is obtained, additional sensors can be introduced as required. In addition, the data produced must be produced in a standardised format such that researchers and other interested users can assess it and employ their own in-house tools to analyse it.

Overall, the greatest benefit of the modelling has been in yielding an understanding of all aspects of the requirements and sharing this with others, with the result that many of the previous "doubters" have become actively involved in the project! This is allowing us to develop a full and consistent specification. Finally, this specification has given us confidence that we have been able to determine exactly what we want and will require our contractors to deliver, as well as what we, as the local implementers, will have to do - and when!

The Crofton project is supported by The Heritage Lottery Fund, Bath University and Scarecrow Consultants, together with grants from the Garfield Weston Foundation, Manifold Charitable Trust, Tanner Trust, Saddlers’ Company, Wolfson Foundation, Sylvia Waddilove Foundation, Charles Hayward Foundation, individual donors, and the Kennet & Avon Canal Trust itself.

"The aim [of the project] is to allow operating and maintenance engineers, students, and visitors to observe how the various components of the pumping station are functioning in real time. It will provide a deeper understanding of the critical 208-year old station's operation and of the condition of its components"
The Last 250 Years...

The Russian Economist Nikolai Kondratiev postulated the theory some 90 years ago, that Western capitalist economies have long term 50 to 60 year cycles of boom followed by depression, where these cycles are interspersed with technological revolutions; these cycles being known as 'Kondratiev waves'\(^1\). These 'cycles' or 'waves' approximately coincide with the technological developments of canal building, railway construction, highway construction, airway developments, and finally the construction of the information superhighway. These technological development waves are depicted in the graph below. In his book 'PostCapitalism'\(^2\), the Economist Paul Mason wonders whether 'today we are on the brink of a change so big, so profound, that this time capitalism itself, the immensely complex system by which entire societies function, has reached its limits and is changing into something wholly new. At the heart of this change is information technology: a revolution that has the potential to reshape utterly our familiar notions of work, production, and value.'

In the field of Systems Engineering, according to the Systems Engineering Body of Knowledge (SEBoK) 'The world may be at the cusp of another global revolution enabled by the information age and the technologies and cultures of the Internet.' Also, in the book Enterprise Systems Engineering\(^3\) the authors make the claim that 'scientific fields undergo periodic "paradigm shifts" rather than solely progressing in a linear and continuous way, and that these paradigm shifts open up new approaches to understanding what scientists would never have considered valid before'. Recognising that Systems Engineering problems were advancing beyond traditional approaches and in order to more efficiently addresses the complex nature of today's systems, the MITRE Corporation established an Enterprise Systems Engineering focus group, drawing its conclusions in the Systems Engineering Guide\(^4\). This guide is a good foundation for Enterprise Systems Engineering.

Many publications regarding Enterprise Systems Engineering have been produced over the last two decades or so, across disparate articles and books with contributions from many leading organisations and individuals e.g. INCOSE, IEEE (SEBoK), MITRE etc. The development of this subject seems to have plateaued and generally lacks definition and agreement.

However, as the author predicts, its importance will grow again and become the new vogue science underpinning the next technological revolution. This article provides some thought provoking ideas, points-of-view, and observations that all Systems Engineers should consider.
The Need for a New Approach

It is unclear when we should call an Enterprise or Supersystem 'an Enterprise', and there are many definitions.

The one used here is: Enterprises are highly complex networks of changing systems of people and technologies, that are not fully under the control of any single entity, and utilise a great degree of cooperation; and as such, are prone to unanticipated consequences to the extent that they can cause great societal harm and economic loss. More generally, Enterprises are considered to be of a certain magnitude and fall into the category of Supersized Systems, including the environments that they operate in.

Future Enterprise(s) and their environments will encompass new system developments. These systems will be deployed in many diverse domains, from meteorological systems (including climate change and environmental management), energy fuel and power systems including renewables, the Internet of Things and digitalisation (including financial transaction technologies), cyber security and surveillance (including air, border, and coastal security), food generation and waste management, fresh water supply, air/land transportation systems (including electric vehicles), medical and social support systems, space exploration and interplanetary travel, to name but a few.

