Loughborough University

Systems Engineering Master's Degree Apprenticeship

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Welcome

We have been teaching Systems Engineering at Loughborough since 1992 with content specifically aligned to the needs of industry partners.

Our new Master's Level Apprenticeship is the next step in our Systems Engineering educational journey, offering apprentices the opportunity to further integrate their academic and practice-based learning whatever their sector – energy, defence, telecommunications, health or infrastructure.

In today's extremely competitive and highly connected world, businesses need well-trained, competent engineers who can take an overview of complex problems, devise innovative solutions, understand and manage the detail. In industries where very large, complex, multidisciplinary ventures are the norm, it is essential that staff are equipped with the knowledge and skills to guide the end-to-end engineering of these projects to ensure smooth and efficient delivery.

The new Apprenticeship programme offers an ideal way to train and invest in valuable early career engineers, whilst boosting your organisations' productivity and competitive advantage in the marketplace by enhancing the effectiveness of your workforce. The combination of compulsory and elective modules provides some element of choice over course content so that it is tailored to your strategic needs, and the Capstone Project is directly linked to your business requirements. It also allows you to unlock value from your Apprenticeship Levy in line with the funding band, and develop possible further collaborative relationships with the University.

The fundamental difference between studying for an MSc and a Master's Level Apprenticeship is the partnership between the University and the employer to deliver a programme directly relevant to the workplace, allowing the apprentice to gain practical experience as well as recognised academic and professional qualifications. To manage this, the University will provide academic tutors as well as training for workplace mentors. It will also put in place a structured programme for ensuring continuous engagement with apprentices and their organisation for the duration of the Apprenticeship.

With a strong emphasis on Model-Based Systems Engineering, it will deliver an MSc and Level 7 Apprenticeship award to a set of industry-standard competencies that comply with the INternational Council On Systems Engineering (INCOSE). It also positions recipients for future application to Chartered Engineer (CEng) status as well as preparing them for future management or engineering roles.

Apprentices continue to work and earn while they study, applying their new knowledge and skills in the workplace. The University provides an enjoyable and supportive experience, combining online and campus-based learning with opportunities for apprentices to interact with their peers from other industry sectors, expanding their professional networks and cross-sector knowledge.

This brochure provides you with an overview of our exciting new programme. If you have any questions or would like to find out more, please get in touch.

Professor Michael J deC Henshaw
Programme Director

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"A rewarding learning experience full of eye-opening insights. I learned to view problems from multiple perspectives and consider everything that might have a bearing on solving the problem at hand."

George Cheeseman
Software Test Engineer, Lockheed Martin

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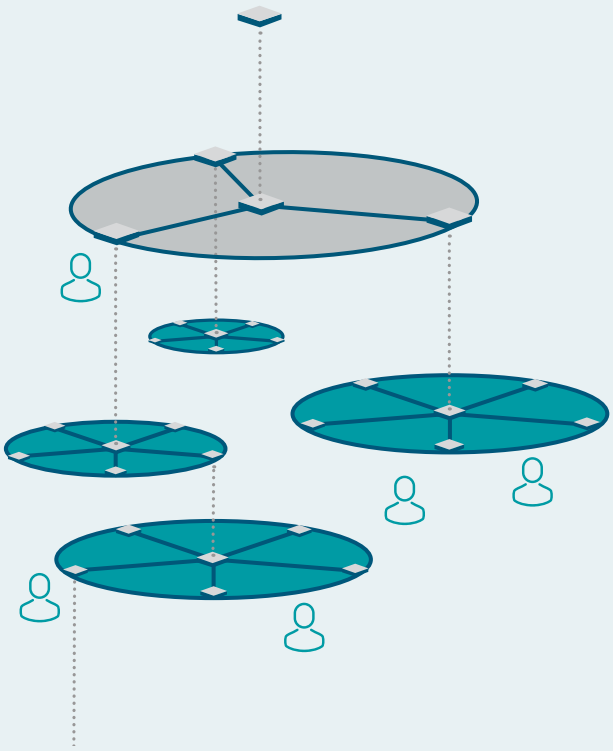
About Systems Engineering

Systems Engineering is a transdisciplinary approach that integrates all disciplines and specialty groups into a team effort, developing an innovation from concept to fully operational system.

It considers business and technical needs to create a quality product that meets all requirements. Systems Engineers are able to think *systemically* (considering the whole system) and *systematically* (adopting a methodical consideration of the system parts) to cope effectively with complexity.

Uncomplicated devices can be created using a bottom-up engineering approach, whereby components are combined into a system that is then tested against required behaviours and either accepted or modified depending on how closely it meets them.



