A Practical Guide to Assessment for Learning

The specification and sample assessment materials for

TLM Level 2 Certificate in Open Systems and Advanced Manufacturing Technologies (RQF)

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High Quality Qualifications for the
2019 School League Tables

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TLM Technology and Quality Assurance

This is version 1.0 of the specification for TLM Level 2 qualification in Open Systems and Advanced Manufacturing Technologies developed in association with companies, universities and experienced teaching staff.

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Overview

The last few decades have seen a rapid acceleration in the development and uptake of smart products and semi- intelligent devices and objects. The barrier to entry has also come down and it is now quite possible for medium sized firms to launch satellites into space using rockets of their own design and manufacture. This was once the realm of sovereign states or even multiple countries due to the cost and complexity. A great deal of this innovation has been driven by the constant improvement and miniaturisation of control systems. Most primary school students have used mini computers such as the Raspberry Pi™ and in 2015 all UK Year 7 students were given their own BBC micro:bit computer to use. The increasing access to these powerful and easy to use control devices has opened up a huge number of possibilities for companies to explore industries from rocket science to artificial intelligence and school students are in an excellent position to follow closely behind.

The object of this qualification is to introduce KS4 students to this fast moving world and equip them for jobs in these industries in the near future. The students will learn how to build and fly rockets, how to build some objects to go into those rockets, such as microsatellites. They will explore artificial intelligence, and look at the issues surrounding the making and use of unmanned vehicles.

1. Introduction

1.1 These qualifications have the purpose of providing pupils with practical technical knowledge, understanding and skills in understanding, designing and manufacturing cutting edge devices and embedded systems across all industrial and commercial sectors. A further design is to involve a number of different departments in their support and delivery to show students the inter-relatedness of technology and science. They preserve the necessary rigour for stretching the highest attaining candidates while including the great majority of the Key stage 4 cohort. In addition, there is a clear intention to reduce the bureaucratic overhead on teachers while preserving the benefits of coursework for motivating learners and dealing validly with recognition of competence in what are essentially practical, technical and pre-vocational skills and activities. We have demonstrated that we can provide Level 1 and Level 2 qualifications that are accessible to all learners while still differentiating the top performing students. This enables a clear progression route for the weakest mainstream learners through to identifying those that are likely to be successful in academic A levels and beyond into the associated professions.

1.2 TLM Level 2 Certificates in Open Systems and Advanced Manufacturing Technologies are qualifications that embody a highly relevant modern approach to product and technology development, design engineering and advanced manufacture. Product and technology innovation is under pressure to be both sustainable and accessible utilising various media streams to create new benefits for customers and clients. For example adding intelligence and interactive user interfaces to existing and new products is a critical strategy to satisfy these needs. 3D printing and the internet is providing product designers and engineers direct access to manufacturing capacity with low-investment and short lead-times. There has never been a better time for product designers and engineers to take projects to market.

http://www.mckinsey.com/insights/manufacturing/the_future_of_manufacturing
http://www.mckinsey.com/insights/business_technology/disruptive_technologies

The boundary between creative arts and engineering is becoming blurred as digital technologies are becoming much easier to use, and manufacturing processes are readily available to all, from micro-businesses and craftsmen to international engineering corporations. A new world where digital and physical processes are made more accessible, knowledge and competence in creating new ideas and preparing them for manufacture and new markets is becoming increasingly important.

The unprecedented opportunities and applications of smart design and manufacturing, as well as embedded systems and processes across multiple industries ensure learner knowledge and skills gained through these qualifications are applicable across a wide range of professional careers and sectors opening up progression routes to both academic and vocational higher level learning.

Further, academic depth and rational critical analysis of progress to ensure successful projects will be critical to integrate a range of subjects demanded by industry in a landscape of rapid technology change and business complexity. [reference from McKinsey report on importance of understanding complex network and systems]

The qualifications offer teachers and learners the opportunity to develop a range of skills, knowledge and understanding that is not available in the core academic curriculum. The content is fundamental to successful engagement in the professional aspects of product and systems design relevant to innovation and manufacturing sectors of industry. This Level 2 qualification will enable progression to Level 3 in a range of hi-tec digital learning.

1.3 This specification is for a Level 2 qualification, targeted on secondary schools and colleges. It has the following key benefits.

- devised in consultation with leading industry consultants, professional bodies and universities
- clear and flexible unit based structure referenced to the European Qualifications Framework (EQF).
- straightforward assessment of competence in real rather than contrived contexts.
- grading through controlled exams introduced progressively from KS3 to KS4.
- provides a focus for continuing professional development for teachers through moderation/verification feedback.
- moderation/verification of coursework on demand.
- examination opportunities throughout the year.
- use of open source cloud based technologies to reduce costs and add value for schools.
- reduced bureaucracy for teachers and flexibility for them to target specific interests.

