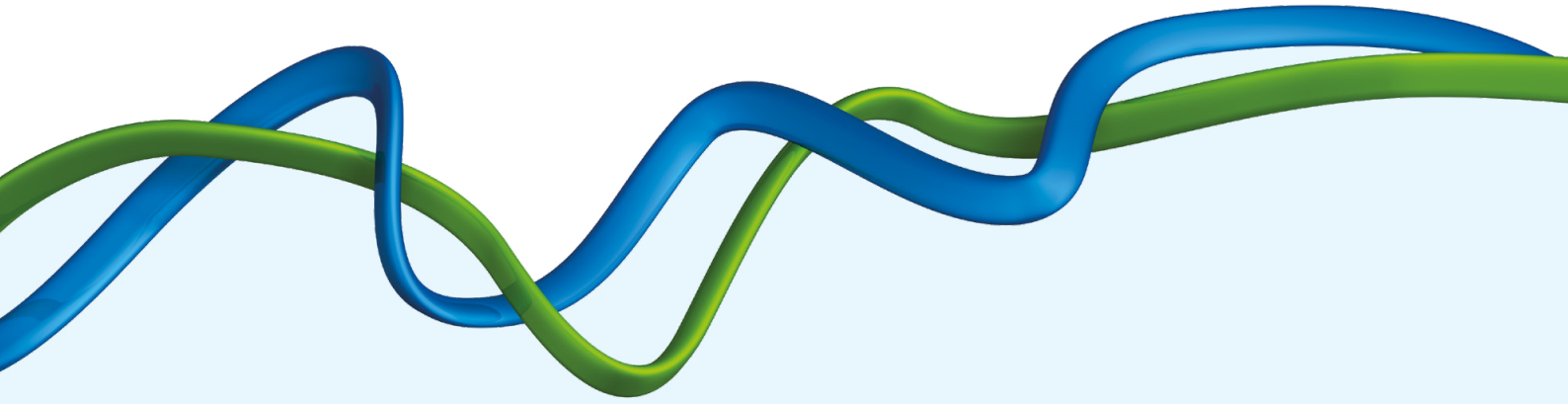
ROYAL ACADEMY OF ENGINEERING

Engineering & Manufacturing T level

Common core content

December 2018



Introduction

Background

1. The Post-16 Skills plan, published in June 2016, accepted the recommendations of Lord Sainsbury's independent review of technical and professional education. The Post-16 Skills Plan will create a simplified progression pathway at age 16 founded on the introduction of a common framework of 15 routes across all technical education, whether college or employment based. *Engineering and Manufacturing* (E&M) is one of those 15 routes.

2. At the start of each route there will be a two-year college-based programme suitable for 16 to 18 year olds, but accessible by adults. Each progamme will have a 'common core' content that applies to all individuals and that is aligned to apprenticeships. The common core will include technical knowledge and skills plus, for example, literacy, numeracy and digital skills.

The E&M T level

3. The DfE occupational map for the E&M route shows three Pathways, associated with each of which are Specialisms which, in turn, each represent a related group of Apprenticeship Standards (**Figure 1**).

4. Each pathway is intended to form the basis for a T level in combination with one or more areas covered by an apprenticeship standard, broadly as represented in **Figure 2**.

Engineering community input

5. In discussion with the Department for Education and the Gatsby Charitable Foundation the Royal Academy of Engineering agreed to host and facilitate a project to bring together the engineering and education communities **to identify a proposed common core content for the E&M T level**.

Common core content development

6. The detailed common-core-content developed by the engineering community to advise the T level panels is presented in **Appendix B**, on page 11. Key stakeholders from the different sectors in engineering and manufacturing were invited to contribute via a series of workshops supplemented by email correspondence. Contributors, listed at **Appendix C**, included representatives from professional engineering institution, sector skills councils, further education institutions and employers and employer representative bodies, all of whom work closely and continually with engineering and manufacturing employers either regionally or nationally.

7. The project approached the identification of a common core content via a 'bottom up' approach, in effect reviewing and importing elements of the knowledge required from a representative sample of apprenticeship standards referenced within the DfE occupational map for E&M. As part of the process a first-attempt was made to identify knowledge that should be included as common core content in each of three Pathways, i.e. to develop three different Pathway-specific sets of common core content. Later, a top-down approach was adopted to bring organization and cohesion to the potential common-core content previously identified.

8. Using this process the following were developed with the intention of assisting the T level Panel:

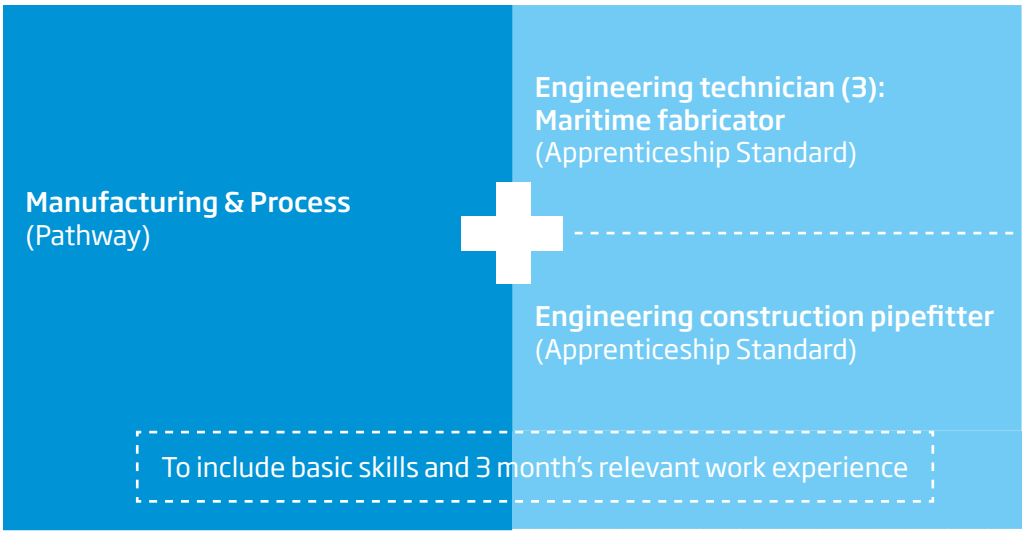
   a. A view about what the E&M T level should aim to achieve;
   b. A set of principles that should guide its development;
   c. A proposed common core content.