Systems exist within a hierarchy that requires Systems Engineers to display technical leadership and systems management skills

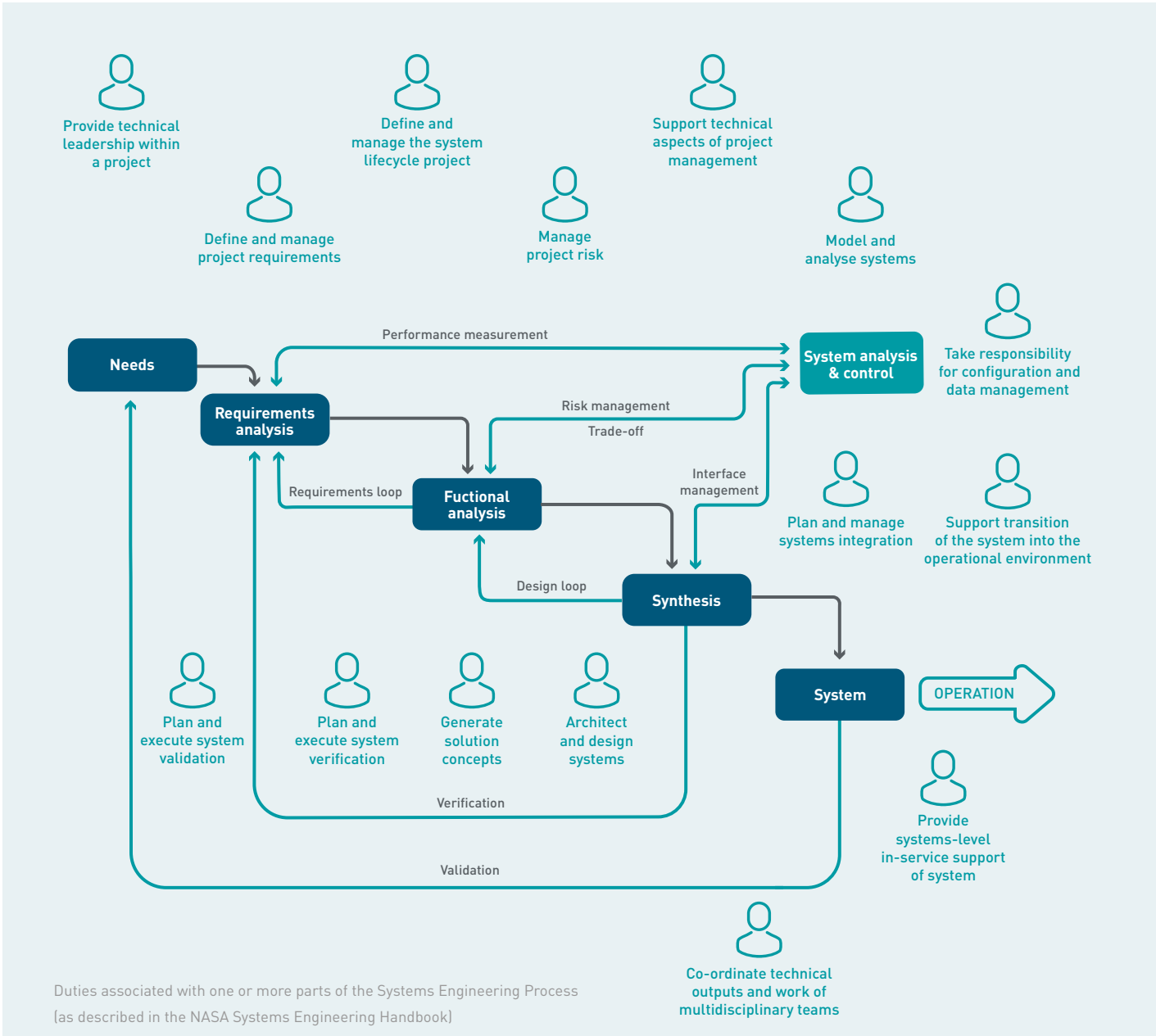
In contrast, complicated or complex problems require a top-down approach that considers the system as a whole: how it fits into its operational environment, its interfaces with other systems, and its anticipated operational lifecycle. A system inevitably exists within a hierarchy – for example, an autonomous automobile exists within a context of other vehicles, transport infrastructure, legislation, and so on – and comprises highly integrated physical and software components.

The development and operation of such systems involves contributions from many people, usually in multiple organisations. The Systems Engineer must be able to provide both technical leadership and systems management.

Model-Based Systems Engineering (MBSE) is a front-loaded engineering methodology to control costs, time and quality in the development and management of today's increasingly complex systems. MBSE is a key feature of the Loughborough Apprenticeship programme.

The Systems Engineering Master's Degree Apprenticeship Standard defines 15 duties that are required at different times in the Systems Engineering process. Most systems organisations will require execution of some or all of these duties in the discharge of their business, although the precise role titles may vary.