Imagining what these future systems capabilities and features will be is difficult. How these systems might interact is even more difficult. To compound the problem, many of these systems are interconnected, creating Supersized Systems that are difficult to characterise and establish boundaries for.

Systems that are difficult to characterise and establish boundaries for. The potential for unanticipated consequences will grow and it is no surprise that information, and how it is generated and utilised, will be key.

Arguably, the only finger hold we have on the future is based on Research and Development including Industrial Strategies, and economic and technological visions and forecasts from various Governments, Institutions and companies. For example, in the domain of aviation, there are publications from Governmental Organisations such as the European Commission i.e. Flightpath 2050, and Aviation Global Market Forecasts produced by aviation manufacturers. These publications spell out some visions and predictions which heavily influence investment strategies.

This is where the economic and political worlds meet; and where the engineering challenge of these complex problems can be compounded by the political and economic approaches of 'doing more with less' and 'innovating with what we have'. These are very much now in vogue. Social issues and new working practices will compound things even further, with intergenerational incongruities.

Systems Engineering is a body of knowledge of processes, methods, and tools applied across the development life-cycle and is an interdisciplinary methodology for understanding, designing, and enabling system solutions for complex problems. As such, it is uniquely placed to devise approaches in the domain of Enterprises for the coming decades, ready to address the needs of the next revolution.

"Imagining what these future systems capabilities and features will be is difficult. How these systems might interact is even more difficult.

To compound the problem, many of these systems are interconnected, creating Supersized Systems that are difficult to characterise and establish boundaries for."

Continued overleaf...
State of the Art...

The traditional or classical Systems Engineering 'top down' approach, honed over many years, starts by trying to elicit the Operational and System requirements. Once known, the development process breaks the problem up into smaller manageable pieces. Once the individual pieces have been developed, then they are aggregated back together. Finally, the whole is tested and qualified. This approach is considered inadequate to address Enterprises, because a number of the traditional Systems Engineering tenets are no longer considered true e.g. requirements may be unstable or unknowable! The SEBoK states ‘...In response to this, Enterprise Systems Engineering (ESE) approaches have been developed, which consider the Enterprise itself as a System to be engineered. Thus, many of the ambitious smart system projects are being delivered as a program of managed life cycles synchronized against a top down understanding of Enterprise needs....’

Some key ESE features and challenges are listed here:

- ESE assimilates traditional approaches and has a requirements and design approach that is a combination of bottom-up, top-down, and middle-out
- ESE environments exhibit Emergent Behaviour which currently lack common definitions and understanding
- ESE Risk and Opportunity prioritises are inverted when compared to a traditional environment i.e. in a traditional environment Risk is treated as a priority, while it is the opposite in an ESE environment
- In complex environments, Systems and Enterprises possess attributes such as flexibility, adaptability, scalability, extensibility, and changeability
- An approach to Enterprise development is to manage it, rather than control it. The requirements and system evolution, rather than being tightly controlled, should be managed to allow the Enterprise capabilities and their interactions to evolve as needed
- The Enterprise Systems that are considered here are characterised mainly by their complex nature, i.e. they exhibit 'Organised Complexity' i.e. Region 3 Systems, where decision making is particularly difficult
- There is a lack of an under-pinning scientific theory and there is some speculation that an emergent ESE theory would be based on complexity systems science
- ESE can provide a ‘discipline bridge’ to assimilate new techniques from other disciplines and the sciences.

An Enterprise in Practice...