9. This report constitutes the output of that work and is offered to the Institute for Apprenticeships and Technical Education, the Engineering and Manufacturing Route Panel and the T level content drafting groups for their consideration when they deliberate on what content should be in the E&M T levels.

Figure 1:
Engineering & Manufacturing T level route occupational map (illustrative)

Route	Pathways	Specialisms	Apprenticeship Standards
Engineering & manufacturing	Design, Development & Control	Specialism 1	
		Specialism 2	
	Manufacturing & Process	Specialism 1	
		Specialism 2	
		Specialism 3	
	Maintenance, Installation & Repair	Specialism 1	
		Specialism 2	

Figure 2:
Generic structure of E&M T level



Proposals

T level aims

10. E&M T level should aim to:

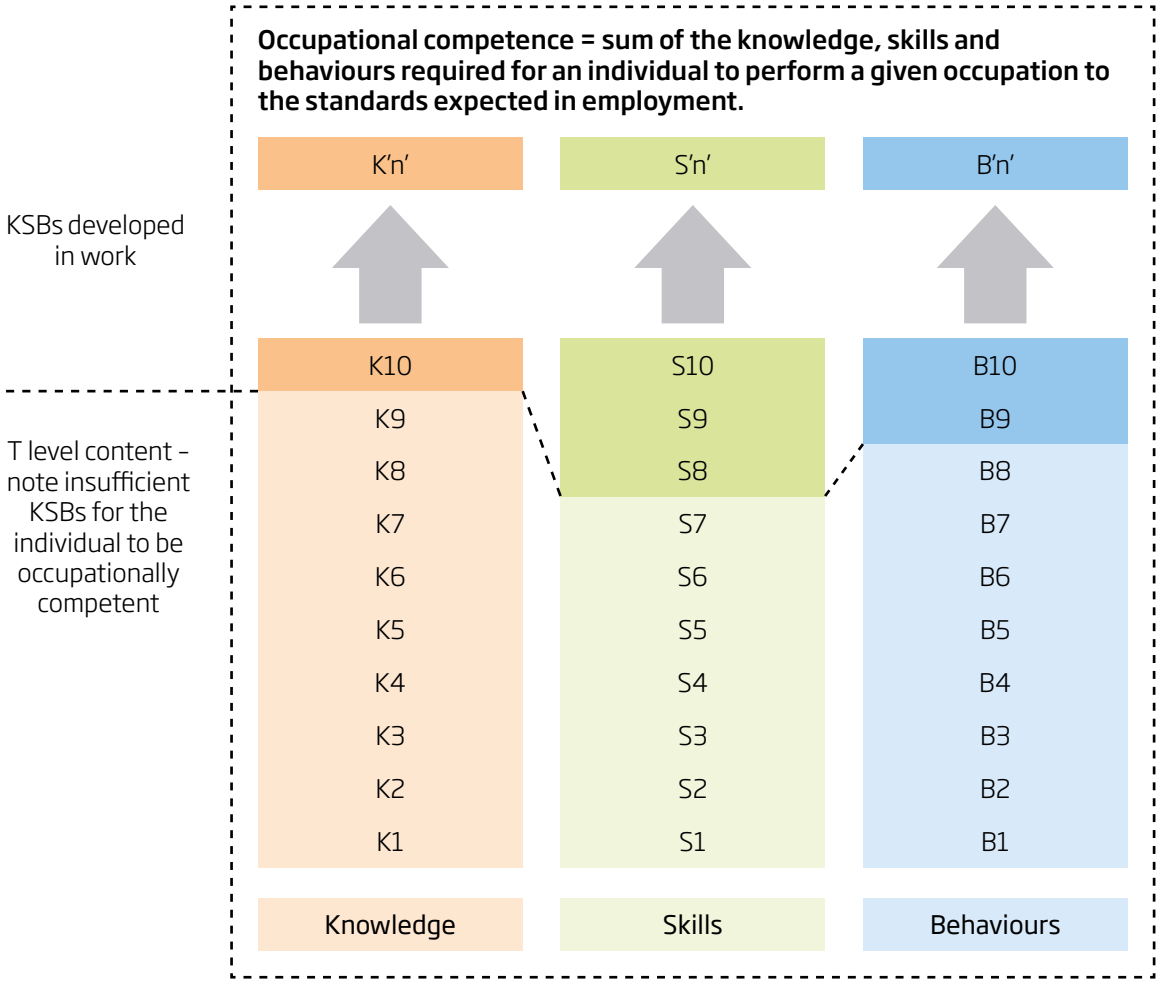
- **a.** Develop the widely applicable knowledge, skills and behaviours (KSB) that will prepare learners for work in a range of different roles within E&M (**Figure 3**);
- **b.** Provide a basis for further development towards the competence required in work (**Figure 3**);
- **c.** Motivate and enable learners to continue their development by way of apprenticeships, further education or higher education;
- **d.** Illustrate the diversity, challenge and career potential of E&M.

Principles

High quality

11. E&M T levels should offer a high quality learning experience that is recognized as a valid and desirable alternative to A levels and that attracts a range of students with different abilities and aspirations. The T level should include knowledge with a recognized academic provenance, mathematics and science in particular, but that is also clearly related to the occupational demands of E&M.

Figure 3:
Illustrative relationship between occupational competence and knowledge, skills and behaviours



Progression

12. E&M T levels should facilitate progression: to E&M apprenticeships, particularly at Level 3 or above; directly to further and higher education with UCAS points; to skilled employment in E&M; and, ultimately, to professional registration.

Prior qualification

13. It is presumed that learners electing to study an E&M T level will have achieved GCSE grades 4 or 5 in English, Mathematics, and Science (double award); in addition they might also have passed GCSE Design & Technology. If they have not, they should be encouraged to undertake a 'transition year' between GCSEs and T levels, during which they can achieve a GCSE-equivalent level of proficiency in English, Mathematics and Science.[1,2]

Qualification structure

14. As was shown in **Figure 3**, individuals will not be able to achieve occupational competence through T levels because of the lack of work-based learning. Thus, the E&M T levels should develop proficiencies in leaners to prepare them for work in a *wide range* of occupations within engineering and manufacturing industries. This broad E&M learning should be supplemented by a greater depth of learning that is specific to an occupation or group of occupations of the learner's choice.