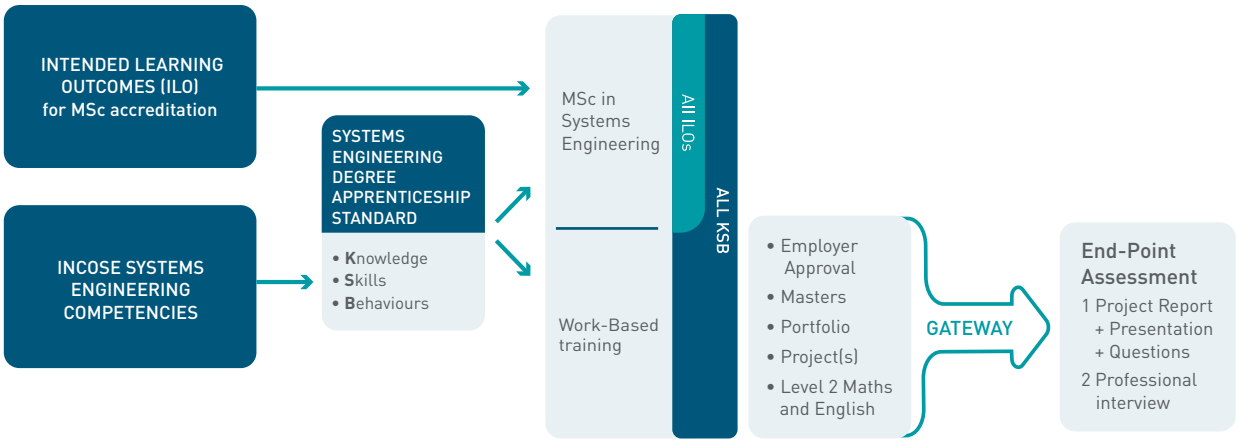
The Loughborough Apprenticeship addresses the Knowledge, Skills, and Behaviours (KSBs) that are required in each duty. Individual apprentices will tailor their learning plan to acquire the KSBs appropriate to the duties of their current or aspirational role.



Duties associated with one or more parts of the Systems Engineering Process (as described in the NASA Systems Engineering Handbook)

Programme overview and entry requirements

Our Master's programme has an established track record of producing high-calibre postgraduates. Launched in 1992 as a response to industry requirements, it was the first of its kind. It has continued to grow and adapt to meet the changing needs of industry, and now underpins the new Master's Level Apprenticeship as shown below.



Competency inclusion and assessment in the Apprenticeship

The programme combines academic study and work-based experience, allowing apprentices to develop essential Systems Engineering Knowledge, Skills, and Behaviours. The KSBs are drawn from the INCOSE competencies, derived from the authoritative Systems and Software Engineering Lifecycle Process Standard (ISO 15288).

The academic element of the training delivers all intended learning outcomes required by the Engineering Council, and is the basis for accreditation of the MSc Degree. To comply with Apprenticeship requirements, employers must make 20% of contracted working hours available to do this.

The final four months of study are dedicated to preparing for the End-Point Assessment (EPA), during which time the apprentice prepares a summary report and presentation demonstrating how they have met the KSB requirements through application in one or more projects.

Entry requirements

The typical applicant will hold an honours degree (normally at 2:1 or above) or equivalent overseas qualification in an appropriate STEM (Science, Technology, Engineering or Mathematics) subject area. For applicants with qualifications slightly below this level, alternative qualifications or professional experience will be considered on a case-by-case basis.

Applicants must hold and be able to evidence a qualification in Mathematics and English at Level 2 (GCSE grades A*-C or equivalent). Applicants who do not have GCSE Mathematics and English, but have an equivalent level qualification may be accepted and will be assessed on a case-by-case basis.

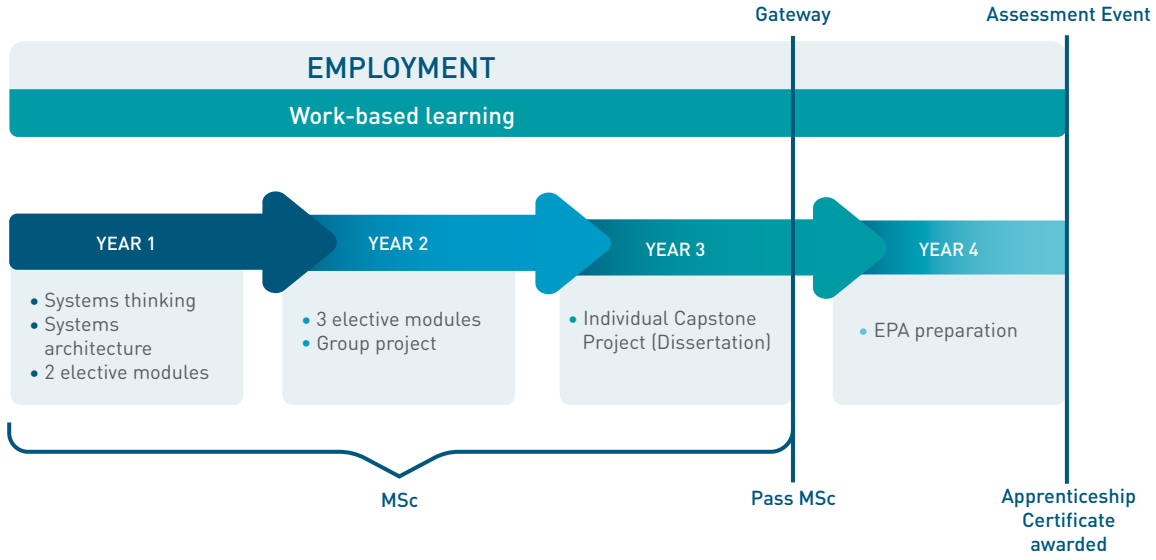
Programme structure

The Master's Level Apprenticeship programme is structured over four years.