Further insights can be gained by looking towards the field of Air Traffic Management (ATM) to provide us with a ready example. In the book Complexity Science in Air Traffic Management, the Authors postulate that ATM is 'too complex to address through classical approaches such as Systems Engineering and Human Factors alone'. This book is based on some of the long term innovative research projects within the Single European Sky ATM Research Programme (SESAR). This programme is a Public Private Partnership and is recognised as an Enterprise and the European ATM is considered a Supersized System! The programme managed to launch over 300 individual projects as part of its first phase and has deployed non-traditional Systems Engineering practices at the Systems of Systems level, though recognised traditional practices have been deployed at the individual project level.

The following observations have been made:

i. The programme is based on a number of Principles: a. Comitology - decisions made by committee, b. Subsidiarity - ensures the balance between members; projects are expected to run with a well-defined degree of autonomy, whilst respecting the programme requirements and co-ordinate needs, c. 'Transversality' - The ability to connect disparate parts of the programme and move emphasis as necessary, d. Diversity - Ensuring the correct balance of viewpoints and collaboration with third party Stakeholders. These principles are not commonly adopted in a traditional systems engineering environment

ii. The usual Customer-Supplier relationship, where the Customer acquires the system from a Supplier through known (or knowable) Operational and System Requirements is not the model employed. The programme is managed by a European Commission Agency known as the SESAR Joint Undertaking. This Agency, which is made up of Members and Contributors, from across Governmental, Public and Industrial Organisations, is in effect the 'Artificial' Customer for the programme on behalf of its European Citizens. The Agency's responsibilities include high-level management functions - providing engineering guidance, processes, methods and tools - and overall programme oversight and control. These functions would normally be performed by the Supplier Management in a traditional environment and not by the Acquirer

iii. A concept validation maturity life-cycle has been adopted allowing for the flexibility of developing various separate concepts and their related design baselines independently whilst measuring the system
developments against established technology readiness levels

iv. Members and Contributors have agreed obligations to perform work and provide deliverables for the programme. However, it is possible that a Member or Contributor may request to change their involvement with the programme, resulting in a need to manage variable participation on condition and as necessary. This feature is not recognised in a traditional environment.

v. Though top-level Key Performance Areas (KPAs) and Indicators (KPIs) are identified that map to notional 'political' requirements to increase capacity, reduce environmental impact, improve safety, reduce cost etc., the individual projects develop concepts and designs that are not mandated, to meet specified derived performance requirement targets. The individual projects initially identify and estimate the KPAs that they believe they can contribute to and, following validation exercises, they confirm (or not) these contributions. The projects intend to achieve the 'best practicable' performance related to KPAs. In this way the approach is a combination of 'bottom up' and 'top down'.

It is thus asserted that SESAR is applying sufficiently different Systems Engineering techniques to those normally performed in a traditional environment and, in this case, the SESAR engineering practice leads the theory!

The Coming Revolution...

The changing Geo-political and Economic and Social landscape will continue to evolve and influence and challenge how system development is conducted. Future system developments within this landscape will be compounded by the next technological revolution and will present challenges that span numerous specialties and disciplines. This revolution, just like the previous ones, will need new methods, processes, tools and competencies to help solve the needs of future systems developments. New methods will be acquired from the sciences and in particular complexity systems science will be its foundation. Enterprise Systems Engineers will be required to adapt their development processes to cater for new social and cultural working practices, including increased considerations of ethical and legal issues, while acquiring enhanced collaboration and negotiation competencies to address business/industrial partnering. Rather than acting like the 'builder of a house', Enterprise System Engineers will need to perform as a 'Conductor of an orchestra'; in particular, they will, as a minimum, require skills and techniques/methods to address the following aspects:

- Formulation of Business/System service/support and capability acquisition models
- Enterprise/Super-system identification and boundary analysis
- Derivation of Enterprise Development Principles
- System properties such as Flexibility, adaptability, scalability, extensibility and changeability
- New working practices and social issues
- Emergent behaviour and unanticipated consequences
- Increased uncertainty via probabilistic methods e.g. programmes planning utilising ensemble prediction methods
- Difficult Decisions, via techniques such as Cynefin Frameworks
- Loose/elastic inter and intra-programme/project coupling dependencies
Enterprise Systems Engineering will be the future framework with information and its utility central to systems developments, and were visions and strategies can be realised for the next technological revolution.