1.4 This qualification lends itself to formative assessment practices allied to summative differentiation by outcome that can optimise and motivate attainment for individuals rather than assume all will reach a certain level or grade at a particular time. We do this by providing a coursework component that is competence based, reflecting the best and most up to date research in assessment in the workplace complemented by a short academic style examination.

1.5 All candidates must complete the coursework before being eligible to take the exam. This provides an incentive to complete the coursework and makes it less likely that those sitting an exam are ill-prepared.

1.6 The Level 2 exam grades candidates from grade C through B and A to A*.

A Level 1 version will be available for 2020. The two qualifications at Level 1 and Level 2 can stand alone but they are designed to provide a coherent progression route starting with coursework at Level 1 and then a multiple choice online exam to determine the Level 1 grades. Level 2 coursework is differentiated from Level 1 by more demanding assessment criteria and the general EQF level descriptor for Level 2. If coursework is completed to the Level 2 standard the candidate can go on to take the Level 2 exam which will then differentiates grades A*-C (9-5).

1.7 In this way we can provide valid competence based assessment and rigorous testing of knowledge and understanding at a lower cost than both traditional vocational and academic methods applied separately. If replicated across schools it would potentially save significantly on current expenditure on assessment and examinations, but more importantly - teacher time. There is research evidence that this approach should enhance motivation that will result in higher attainment by supporting both performance-approach goals that focus on displaying competence and performance-avoidance goals focus on avoiding a display of incompetence. (Conclusions from Effects of Classroom Assessment Practices on Students' Achievement Goals, Hussain Alkharusi Sultan Qaboos University, Oman.)

2. Summary of the qualifications specifications

2.1 The Level 2 certificate is graded across 4 levels from A*- C (9-5) with A* the highest grade equating to 80%+ of the available marks and grade C equating to a minimum of 50%.

[The published grade boundaries may be subject to change]

Content

2.2 The qualification content has been designed for use in schools and colleges by referencing it to similar assessments carried out in current Level 2 qualifications. It is designed to meet the needs of employers, through consultation with leading design and manufacturing agencies, progressive universities and professional bodies representing a wide section of the industry. Guidance for coursework is aligned with the CBI employment criteria.
http://www.cbi.org.uk/business-issues/education-and-skills/in-focus/employability/

Guidance takes into account the lack of experience of many teachers in this area ensuring that the most academically able can be stretched and routed to appropriate academic progression at Level 3. Strong industry support provides great potential for staff development, keeping teachers up to date in what is still a rapidly changing sector. Unlike purely academic qualifications, regular reference is made to practical skills and standards and the use of real equipment and technology rather than simulations or generic terms only. There is an emphasis on increasing understanding of the importance of innovation and technology to the UK economy e.g. government TSB strategy to support development of new innovative products and supporting them to production and market.

Assessment

2.3 The qualifications at both Level 1 and Level 2 have two assessment components both of which cover the full content of the qualifications.

1. Coursework assessed in terms of competence in practical areas where knowledge and understanding can be applied in real and motivating contexts.
2. An externally set and externally marked examination to assess knowledge and understanding that underpins user competence.

2.4 Both qualifications are unit based and each consists of 4 units. Units have credit values in the regulated qualifications framework (RQF). A minimum of 16 credits is needed for each qualification equating to 160 guided learning hours and 180 hours Total Qualification Time. The mode of teaching is entirely up to the school.

2.5 The synoptic examination of knowledge and understanding that is used for grading is based on a syllabus related to all the available criteria across all units. The design does not allow candidates to compensate for weak coursework by doing well in the exam only. They must complete the coursework to a satisfactory standard at the level to be eligible to take the examination. A weak examination performance will limit the attainment to a pass and could prevent the award of any grade at all. It is likely that candidates with a satisfactory coursework performance will at least pass at the level but that is not inevitable and they must take the exam to pass. The exam then provides an additional very low cost dimension to external moderation/verification feedback for the coursework. Centres with a high proportion of candidates judged to be satisfactory on coursework yet failing to gain sufficient marks in the examination flag up a need for further investigation and will help prioritise CPD.

Summary of the rationale

2.6 The assessment is specifically designed to motivate learning that will support the highest grade(s) attainable by each candidate but also broader aspects of learning that can not be assessed in a traditional exam. Learners must demonstrate that they can achieve at least 16 credits before being eligible for the examination with both coursework and exam covering the entire subject content.

There is considerable flexibility to enable contexts of individual interest to be explored in depth. Those that have completed the coursework in areas of personal interest and to a high standard are far less likely to fail to achieve at least the minimum standards set in the examination. This ensures basic practical competence in realistic and motivating scenarios as well as at least some general knowledge and understanding in the more academic sense.