15. The T shape is a useful descriptor for the principle of the content for the T level qualification. **Figure 4** illustrates different T shapes;

- **Figure (4a)** a long and narrow T: limited breadth of study across many disciplines, but significant specialist knowledge and skills development in a specific area – typical of the learning undertaken by an apprentice to achieve occupational competence,
- **Figure (4b)** a broad and short T: which provides the learner with a greater depth of knowledge and skills across a broader range of subject content, with a relatively small amount of additional specialist knowledge and skills for the chosen area.

16. The engineering community undertaking this work strongly support the broad and short T shaped qualification, based on the principle that college-based T levels should provide a breadth of knowledge and skills across a wide range of engineering disciplines. This would provide learners with greater occupational mobility than a significant amount of specialisation towards a single or small number of occupations. In addition, the engineering community undertaking this work believe that:

a. The majority of E&M occupations require similar generic foundation knowledge skills and behaviours. For example, mathematical principles and the principles of design are both common even when applied in different contexts and to different ends.

b. Many learners will not have decided on the area of E&M in which they wish to make a career and so should be offered learning that will allow them to follow a multitude of E&M career paths.

c. E&M employers will have a wider pool of potential recruits on which to draw.

d. T levels will be college-based qualifications and so better suited to providing generic content.

'Future proofing'

17. The T level qualification specification, teaching practice, industrial work placements and general context of learning should be constructed so as to illustrate emerging technologies and the changing and increasingly inter-disciplinary nature of engineering, in particular the significant growth and integration of digital tools and processes such as AI, autonomous systems and robotics.

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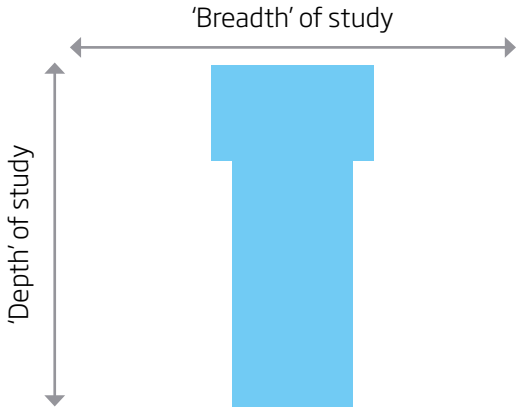
1 See Post 16 Skills Plan, chapter 4 Ensuring the new system works for everyone (DfE)

2 See, *Thinking like an engineer; implications for the education system*; Royal Academy of Engineering; May 2014; www.raeng.org.uk/publications/reports/thinking-like-an-engineer-implications-full-report

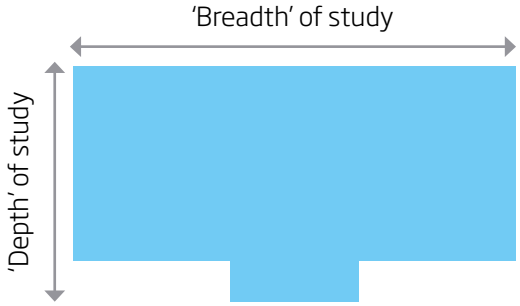
Figure 4:
Illustrative qualifications structures showing knowledge skills and behaviours specific to an occupation, group of related occupations or that are generic, i.e. needed by all occupations within a specific sector of the economy.

'Breadth' of study – wider column indicates greater range of knowledge, skills and behaviors.
'Depth' of study – taller column indicates greater depth of study.

4a:
Qualification contains knowledge skills and behaviours needed for a group of related occupations (e.g. Engineering design & draughtsperson) and some needed for a specific occupation (e.g. Engineering design & draughtsperson (Structural).



4b:
Qualification contains primarily knowledge skills and behaviours needed by all occupations in E&M, plus a small amount specific to a specific (e.g. Engineering design & draughtsperson (Structural).



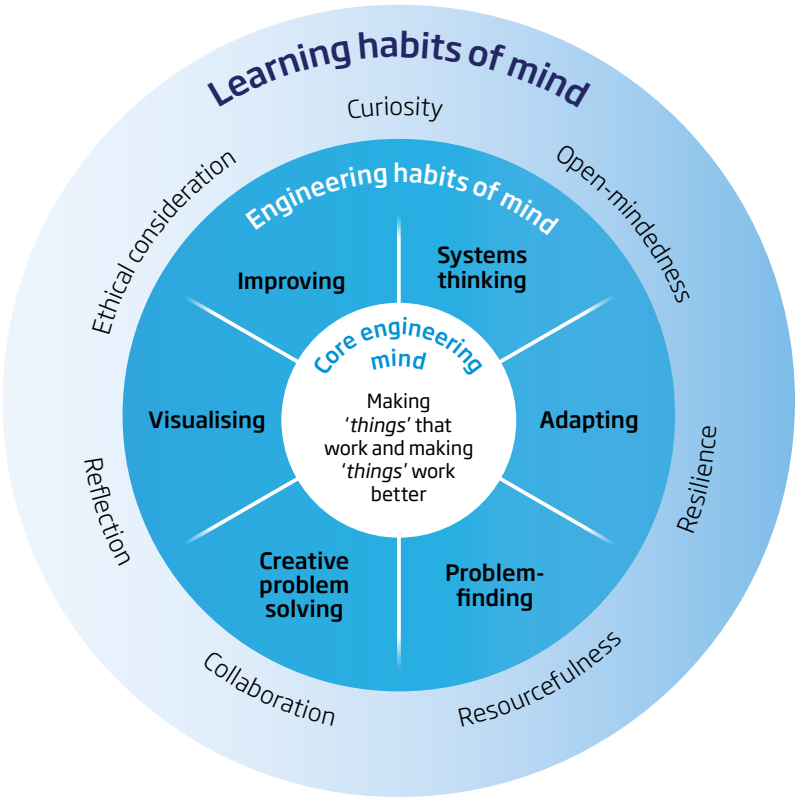
18. Digital skills are key in the current and future economy. Most engineers and technicians, and some operatives, will require a higher level of digital skills than will the average employee in the wider economy. The Skills Matrix for industrial digitalisation, contained in the *Made Smarter Review 2017*, should be used when developing the E&M T level content. Specifically, content should be included to cover each of the areas identified as being *mature skills that are widely used in many organisations and new skills that are currently used in a limited way or in a few organisations* on pages 114 and 115 of the Review[3]. Where possible, these should be embedded in the Common Core Content and developed in context. Regular and frequent review and update of the nature of the underpinning digital content will be required as well as of the pre-cursor maths and science content and standards.