### Biography

John Lomax is a Programme Systems Engineer with over 30 years of experience gained mainly across the Aerospace, Defence, and Air-traffic Management Domains, and currently works for Communications, Intelligence & Security (CIS), AIRBUS. He has previously worked for BAESYSTEMS and for periods at Lockheed Martin and at the SESAR Joint Undertaking. He has worked in various countries including Saudi Arabia, USA, Belgium, and France. He has recently returned from a 7-year expatriation providing direct Customer Liaison to the SESAR Joint Undertaking (SJU) European Commission Agency of the Single European Sky Air Traffic Management Research (SESAR) Modernization Programme located in Brussels Belgium. He is an INCOSE CSEP and INCOSE CAR.

---

**Bibliography**

[i] Russian Economist Nikolai Kondratiev who is best known for proposing the theory that Western capitalist economies have long term (50 to 60 years) cycles of boom followed by depression. These cycles are interspersed with technological revolutions, for example, chronologically: canals, railways, roads, airways and now the information high-way. The technological cycles can be labeled as follows:

- The Industrial Revolution-1771
- The Age of Steam and Railways-1829
- The Age of Steel and Heavy Engineering-1875
- The Age of Oil, Electricity, the Automobile and Mass Production-1908
- The Age of Information and Telecommunications-1971


[v] An Introduction of General Systems Thinking, a Book by Weinberg introduced the notice of Regions. Region 1 he called 'Organised Simplicity', Region 2 - 'Unorganised Complexity' and Region 3 - 'Organised Complexity'. Systems in Region 2 and 3 exhibit particularly difficult decision making situations.


I was the associate research engineer for the Apollo spacecraft Systems Engineering specialist group. The super-specialists (as they were known) were systems engineers that were recognised as "state of the art" in their engineering specialty - guidance and navigation, electrical systems, etc. They made all the final decisions regarding launch readiness and I provided them with the real-time data for pre-launch test, checkout, and troubleshooting tasks. I served on the launch team for the flights of Apollo 7 through to Apollo 11 and I then joined the flight-crew training group as a lead systems engineer, to provide input on sequential systems programming for the flight simulators.

Can you give us a little bit of information about your background at NASA?

The morning of the launch, the Florida weather was foggy and high in humidity but with no threat of storms. After the incident, there was intense debate about whether or not the launch vehicle and spacecraft took a direct hit from lightning (twice within seconds which is statistically illogical) or if it somehow generated the appearance of a lighting strike as it passed through the supercharged atmosphere and discharged the built up static electricity on its skin. The bigger question was simpler: how would you test the competing theories? The time, expense, and risk of creating a series of tests to control all possible variables within this complex Super-System might also be inconclusive. One thing was certain: the launch protocols concerning weather conditions could easily be changed to avoid the risks. All further launches of any kind - manned or unmanned - following Apollo 12 took place in the pristine conditions of clear skies.

With systems such as the Apollo missions, there are many interactions, and a huge amount of monitoring at every stage. What is the strangest thing that you recall finding through the monitoring?

Following the Apollo 1 fire (in which three astronauts lost their lives in a fully-fuelled and manned launch countdown test that routinely took place about one week prior to launch), the entire Apollo Saturn V systems teams - from booster to spacecraft launch escape tower - were committed to a new level of situational awareness. We had learned (or been reminded "the hard way" as some would say) that a combination of knowns and unknowns can turn the predictable into the unpredictable and create massive failures.

You must have seen many potential problems, and worked with many unknowns. Would you describe for us an example of something that went wrong and changed how you worked in future missions?