The award of the MSc requires the completion of 180 credits, and the grade boundaries are drawn at:

- Pass – 50% or above
- Merit – 60-69%
- Distinction – 70% or above

The MSc element of the Apprenticeship is completed in Years 1-3, with the final months, in Year 4, dedicated to pulling together the information required for the Apprenticeship End Point Assessment as detailed below. The final L7 Apprenticeship certificate is awarded with pass or distinction.



Typical structure of the Apprenticeship

Typical applicants will complete the Apprenticeship over a period of 40 months, and complete 60 credits each year. All Year 1 and 2 modules are worth 15 credits, and the final Capstone Project, completed in Year 3, is weighted at 60 credits.

End Point Assessment

The End Point Assessment comprises a report and presentation based on one or more projects completed during the Apprenticeship, plus a separate professional interview, based on a portfolio of evidence. This will be examined by industry-based assessors and must be passed to achieve the Level 7 Apprenticeship award.

To begin the four-month EPA, apprentices must have met the five gateway criteria:

- Employer approval that the apprentice is ready for assessment
- The MSc has been passed although it may not yet have been awarded
- The portfolio of KSB evidence has been prepared and submitted
- One or more projects suitable for inclusion in the summary report have been completed
- Attainment of Level 2 English and Mathematics has been evidenced

At the end of the Apprenticeship, the apprentice will receive an MSc award, a Level 7 Apprenticeship Certificate and a portfolio of professional evidence. Further details are provided in the Systems Engineering Assessment Plan, available on the Institute for Apprenticeships website.

Programme modules

Apprentices are invited to shape their programme of study to suit their specific industry requirements by choosing the most appropriate modules on offer.

In addition to the compulsory elements of the programme, apprentices must complete five elective modules. These must include one or both modules from group A (below), with the balance (three or four) selected from groups B and C. Apprentices may select this balance of modules entirely from group B, or replace one group B module with a choice from the specialist modules in group C, which are subject to availability.

We intend to adopt a blended learning approach, allowing apprentices to choose whether to study some parts of modules on campus or via online distance learning. Distance learning will include participation in online discussion forums and other group activities. Although modules will still require some attendance on campus, this arrangement will enable apprentices to manage their study and work commitments with greater flexibility.

The academic study for the Apprenticeship is taught alongside our MSc Systems Engineering. The MSc programme is available to students for whom the Apprenticeship is not suitable.

"The immense knowledge of the professors and lecturers involved in the programme makes them truly world-class. They are at the forefront of driving their areas and, ultimately Systems Engineering, forward which I find very inspiring and exciting."

Caroline Flohil
Senior Consultant, Capgemini

Compulsory modules

All apprentices must complete:

Applied Systems thinking
- Philosophy of systems thinking
- Appreciate the nature of complexity
- Practice applying systems thinking tools to real world problems

Systems architecture
- Gain practical knowledge of system and enterprise architecture frameworks
- Modelling languages and methods
- Underpin model-based engineering principles by using them to assess systems functionality and performance

Group systems project

Individual Capstone Project

Elective modules

Group A – At least one of the following:

Sensors and actuators for control
- Learn about sensor and actuator types and appropriate selection for control systems
- Design of sensors, actuators and control systems
- Practical experience through laboratory work

Understanding complexity
- Understand the problems created by complexity as system size increases eg. optimisation, reliability and simulation
- Use of tools and numerical methods such as MATLAB for system analysis
- Application of techniques such as Neural Networks and Genetic Algorithms to simulate real-world, physical problems

Elective modules

Group B – Three or four from:

Holistic engineering
- Understand the challenges of managing complex engineering projects and the techniques used to overcome them
- Theory and practical work on requirements definition, problem analysis, system architecture, product lifecycle and engineering organisation design

Validation and verification (V&V)
- Learn V&V procedures and tests aligned to ISO/TEC 15288 and IEEE1516 from a model-based systems viewpoint
- Practical design of a robust system
- Introduction to software and systems modelling languages and methods
- Use of commercial tools for hardware and software in-the-loop testing

Modelling, simulation and visualisation for engineering
- Modelling and simulation of systems and processes
- Assumptions, approximations, limitations, verification and validation of models
- Practical experience of methods for gaining an insight into complex systems, including visualisation

Engineering and managing capability
- Practical aspects of managing large-scale, complex systems within their social, political and commercial environments
- Development of systems ideas to meet capability needs, using a participative scenario