Learner attributes

19. T levels should not only develop knowledge, skills and behaviours for the workplace, but should also seek to develop an *engineering mind-set* among learners. The attributes and characteristics of engineers and technicians identified by the Royal Academy of Engineering include; problem finding, creative problem solving, adapting, visualising, improving and systems thinking. These *engineering habits of mind* are underpinned by a wider range of *learning habits of mind*. These skills and behaviours are important for engineering in the 21st century and should be built into the teaching and learning of T levels for E&M. The engineering habits of mind are illustrated in **Figure 5**:

3 Made Smarter review 2017 www.gov.uk/government/publications/made-smarter-review

Figure 5:
Engineering habits of mind



Learning outcomes

20. T level content should reflect the needs of E&M employers, provide a basis for further development and enable learners to see a route to professional registration. We therefore proposed that the common core content be structured using a framework based on the Engineering Council's Output Standards for approved qualifications and apprenticeships[4] (the 'Output Standards)'. The Engineering Council, on behalf of the engineering profession, uses the Output Standards as the basis for approving qualifications and apprenticeships that provide the education base for registration as an Engineering Technician. They are, therefore:

- **a.** Designed specifically for assessing the professional relevance of engineering, including manufacturing, qualifications;
- **b.** Developed on behalf of the engineering profession and so already have support from the engineering profession and community;
- **c.** Internationally benchmarked.

21. The Output Standards identify Learning Objectives within each of the following six key areas of learning:

- **a.** Science and mathematics
- **b.** Engineering analysis
- **c.** Design
- **d.** Economic, legal, social, ethical and environmental context
- **e.** Engineering practice
- **f.** Additional general skills

22. We have adapted the Learning Objectives for use with T levels. **Appendix A** shows the T level Outcomes alongside the original Output Standard learning objectives.

4 www.engc.org.uk/engcdocuments/internet/Website/20150317_Technician_Learning_Outcomes_AQAH_Extract.pdf

T level content

23. To identify suitable common core content we referred to a sample of relevant taught qualifications and apprenticeships currently delivered within the Further Education sector. These qualifications also provide the knowledge required by apprenticeship standards that are included on the E&M T level occupation map. Content from these was re-worded and/or de-contextualized as appropriate, added to and altered by various contributors.

24. The selected content was then allocated to the Outcomes shown at **Appendix A**. The resulting proposed common core content is shown at **Appendix B**.

Other issues

Work placements

25. Although not within the scope of this report concerns have been raised about the availability of work placements on the scale likely to be needed. Similarly, contributors to this work indicate a strong desire that the work placements should be structured and managed such that they make a positive contribution to the overall learning experience.

Projects

26. While out of scope for this report, the pedagogic approach for the delivery of T levels will be an important factor in the development of the knowledge, skills, behaviours and the *engineering habits of mind* of students undertaking these qualifications. The engineering community strongly encourages the T level Panel to consider including active, student-led learning approaches and structured industrial projects as a significant part of the learning process in engineering and manufacturing T levels. This would encourage practical skills to be developed, learners to understand how theory is applied in real-life contexts and to develop some of the behaviours needed for the workplace. Projects should focus on various aspects of the engineering habits of mind, including problem identification, creative problem solving, ethical considerations, reflection, working collaboratively in teams, and systems thinking.

Diversity

27. With significant under-representation in engineering among many groups it is essential that the T level content or its delivery does not exclude any individual from participating in the qualifications. Moreover, where possible, the content should make explicit use of the need for inclusive design and more general inclusivity across engineering and should nurture inclusive behaviours in the learners.

Impact on apprenticeships

28. We note that learners who have completed an E&M T level might be able to complete an apprenticeship in a shorter than usual time. These learners will have already acquired relevant KSBs that would otherwise be provided through the apprenticeship. This is likely, however, to vary depending on the specific apprenticeship framework in question.

Appendix A:

Proposed T level Outcomes and the Engineering Council Output Standards for approved qualifications and apprenticeships on which they are based

Six key areas	Proposed T level Outcomes Learners should:	Engineering Council Output Standards for approved qualifications and apprenticeships: Learning Objectives
A **Science and mathematics**	**Outcome A1** Understand the scientific principles that underpin relevant technologies and use the main formulae associated with them	**LO A1** A descriptive, formula-based knowledge and understanding of the scientific principles underpinning relevant current technologies
	Outcome A2 Apply relevant mathematical techniques to solve problems	**LO A2** Knowledge and understanding of relevant mathematics, including numerical and data analysis, that is necessary to support the application of technical and practical skills
B **Engineering analysis**	**Outcome B1** Apply standard tests and measurements	**LO B1** To understand the limitations of standard tests and measurements relevant to their field of activity
	Outcome B2 Use results of engineering analysis to identify solutions to well-defined problems	**LO B2** Know-how to use the results of engineering analysis for the purpose of developing solutions to well-defined engineering or ICT problems
	Outcome B3 Apply appropriate solutions to well-defined problems in common fields of activity	**LO B3** To apply appropriate solutions to well-defined engineering or ICT problems using methods specific to their field of activity

Six key areas	Proposed T level Outcomes Learners should:	Engineering Council Output Standards for approved qualifications and apprenticeships: Learning Objectives
C **Design**	**Outcome C1** Recognise business, customer, and user needs	**LO C1** Awareness of business, customer, and user needs
	Outcome C2 Outline the constraints on the design process including environmental and sustainability limitations; ethical, health, safety, security and risk issues; intellectual property; codes of practice and standards, product lifecycle	**LO C2** Awareness of constraints on the design process including environmental and sustainability limitations; ethical, health, safety, security and risk issues; intellectual property; codes of practice and standards
	Outcome C3 Outline the engineering design process	**LO C3** Knowledge that supports design for the purpose of developing solutions to well-defined engineering or ICT problems
	Outcome C4 Know the roles of those involved in the design process	**LO C4** Know-how to contribute to the design and/or the design process
	Outcome C5 Communicate their work to technical and non-technical audiences	**LO C5** Know-how to communicate their work to technical and non-technical audiences
D **Economic, legal, social, ethical and environmental context**	**Outcome D1** Demonstrate profession and ethical behaviour and have a basic knowledge of professional codes of conducts	**LO D1** Understanding the need for a high level of professional and ethical conduct in engineering or ICT and a knowledge of professional codes of conduct
	Outcome D2 Outline the commercial, economic and social context of engineering and manufacturing	**LO D2** Knowledge of the commercial, economic and social context of the engineering or ICT processes
	Outcome D3 Explain the need for engineering and manufacturing activities to promote sustainable development	**LO D3** Understanding the requirement for engineering or ICT activities to promote sustainable development
	Outcome D4 Know the main legal requirements governing engineering and manufacturing activities, including personnel, health & safety, contracts, intellectual property rights, product safety and liability issues	**LO D4** Awareness of relevant legal requirements governing engineering or ICT activities, including personnel, health & safety, contracts, intellectual property rights, product safety and liability issues
	Outcome D5 Know and explain key risk issues, including health & safety and environmental risk	**LO D5** Awareness of risk issues, including health & safety and environmental risk