About one-minute into the flight of Apollo 12 it was hit by a lightning strike and then, shortly afterward, a second. The spacecraft "dashboard" displayed multiple alarms along with a loss of the gyro displays for guidance, etc. There was, of course, no precedent for this type of event and it would have

Supersized Systems; An Interview With Dr Larry Kennedy

This issue we are delighted to include an interview with Dr Larry Kennedy, who discusses his time on the launch team for the Apollo flights and his views on the Space Race as a Supersized System.
Several weeks prior to the Apollo 11 launch, an often but irregularly occurring "data glitch" kept appearing in a wide variety of measurements from a very large number of transponders on the spacecraft and its many systems. Because of the due diligence and rigor of each systems team, it was clear that "something" really odd was happening to "cause" these irregularities. The specialists had to determine the cause and significance of these events and what possible consequences the events could cause during a launch sequence. To do that we had to find a root cause. That included testing and/or replacing transponders and various electrical supports, etc. as well as comparing each event (and there were hundreds) against test procedures and actual timelines.

The research data was massive and included such extreme ideas as placing a strip-chart recorder on the light switches on the launch tower complex. We even considered the possibility that our PCM data was being scrambled by a Russian fishing trawler (which was more like a powerful radar station) that regularly shadowed launches off the Florida coast. Would they possibly risk being caught doing such a thing, especially on the biggest stage of the most important launch in space history? The specialists had to consider even the most remote possibilities. Although monitoring was a "norm" for us, this effort was extremely intensive. At the end, we could not find the root cause. The specialists determined that there was no real known or predictable consequence and that there had been no observable or troublesome chain of events; so we launched, and with notable success. It was a strange example of measuring risk vs. reward in real-time while ultimately someone had to decide.

We have progressed technologically since the Apollo programme; in your opinion, has the quality of Systems Engineering and problem solving improved, stayed the same, or deteriorated?

The quality of Systems Engineering has both improved and deteriorated even though the problems of development and deployment are relatively the same as always - people and processes that are supported by the tools of the discipline, etc. - all with the demand of satisfying a set of requirements described by a customer or customers.

First, things like computer-aided engineering have greatly improved the speed and accuracy of engineering decisions.

Second, it's deteriorated because of the lack of due diligence, rigor, and systems thinking; the failure to apply the scientific method to research and decision-making; the disengagement of the workforce (70% in the U.S. and over 80% in Europe and across all disciplines) that has produced lowered competencies and ethics which undermine reliable Systems Engineering. Higher education has also failed to produce a workforce that is highly competent, with as many as 50% of four-year college graduates in the U.S. (again, across all disciplines) unable to pass a basic literacy exam.

We've also created some unrealistic goals for quickly producing an innovation and getting it to the marketplace. That's why we need a second quality revolution and why 2QR is being promoted around the world by QMI along with organisations like INCOSE.

http://www.qualitymanagementinstitute.com/2QR/default.aspx

What do you see as the legacy of Apollo in the current business and Systems Engineering environment?

The Apollo project was one of the first of the "known and public" Supersystems produced by the aerospace industry. Of course those of us with connections to the defence industry know that there were many and varied "wonders" produced over the years that the average citizen does not hear about - if ever - until they've become obsolete. The Apollo and Shuttle programs are what people often refer to when they think of high-quality Supersystems. There are at least two levels of significance to the business and Systems Engineering environments of today.

First, Supersystems require an enormous amount of vision, the courage for investment and the foresight of implementing a culture of quality management; when properly executed, they produce big profits, impact nations, and create enduring legacies. Secondly, the success of Supersystems breaks down to the practice of the
fundamentals of competency, ethics, and self-accountability. Unfortunately, we're seeing a drift downwards for these attributes in both business and Systems Engineering.

At what point did they realise that one of the best written requirements of all time was going to be realised; "This nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth."

Almost anyone outside of the aerospace and Systems Engineering communities who heard those initial words presented by President Kennedy could have reasonably thought "Sounds great but why and how?". But the resources were made available and the great thinkers of our time broke the vision down into its operational requirements and began to prove each part of the viability of the process and the people who are laboring within it.