Innovation and entrepreneurship in engineering
- Study success factors for introducing new products to market
- Explore critical strategies for planning and executing innovative projects in manufacturing and engineering
- Explore the relationship between innovation, entrepreneurship, market analysis, competitor assessment, resource management operations and supply chain management

Systems design
- Practical study of design and requirements engineering using model-based techniques
- Understand links between system design, system architecture, verification and validation
- Introduction to software and systems modelling languages, methods and tools
- Follow the system design process aligned to ISO/IEC/IEEE15288

Elective modules

Group C – One module may be chosen from:

Engineering for sustainable development
- Principles and practices
- Improvement of environmental sustainability of manufacturing
- Advanced manufacturing processes automation
- Understand and critically evaluate state-of-the-art manufacturing processes and technologies

Additive manufacturing (AM)
- Demonstration of the AM techniques available at the University and their industry applications
- Critical understanding of various AM technologies
- Lean and agile manufacture
- Specification, design and evaluation of an appropriate lean or agile business system, including distribution chains

Computer aided engineering
- Selection and application of appropriate computer-based methods for modelling engineering products, analysing engineering problems, and supporting the design process

Engineering design methods
- Develop a working understanding of the main methods employed in the systems design
- Identification of appropriate methods and techniques for different lifecycle stages

Digital signal processing
- Critical understanding of the fundamentals of digital signal processing, as applied to digital systems, using computer simulation based tools.
- Understand sampling theorem, z-transform and Fourier transform and their application
- Critically evaluate structures for realisation of finite and infinite impulse responses and the basics of real-time processing

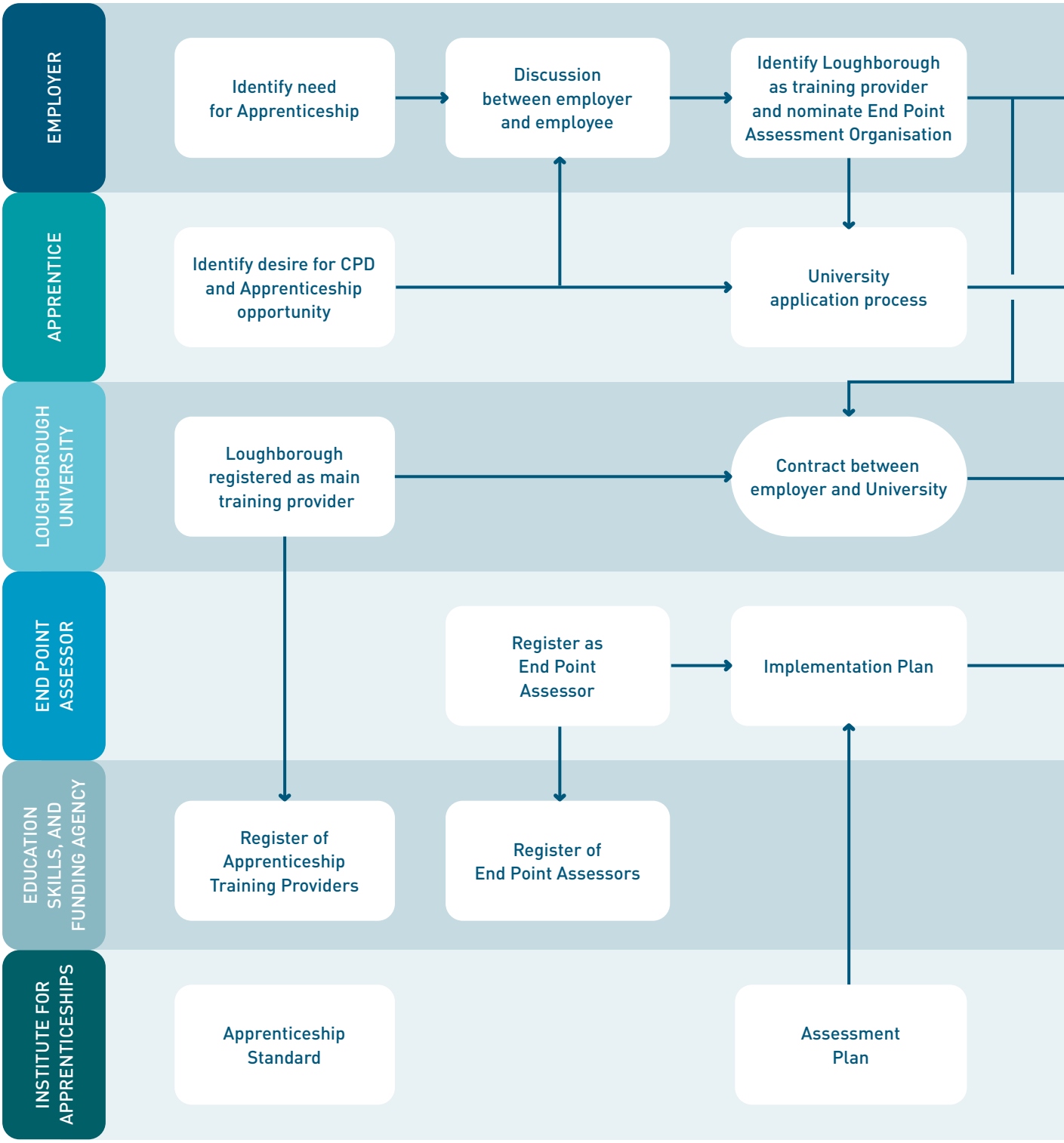
Communication networks
- Analysis of the behaviour of a communication network protocol, and predict how it would support different types of offered traffic
- Evaluation of real-time performance of a working network, and design-suitable protocols for certain conditions