Six key areas	Proposed T level Outcomes Learners should:	Engineering Council Output Standards for approved qualifications and apprenticeships: Learning Objectives
E **Engineering practice**	**Outcome E1** Demonstrate how to use a range of relevant and commonly used materials, equipment, tools, processes, or products in electrical and mechanical contexts	**LO E1** Know-how to use relevant materials, equipment, tools, processes, or products
	Outcome E2 Know and demonstrate the procedures and practices for common industry standard operations and processes	**LO E2** Knowledge of procedures and practices for industry standard operations and processes
	Outcome E3 Know how to find information in technical literature and understand how it is applied	**LO E3** Know-how to use and apply information from technical literature
	Outcome E4 Comply with commonly available codes of practice and industry standards	**LO E4** Know-how to use appropriate codes of practice and industry standards
	Outcome E5 Outline and apply the principles of quality assurance and continuous improvement	**LO E5** Awareness of quality issues and the potential for continuous improvement
	Outcome E6 Work effectively as part of a team	**LO E6** Awareness of team roles and the ability to work as a member of an engineering or ICT team
F **Additional general skills**	**Outcome F1** Demonstrate basic skills in problem solving, communication, information retrieval, working with others and the effective use of general IT facilities	**LO F1** Apply their skills in problem solving, communication, information retrieval, working with others and the effective use of general IT facilities
	Outcome F2 Plan self-learning and improve performance as the foundation for lifelong learning/CPD	**LO F2** Plan self-learning and improve performance, as the foundation for lifelong learning/CPD
	Outcome F3 Demonstrate how to plan and carry out a personal programme of work	**LO F3** Plan and carry out a personal programme of work
	Outcome F4 Demonstrate how to exercise personal responsibility, as an individual and as a team member	**LO F4** Exercise personal responsibility, as an individual or as a team member

Appendix B:

E&M T level common core

A – Science and mathematics

Science, mathematics and other associated disciplines that underpin engineering.

Outcome A1 **Understand the scientific principles that underpin relevant technologies and use the main formulae associated with them**		
Outcome statement		**Outcome scope: includes but not limited to:**
A1.1	Demonstrate the use of SI units	Range of SI units relevant to engineering
A1.2	Explain how matter is structured	Elements; Atoms; Molecules and compounds; Mixtures, solutions, suspensions and solubility; Crystals; Metals; Density
A1.3	Explain and apply the principles of Dynamics	Newton' s laws of motion (angular and linear); Speed, time and distance; Velocity; Acceleration; Position; Force, mass and gravity; Linear momentum
A1.4	Solve problems involving forces	Scalar and vector quantities; Centre of gravity; Coplanar forces in equilibrium; The resultant of two coplanar forces; Triangle of forces method; The parallelogram of forces method; Resolution of forces
A1.5	Solve problems involving simply supported beams	The moment of a force; Equilibrium and the principle of moments; Simply supported beams having point loads
A1.6	Solve problems involving work, energy and power	Work done; Energy; Power; Potential and kinetic energy
A1.7	Explain and apply the principles of friction	Coefficient of friction; Applications of friction (including air resistance and friction)
A1.8	Explain and apply the principles of torque	Couple and torque; Work done and power transmitted by a constant torque; Kinetic energy and moment of inertia; Power transmission and efficiency; Angular momentum
A1.9	Explain and apply the principles of simple machines	Force ratio, movement ratio and efficiency; Pulleys; The screw-jack; Gear trains; Levers; Control systems, sensors and actuators; Logic, programming and feedback.
A1.10	Explain and demonstrate the effects of forces on materials	Tensile force; Compressive force; Shear force; Stress and strain; Elasticity and elastic limit; Hooke' s law

A1.11	Recognise the properties and uses of materials	Classification; Elasticity, Fatigue and plastic deformation, Hooke's Law, Young's Modulus, Mechanical properties, Changes in property, High temperature treatment processes and their effects; Composites; Alloys; Polymers; Electrical conductors and insulators; Smart materials (e.g. shape-memory); Destructive and non-destructive testing; Thermal insulation
A1.12	Summarise how chemicals are used in electricity	Electrolysis; Electroplating; The simple cell; Corrosion; Internal resistance of a cell; Primary cells; Secondary cells; Cell capacity
A1.13	Calculate values of series and parallel electrical networks	Potential divider; Kirchhoff' s current and voltage laws
A1.14	Outline the principles of capacitance and inductance	Capacitors and capacitance; The parallel plate capacitor; Capacitors connected in parallel and series; Dielectric strength; Energy stored in capacitors; Practical types of capacitor; Discharging capacitors; Inductance; Inductors; Energy stored by inductors
A1.15	Explain and demonstrate the relationship between electricity and magnetism	Magnetic field due to an electric current; Flux; Induction; Force on a current-carrying conductor; A.C. and D.C. motors and generators; Features of waveforms; Transformers
A1.16	Select, connect and use electrical measuring instruments	Analogue & digital instruments; Moving-coil instruments; Rectifier circuits; Shunts and multipliers; Electronic instruments; The ohmmeter; Multimeters; Wattmeters; Instrument 'loading' effect; Oscilloscope; D.C. potentiometer; Measurement errors

Outcome A2

Apply relevant mathematical techniques to solve problems

Outcome statement		Outcome scope: includes but not limited to:
A2.1	Solve arithmetical problems	Fractions; Decimals; Ratios; Proportions; Percentages; Simple powers of numbers & roots
A2.2	Solve problems using algebra	Transpose and solve formulas; Factorising and quadratics; Indices and standard form; Laws of logs; Logs (base 10) & natural logs (base e); Linear equations & straight line graphs; Linear simultaneous equations; Application to problems involving exponential growth & decay; Lowest common multiples; Quadratic equations
A2.3	Calculate areas and volumes	Standard formulae to solve surface areas and volumes of regular solids
A2.4	Apply complex numbers to solve problems	Routine arithmetical operations
A2.5	Construct and use charts and graphs to analyse data	Types of charts and graphs; Principles of graphical representation; Create, interpret & extract data