Just across the peninsula from the Kennedy Space Center was Cape Canaveral, where all the aerospace defense projects were ongoing. There was a certain fear-based motivation produced by the cold war with the Soviet Union which spilled over into all of our programs in the day. In a famous United Nations speech, Nikita Khrushchev had declared that the Soviets would "bury us". The Soviets had also declared their intentions of beating us to the moon and to use it for strategic advantage. We were in a "win at all costs" battle-mentality in all aspects of our engineering world. The costs to family were enormous and only history and personal reflection can judge whether an individual's commitment was too much. It's interesting to note a study by what was then the U.S. Health and Human Services (which studied our work habits coined it the "rat race"): notwithstanding the downside of the story, the level of competence, ethical restraint, and due diligence was remarkable. Now, with modern concerns for HR and sensitivity to people's individual needs, an orthodox quality management culture can create the proper balance between success at work and our personal life.

Some would say that the space age is over, Do you agree, do you think that was inevitable, and how do you feel about it?

The space race was a boost to the technological age, both of which are and will continue long into our future with no end in sight. The materials, products, advanced technologies, and many social supports we enjoy are the result of converting the outcomes of space exploration and research.

Our work and home cultures are now very dependent upon things that are going on in space; everything from GPS driven services to the many and varied connections to the IoT. The defense of nations has also become very much dependent upon increasing our ability to control and make safe the reaches of space in which we operate our Supersystems. We also have to contend with the threats of despots around the world who want to build and arm ICBM's and threaten democracies. So either by commercial desire or strategic necessity - the race is still on!
<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thursday 15th March</td>
<td>North West Group</td>
<td>Requirements Engineering in Rail</td>
</tr>
<tr>
<td>19:00 - 21:00</td>
<td>Network Rail, Square One, 4 Travis Street, Manchester, M1 2NY</td>
<td>Ahead of a Institute of Rail Signalling Engineers (IRSE) conference in April, Adam Rixon (WSP) and Kevin Gedge (Network Rail) will look at how requirements engineering is used within the rail industry.</td>
</tr>
<tr>
<td>Wednesday 6th May</td>
<td>Early Careers Forum</td>
<td>Designing Hyperloop</td>
</tr>
<tr>
<td></td>
<td>Location to be announced</td>
<td>This tutorial will give you practical experience of designing an effective operational capability. Based upon the 2014 INCOSE UK Capability Systems Engineering Guide, attendees will have the opportunity to apply Capability SE processes to manage a real world case study. Further details will be available in the near future. To receive updates, please register your interest in the Early Careers Forum via the INCOSE UK website.</td>
</tr>
<tr>
<td>Wednesday 6th June</td>
<td>UK Chapter</td>
<td>INCOSE UK Training Day</td>
</tr>
<tr>
<td>Full day</td>
<td>Marsh Farm Hotel, Royal Wootton Bassett, Swindon, Wiltshire, SN4 8ER</td>
<td>We are pleased to confirm that this year’s Training Day will take place at the Marsh Farm Hotel. This year there will be some courses of a new format and we will also be running a SEP exam. Please keep an eye on the INCOSE UK website - full details and a booking system will be available shortly.</td>
</tr>
<tr>
<td>7th July - 12th July</td>
<td>INCOSE International</td>
<td>INCOSE International Symposium (IS)</td>
</tr>
<tr>
<td>Full days</td>
<td>Grand Hyatt Washington, 1000 H Street NW, Washington, DC 20001, USA</td>
<td>This year’s IS will be taking place in Washington DC and has the theme of ‘Delivering Systems in the Age of Globalization’. For full details, please check the event website here.</td>
</tr>
</tbody>
</table>
INCOSE UK Secretariat
The Dyers Building, 21 Silver Street, Ilminster, Somerset, TA19 0DH
Tel: +44 1460 298 217
Email: publications@incoseonline.org.uk