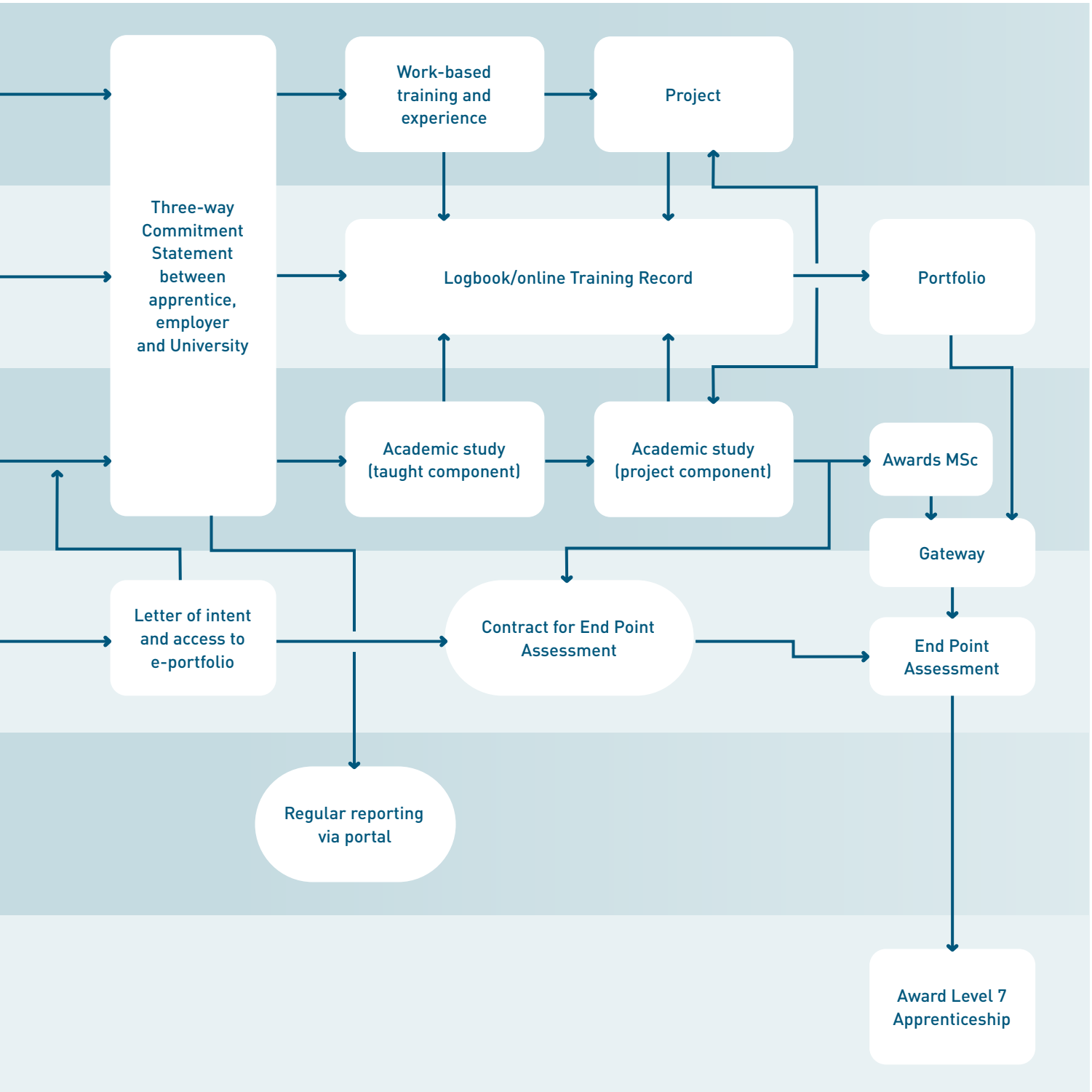
Telecommunications network security
- Understand security challenges, and the countermeasures that may be used in network systems
- Analyse security policies, services, and mechanisms for a given communications network; both hardware and software solutions will be addressed

Lean and agile manufacturing
- Understand lean and agile concepts in manufacturing business, including its distribution chains
- Explore lean and agile operations philosophies, the distinction between them and their strategic implications, as well as evaluating the trade-offs in designing mass customisation systems

The Apprenticeship process

A simplified view of the Apprenticeship journey, is shown in the Swimlane diagram below.
It illustrates the roles of the various parties involved and how they interact with one another.