A2.6	Use matrices and determinants to solve problems	Routine arithmetical operations
A2.7	Use statistics and probability to identity patterns and trends	Probability distributions; Data handling and sampling; Mean, median and mode; Normal distribution; Percentiles and quartiles; Standard deviation
A2.8	Use trigonometry to solve problems	Pythagoras' Theorem; Applications of vectors (covered in Forces & Motions and in Alternating Current); Circular measure; Functions; Sine and Cosine rules; Triangular measurement; Sinusoidal functions
A2.9	Use calculus to solve problems	Gradients; Areas; Maxima and minima
A2.10	Use sequences and series to solve problems	Arithmetic and geometric progressions; Binomial expansion, Power series

B - Engineering analysis

Engineering analysis involves the application of engineering concepts and tools to the solution of engineering and manufacturing problems.

Outcome B1 **Apply standard tests and measurements**		
Outcome statement		**Outcome scope: includes but not limited to:**
B1.1	Use measuring systems to collect and interpret data	Purposes and applications of common measurement systems; Operation of measurement system components; Testing and calibrating a measuring system; Use of testing, recording and display equipment for measurement
B1.2	Undertake electronic measurement and testing	Selection, calibration and use; Virtual test instruments and software
B1.3	Undertake mechanical measurement & inspection	Measurement and inspection methods; Types of measurement (linear, surface texture, straightness, squareness and flatness, angular); Comparators; Gauging
B1.4	Identify defects in materials	Typical defects; Inspection techniques

Outcome B2 **Use results of engineering analysis to identify solutions to well-defined problems**		
Outcome statements		**Outcome scope: includes but not limited to:**
B2.1	Manage test data	Validating, storing and recording data required to develop solutions
B2.2	Recognise the causes of failure	Ductile and brittle fracture; Fatigue; Heat; Vibration; Corrosion; Components; System; Human
B2.3	Use fault finding techniques	Techniques and tests (destructive and non-destructive); Root cause identification and analysis; Using current and historic data for fault finding, Investigation procedures, Fault finding techniques, Aids to diagnosis, Fault finding equipment; Diagnostic aids,
B2.4	Use available test results to diagnose faults	Diagnosis techniques; Monitoring and reliability systems

Outcome B3 **Apply appropriate solutions to well-defined problems in common fields of activity**		
Outcome statement		**Outcome scope: includes but not limited to:**
B3.1	Outline how to implement a chosen solution	Produce an implementation plan; Assess impact; Scheduling; Assess cost implications; Reporting and authorisation

C - Design

Design is the development of an economically viable product, process or system to meet a defined need.

Outcome C1 **Recognise business, customer, and user needs**		
Outcome statement		**Outcome scope: includes but not limited to:**
C1.1	Identify stakeholder needs	Identify a range of internal and external stakeholders and their needs; 'Voice of the customer'; Market needs

Outcome C2 **Outline the constraints on the design process including environmental and sustainability limitations; ethical, health, safety, security and risk issues; intellectual property; codes of practice and standards, product lifecycle**		
Outcome statement		**Outcome scope: includes but not limited to:**
C2.1	Recognise the need for design optimisation	Practical application of design optimization; Design constraints variables and objectives
C2.2	Recognise the need for design to meet manufacturing requirements	Design for manufacturability; Production planning; Value Stream Mapping and LEAN principles
C2.3	Recognise the need for design to meet maintenance requirements	Maintenance strategies and operations; How maintenance issues can influence design
C2.4	Recognise the need for design to meet decommissioning requirements	Decommissioning strategies and operations
C2.5	Outline the need for and the principles of prototyping	Design, manufacture, assembly and testing

Outcome C3 **Outline the engineering design process**		
Outcome statement		**Outcome scope: includes but not limited to:**
C3.1	State the principles of design	Research; Design requirements; Feasibility; Conceptualization; Preliminary design/prototyping; Detailed design; Design lifecycle and established design methodologies
C3.2	Apply the principles of design to a well-defined engineering problem	Use appropriate computer software and manufacturing technologies (e.g. CNC / Additive Manufacturing); Electrical/electronic and mechanical contexts and established design methodologies

Outcome C4 **Know the roles of those involved in the design process**		
Outcome statement		**Outcome scope: includes but not limited to:**
C4.1	Identify the roles of those involved in the design process	Client/customer; Contractor; Design team hierarchy (e.g. Senior Engineer, Section Head)

Outcome C5 **Communicate their work to technical and non-technical audiences**		
Outcome statement		**Outcome scope: includes but not limited to:**
C5.1	Identify the common relevant form of communication	Oral, written, visual, graphical etc.; Benefits of effective communication; Explain the principles of and use a CAD system
C5.2	Demonstrate effective communication	Presentation skills, use of ICT and other aids; Read and interpret freehand 2D and 3D drawings and sketches; Produce 2D and 3D drawings and sketches; Drawing standards and conventions; Standard representations; Use CAD to produce 2D and 3D industry standard engineering drawings

D – Economic, legal, social, ethical and environmental context

Engineering and manufacturing activities impact on the environment, commerce, society on individuals. Learners therefore need to be aware of these activities and to understand their impacts and the various legal and ethical constraints relevant to engineering and manufacturing.

Outcome D1 **Demonstrate profession and ethical behaviour and have a basic knowledge of professional codes of conducts**		
Outcome statement		**Outcome scope: includes but not limited to:**
D1.1	Outline the principles and the need for professionalism and ethical behaviour	Ethical principles; Professionalism and Codes of Conduct; Constraints to ethical conduct; Whistleblowing
D1.2	Demonstrate professional and ethical conduct	Comply with relevant codes of conduct

Outcome D2 **Outline the commercial, economic and social context of engineering and manufacturing**		
Outcome statement		**Outcome scope: includes but not limited to:**
D2.1	Outline the commercial economic and social context	The competitive/collaborative environment; Contracts and legal issues; Social issues and impacts
D2.2	Outline key business principles	Business types and functions; Business strategies and techniques to improve business; Key business stakeholders
D2.3	Outline key business operations	How engineering companies operates; Impact of legislation, regulation and other constraints on the engineering businesses; Costs and cost control; How external factors and the economic environment can affect the operation of an engineering company; Research and development processes
D2.4	Outline business and engineering innovation	Impact of innovation on existing products; The introduction of new products; Legal issues (intellectual rights, patents etc.)