Three-way Commitment Statement between apprentice, employer and University
Work-based training and experience
Project
Logbook/online Training Record
Portfolio
Academic study (taught component)
Academic study (project component)
Awards MSc
Gateway
Letter of intent and access to e-portfolio
Contract for End Point Assessment
End Point Assessment
Regular reporting via portal
Award Level 7 Apprenticeship

Teaching facilities and staff

We are one of the UK's largest Engineering Schools and have an outstanding international reputation for research which drives everything that we do. Our cutting-edge research feeds directly into our teaching, ensuring that students are taught about the latest developments by world-leading experts.

Our new STEMLab has been created to provide state-of-the-art learning facilities for our students, covering most of our science and engineering disciplines on campus. In addition, the Wolfson School of Mechanical, Manufacturing and Electrical Engineering has recently undergone a major refurbishment; creating a modern, vibrant learning environment with state-of-the-art lecture rooms and laboratories, as well as plenty of meeting areas to promote collaborative working.

Systems Engineering teaching excellence

Our Systems Engineering programmes are taught by a range of high-calibre staff, a high proportion of whom are professors with a wealth of experience in industry as well as academia: they are experts in their field who understand first-hand what industry needs from its systems engineers. Our key staff include:

Michael Henshaw
BSc, PhD, MBA, MRAeS, MINCOSE, MIEEE, MIEHF

Michael Henshaw is professor of systems engineering: his research focuses on the integration and management of complex socio-technical systems. A graduate in Applied Physics, he spent 17 years working in aeronautical engineering and latterly multi-disciplinary projects for BAE Systems, before joining Loughborough University in 2006. He is Co-chair of the IEEE Systems of Systems Engineering Technical Committee.

Charles Dickerson
BA, PhD, MINCOSE, FIEEE, RAEng/EPSRC/BAES

Charles Dickerson is RAEng/EPSRC/BAES Chair of Systems Engineering. His previous roles include Technical Fellow at BAe Systems, avionics systems design at the Lockheed Skunkworks, air vehicle survivability at Northrop, Aegis Systems Engineer for ballistic missile defence, and Director of Architecture in the Office of the Chief Engineer for the US Navy. His research focuses on Systems Architectures, and he chairs the INCOSE Systems Architectures Working Group.

Roy Kalawsky
BSc, MSc, PhD, CEng, MIET, FRSA, Airbus/RAEng Chair Digital and Data Engineering Information Systems

Roy Kalawsky holds the RAEng/Airbus Research Chair of Data and Digital Engineering Information Systems. He joined Loughborough in 1995 after 18 years with BAe Systems, starting as a systems engineer and progressing to being responsible for cockpit research and development across the entire Military Aircraft Division. His research focuses on modelling, simulation and virtual reality.

Melanie King
BA, PhD

Initially trained as a buildings architect, Melanie King has held roles in research and design of digital products such as laboratory simulation software, integrated information systems and data architectures. She has a wealth of project management experience and headed up Loughborough's Centre for Engineering Design and Education.

The programme is taught by 17 full-time staff who are supported by various visiting professors and lecturers, many of whom are drawn from industry.

Mike Wilkinson
PhD, MINCOSE, Visiting Professor

Mike Wilkinson has over 20 years' experience of successful delivery within a technical management environment and five years' experience as an academic researcher. He has served in a variety of leadership roles, including founding Director of Reference Information Systems, Technical Director of Niteworks, Technical Director (Strategy) within Atkins Defence. He is a former president of INCOSE UK.

Neil Lindsay
DSTL Fellow

Neil Lindsay leads Information Advantage at Defence Science and Technology Laboratory (Dstl). He has significant experience in various security areas, and is increasingly working across Government to provide technical and systems expertise to Government departments.

Andrew Bradley
PhD, RAEng, Visiting Professor

Prior to retirement, Andrew Bradley was Systems Chief Engineer for the HAWK Advanced Jet Trainer Aircraft, responsible for the design, construction, certification, and through-life support. Before joining the aerospace industry he was Systems Engineer for design and construction of Advanced Gas-Cooled Reactor Nuclear Power Stations. He has particular expertise in the safety and reliability assessment of complex, digital, real-time control systems in safety-critical applications.

Craig Wrigley
Technical Director of SYOS Engineering

Professor Craig Wrigley is Technical Director of SYOS Engineering Ltd, and a former member of the Technical Directorate at Lockheed Martin UK IS&GS Security. His Systems Engineering experience includes Radar Pule environment modelling, air traffic systems design and modelling, sensor fusion modelling, datalink protocol modelling, and risk modelling for the UK Command and Control System of Systems.