Outcome D3 **Explain the need for engineering and manufacturing activities to promote sustainable development**		
Outcome statement		**Outcome scope: includes but not limited to:**
D3.1	Summarise the principles of sustainability	Growth; Consumption; Circular economy, Population and urbanisation
D3.2	Outline engineering's relationship with the environment	Environmental impact (Local, national and global); Environmental risk
D3.3	Describe emerging technologies and their impact on sustainable development	Emerging products and technologies (e.g. battery technologies, additive manufacturing; Artificial Intelligence); Materials (e.g. smart materials, nanotechnology, composites, advanced simulations)
D3.4	Summarise a range of sustainable practices	Consequences of not adopting sustainable practices; Design methodologies; Efficient use of resources; Waste management; Renewable and Low Carbon energy

Outcome D4 **Know the main legal requirements governing engineering and manufacturing activities, including personnel, health & safety, contracts, intellectual property rights, product safety and liability issues**		
Outcome statement		**Outcome scope: includes but not limited to:**
D4.1	Be aware of and be able to work to the minimum legal requirements	Health and Safety at Work Act (and its associated elements such as RIDDOR and COSHH); Personnel and employment law; Industrial relations; Intellectual property rights; Product safety and liability

Outcome D5 **Know and explain key risk issues, including health & safety and environmental risk**		
Outcome statement		**Outcome scope: includes but not limited to:**
D5.1	Outline hazards and risks in the workplace	Hazards (e.g. Climate; Fumes, Noise, Motion and vibration, Illumination, Layout); Identifying hazards in the workplace; Risks (e.g. Falling; Contamination; Inhalation of fumes); Risk assessments; Control measures (e.g. PPE, Storage, Permits to work)
D5.2	Explain the key features and limitations of human factors	Effects of (for example) setting inappropriate deadlines, shift work on sleep and fatigue, stress, personal health and fitness, physically demanding work, repetitive tasks, degraded eyesight and hearing, alcohol, medication and substance abuse
D5.3	Be able to work according to safe working practices	Maintaining a safe work area; Safe use of tools; Hardware and consumable components; Tool management; Workshop information sources and standards; Operating environment safety procedures and control measures

E - Engineering practice

The practical application of engineering and manufacturing knowledge and skills.

Outcome E1 **Demonstrate how to use a range of relevant and commonly used materials, equipment, tools, processes, or products in electrical and mechanical contexts**		
Outcome statement		**Outcome scope: includes but not limited to:**
E1.1	Demonstrate the use of measurement and marking out tools and techniques	Measuring tools, equipment and aids to marking out (meters, gauges, weighing equipment, marking out tables and plates, angle plates, parallel strips, vee blocks, jack screws, clamps, vices); Errors; Methods
E1.2	Demonstrate the use of common tools and techniques	Hand tools; Power tools; Workshop machinery & equipment (including CNC); Work and tool holding methods (including setting up); Computer hardware and software (including CAD/CAM)
E1.3	Demonstrate common material processing techniques	Forming; Moulding; Bonding; Shaping; Bending; Joining of a range of common materials (e.g. ceramics, composites, alloys, metals, polymers, wood) for common purposes (e.g. wiring, sheet and pipe)
E1.4	Summarise the properties and use of composites	Key materials; Properties; Applications; Key processes; Techniques

Outcome E2 **Know and demonstrate the procedures and practices for common industry standard operations and processes**		
Outcome statement		**Outcome scope: includes but not limited to:**
E2.1	Outline the key features of project Management and control	Principles; Stages of project management; Project roles; Project management tools (e.g. Gantt charts); Initiation; Project planning and scheduling; Budgets; Quality; Risk management; Resources; Closure; Bids tenders and estimates
E2.2	Outline the principles of engineering maintenance	Different types of maintenance; Failure modes; Inspection; Installation and replacement; System servicing; Methods and techniques
E2.3	Demonstrate the disassembly, assembly and fitting of components and systems	Specifications and instructions; Strip-down; Cleaning; Checking, Examining and inspecting for wear damage and corrosion; Precision measuring; Repairs; Component replacements; Modification; Hand fitting; Adjusting; Recording readings; Testing Compliance; Consumables; To cover electrical, mechanical and pressurised fluid systems.

Outcome E3 **Know how to find information in technical literature and understand how it is applied**		
Outcome statement		**Outcome scope: includes but not limited to:**
E3.1	Identify and use key sources of technical information	Identify, gather and organise relevant information (e.g. BSI, data sheets, technical drawings, specifications)

Outcome E4 **Comply with commonly available codes of practice and industry standards**		
Outcome statement		**Outcome scope: includes but not limited to:**
E4.1	Comply with the key features of relevant codes of practice	Know and apply codes of practice form current legislation such as the electricity at work regulation, woodworking regulation, the use of BSI7671/IET wiring regulation, regulations of the employers' workplace, Equality Act, Working time directive, Working with computers, Visual Display Unit, Equipment and workstation environment

Outcome E5 **Outline and apply the principles of quality assurance and continuous improvement**		
Outcome statement		**Outcome scope: includes but not limited to:**
E5.1	Summarise business improvement techniques	Continuous improvement; Workplace organization (incl. efficiency); Common problem-solving techniques; Categories of work; Waste, cost and sustainability; Visual management; Transport; Inventory, Motion; Waiting; Overproduction; Over processing; Defects; Skills/ unrecognised people potential
E5.2	Outline the principles of continuous improvement	Purpose; Improvement planning; Use of data; System performance indicators; Identification of intended outcomes (e.g. TQM, Six Sigma)
E5.3	Be aware of and apply quality processes	Quality management systems (e.g. BS EN ISO 9001)
E5.4	Prepare a continuous improvement plan	Data analysis; Planning; System performance indicators; Identification of intended outcomes; Managing for intended outcomes

Outcome E6 **Work effectively as part of a team**		
Outcome statement		**Outcome scope: includes but not limited to:**
E6.1	Work effectively as part of a team	Allocating tasks; Effective communication; Motivation; Planning; Strengths and limitations of team members; Use own knowledge and expertise to help others when requested; Working with others and understanding role within a team, Peer pressure

F - Additional general skills

Learners should have developed additional basic transferable skills that will be of value in a wide range of situations.

Outcome F1		
Demonstrate basic skills in problem solving, communication, information retrieval, working with others and the effective use of general IT facilities		
Outcome statement		**Outcome scope: includes but not limited to:**
Embedded in other content throughout		

Outcome F2		
Plan self-learning and improve performance as the foundation for lifelong learning/CPD		
Outcome statement		**Outcome scope: includes but not limited to:**
F2.1	Reflecting on own performance and planning for self-improvement	Plan self-learning and improve performance as the foundation for lifelong learning/CPD; Goal-setting

Outcome F3		
Demonstrate how to plan and carry out a personal programme of work		
Outcome statement		**Outcome scope: includes but not limited to:**
F3.1	Content not identified.	Examples of possible content might include: 1. Researching and planning future career in engineering & manufacturing 2. Potential for entrepreneurship and establishing a business

Outcome F4		
Demonstrate how to exercise personal responsibility, as an individual and as a team member		
Outcome statement		**Outcome scope: includes but not limited to:**
F4.1	Exercise responsibility within a group	Take responsibility for own actions; act within authority level

Appendix C

Organisations that contributed to the development of this report

The following organisations were represented at one or more of the workshop(s) that led to the development of this report or have specifically expressed support for the report and its outcomes:

BCS, The Chartered Institute for IT
British Institute of Non-destructive Testing
Chartered Institute of Building Services Engineers
City and Islington College
CogentSkills
Engineering Construction Industry Training Board
Engineering Council
High Value Manufacturing Catapult
Institute of Physics
Institution of Civil Engineers
Institution of Mechanical Engineers
James Dyson Foundation
National Forum for Engineering Centres
National Skills Academy for Nuclear
Royal Academy of Engineering
Royal Aeronautical Society
Semta
The IET
The Welding Institute
UK Electronic Skills Foundation

ROYAL
ACADEMY OF
ENGINEERING

Royal Academy of Engineering

As the UK's national academy for engineering and technology, we bring together the most successful and talented engineers from academia and business – our Fellows – to advance and promote excellence in engineering for the benefit of society.

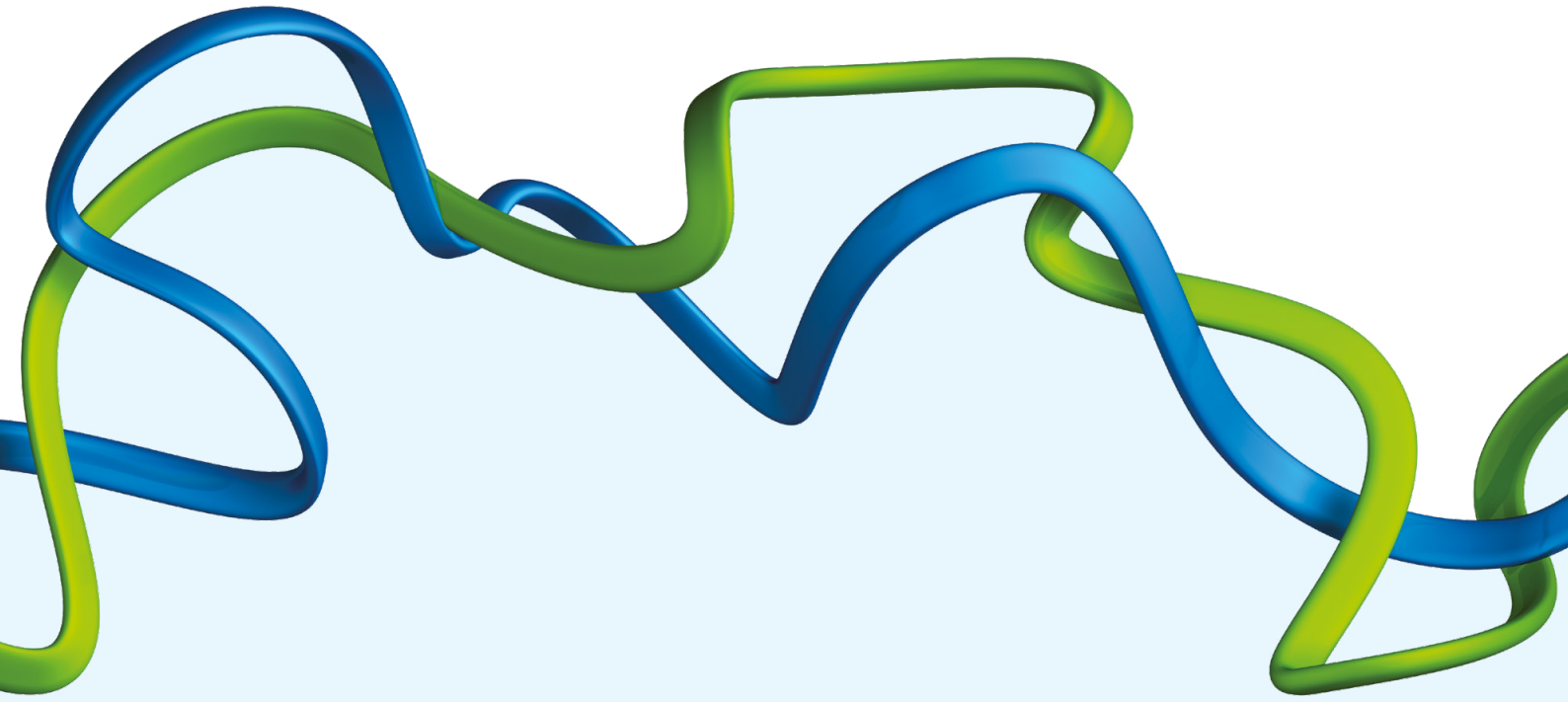
We harness their experience and expertise to provide independent advice to government, to deliver programmes that help exceptional engineering researchers and innovators realise their potential, to engage the public with engineering and to provide leadership for the profession.

We have three strategic priorities:

- Make the UK the leading nation for engineering innovation and businesses
- Address the engineering skills and diversity challenge
- Position engineering at the heart of society

We bring together engineers, policymakers, entrepreneurs, business leaders, academics, educators and the public in pursuit of these goals.

Engineering is a global profession, so we work with partners across the world to advance engineering's contribution to society on an international, as well as a national scale.



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