Some components of the programme are taught by industrialists with expertise across a range of fields. They join us from a variety of companies and organisations including BAE Systems, Bombardier Rail, Bruker Daltronics Ltd, Galorath, JSyS, the Mitre Corporation, Jaguar Landrover and the MoD. We welcome further engagement from industry partners willing to contribute in this invaluable way to student and apprentice learning.

Frequently asked questions

Will apprentices have to attend the University to study?
We realise that people are busy and need flexible learning options. Therefore, the programme may be pursued using a blended learning approach. Apprentices will need to complete some of their studies on the University campus – benefitting from interaction with other students and staff – but are also able to use some distance learning methods.

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How are the modules taught, for example, one day a week or as a block?
All of the modules are block taught and most take a week, with a couple lasting two.

Is an HND an acceptable entry qualification?
The standard entry qualification, in addition to Level 2 English and Mathematics, is an honours degree (normally at 2:1 or above) or equivalent overseas qualification in an appropriate STEM (Science, Technology, Engineering or Mathematics) subject area. However, applications will be considered on a case-by-case basis from people with HND qualifications, if supported by appropriate experience.

Is the traditional MSc route available as a part-time programme, if we prefer not to use the Apprenticeship route?
Yes, the MSc can be studied part- or full-time. Talk to us about your study requirements.

Are the case studies used in teaching drawn from a range of industries?
Yes, they are. We want the programme to be applicable to as wide a range of industries as possible. All of the programme lecturers have industry experience and some teaching is delivered by industry partners. We welcome enquiries from industry partners willing to contribute in this invaluable way to student learning.

How is the programme aligned to any other professional qualifications such as INCOSE or Chartered Engineer status?
Although achievement of chartered status or CSEP (Certified Systems Engineering Professional, awarded by INCOSE) are not part of the Apprenticeship, completion of the programme will put apprentices in a strong position to apply for them.

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How will new technologies be incorporated into the programme?

Our modules are updated every year to incorporate any advances in technology. Some elements of the programme are taught by industrial partners, helping us to keep up to date with industry thinking and ways of working – ensuring that the programme remains current and relevant.

How regularly will apprentices' progress be monitored?

Each apprentice will have an academic tutor and an employer mentor. Together, they will agree the Apprenticeship plan at the start of the programme, and progress against this will then be monitored through three or four tripartite meetings each year. The first meeting is likely to be face-to-face, but other channels may be used subsequently, depending on what best suits everyone. Additional support will be provided to the apprentice throughout the programme by the academic tutor, but times and frequency will be agreed with the apprentice depending on his or her requirements. The University will also provide forums for ensuring the exchange of good practice in industrial mentoring across the programme's community of mentors.

How can we manage the 20% off-the-job training?

To release the money from the Levy Account, the University must record and submit the 20% off-the-job training to the Education, Skills and Funding Agency (ESFA). However, by maintaining an ongoing relationship with you as an employer or apprentice, we will provide a platform for recording this and do the reporting on your behalf. We will confirm, at our tripartite meetings, how the 20% off-the-job training is being managed so that we can report on it. The MSc course more than accounts for the 20%, providing the study time is allocated during the normal working week.

Does the University or the company provide mentors?

Both. The University will provide each apprentice with a tutor who will guide them in their studies, offer academic support and be the University representative in tripartite meetings between the apprentice, the employer and the University. They will log progress on the University system in order to provide the monthly reports required by ESFA. In addition, the employer must provide a mentor who offers guidance and support in the workplace, including the maintenance of an experience log. The University will provide training for these mentors at the start of the programme.

Is there overnight accommodation on campus that we can use?

There are three hotels on or very close to campus which offer short-stay visitors affordable and convenient accommodation.

- **Burleigh Court Conference Centre and Hotel**
  Burleigh Court, located on the University's West Park, provides four-star accommodation.
  www.burleigh-court.co.uk
- **The Link Hotel**
  The Link Hotel, a short walk from the University campus, offers three-star accommodation.
  www.linkhotelloughborough.co.uk
- **The University Lodge**
  Not a hotel as such, the Lodge offers convenient and affordable short-stay, single room accommodation for visitors to the University campus.
  www.lboro.ac.uk/services/accommodation/short-stay/lodge

TOP 10 IN EVERY
UK UNIVERSITY
LEAGUE TABLE

For further information about the Systems Engineering programme, please get in touch with:

Richie Emerson-Wood
Postgraduate and Professional Development Programme Manager
Wolfson School of Mechanical, Electrical and Manufacturing Engineering

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E: WSPGSupport@lboro.ac.uk

The University also offers MBA and an MSc in Strategic Leadership as L7 apprenticeship programmes.

For enquiries about these, please contact:

Vicki Unwin
Business Development Manager
School of Business and Economics

T: +44 (0)1509 222160
E: V.E.Unwin@lboro.ac.uk

For information about the Apprenticeship Standard and Assessment Plan, please visit
www.instituteforapprenticeships.org/apprenticeship-standards/systems-engineering-degree

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