Aggregation of marks

2.7 Level 2 candidates will gain 30 marks from providing coursework evidence that meets the Level 2 assessment criteria as determined by their assessor with independent moderation/verification samples. They are then eligible to take the examination which provides a further potential 70 marks.. In this way those candidates that are more suited to academic work will be differentiated from those more likely to benefit from further practically based study at Level 2 or Level 3. The examination questions get progressively more difficult and those achieving the highest marks will be those most likely to be suited to academic A level study at Level 3.

The following table illustrates the grading structure.

Course work - pass for 30 marks		
Exam Score	20	Total = 50 marks - C
	30	Total = 60 marks - B
	40	Total = 70 marks - A
	50 +	Total = 80+ marks - A*

2.8 Any candidate that completes the coursework to a satisfactory standard at Level 2 but fails to gain sufficient marks in the examination can take the Level 1 examination if they have not already been awarded the Level 1 certificate. We expect this situation to be relatively rare but from an individual's point of view it prevents them doing 2 years' work and coming away with nothing because they had a bad day in an exam or missed the exam through unavoidable personal circumstances.

2.9 An optional subscription model that covers all these qualifications means that schools can enter as many candidates as they believe can meet the criteria and there are no hidden costs such as late entry fees, double entries or replacement certificate fees. This maximizes the opportunities for learners to get their achievements recognized without the school worrying about financial penalties.

3. Qualification Content

3.1 The qualification is referenced to the European Qualifications Framework (EQF), the largest system for referencing nationally accredited qualifications in the world. Unit credit is designed to be compatible with the European international credit transfer system ECVET. The units were designed by TLM in collaboration with teachers currently working in the classroom, industry consultants, professional bodies and universities. In order to provide learners with the skills needed by all sector employers, extensive consultation with business leaders has taken place. This specification is a distillation of this extensive market research specifically geared to supporting learning in schools. There is an emphasis on developing the transferable knowledge, skills and competences that will support raised attainment in the core subjects of the curriculum as well as providing the grounding needed for future hi-tech manufacturing industry professionals.

There are references to science and mathematics especially in terms of energy efficiency and sustainability, dynamics, mechanics and measurement, computer numeric control. Specialist vocabulary with words such as sustainability, life cycle, user interface, product performance, Smart embedded electronics, energy efficiency, digital fabrication, visual and functional prototypes, critical paths, will help support technical English at a level beyond that of most adults.

Key subject aims

3.2 The overarching aim is to enable learners to develop knowledge skills and capabilities that underpin applying digital technologies to create "intelligent" physical products, using modern processes designed to exploit agile manufacturing technologies, and capabilities employed via the internet or via Smart electronic devices.

3.3 A principal focus is on industrially produced Smart consumer devices incorporating user and environmentally responsive, customised products and systems.

Subordinate aims include:

- acquisition of technical understanding, knowledge and skills that are not provided in the mainstream academic curriculum.
- developing the skills that underpin employability across a wide range of sectors
- gaining practical experience and competence with contemporary product and systems design, rapid prototyping and manufacturing technologies including 3D printing
- gaining practical experience and competence by applying 'Smart' technology to transform passive products to active products, and active products to connected products
- developing practical skills in creativity and problem solving in the context of creating solutions to project briefs
- developing practical skills in problem analysis, and making real things work developing the skills to collaboratively develop product concepts through to functional prototypes
- develop practical skills applying additive and direct design to product manufacturing technology knowledge in the field of critical evaluation, feedback and iterative design.

Knowledge and understanding

3.4 The following knowledge and understanding will be required to underpin the desired learning outcomes for each qualification. At each level the understanding needed is in keeping with the general description of the qualification level.

Demonstrate knowledge and understanding associated with product and system design development and advanced manufacture terms: Product life cycle, project planning, visual prototype, functional, aesthetic and pre-production prototypes, 2D, 3D, embedded electronics, rapid prototyping, 3D printing, additive manufacture, computer aided design, fit and clearance, tolerance, sketch design and modelling, user interface, environment sensing, sustainability, mind maps, project plans, design for manufacture (DFM), user testing and evaluation, ergonomics and anthropometrics.

Demonstrate mathematical knowledge associated with quantitative methods, programming, simple statistics, algebra, geometry, Cartesian coordinates, 2D and 3D, rotation axis and planes, perspectives, computer numeric control.

Demonstrate scientific knowledge associated with physical properties of atoms and electrons, voltage and electricity, magnets and electromagnets and applications in motors and relays, material science and basic mechanical properties of materials such as stress, breaking point, fatigue, bending, elasticity and using them within product application.

Demonstrate knowledge and understanding associated with the information and data terms: Data, information, file type, file properties, compatibility, export, import, conversion, units, scale, visualisation, render, computer aided design, computer aided manufacture, digital modelling, physical modelling, measurements, standards, input output, analogue, digital, logic, controller, software, program, transducer, sensor.

Deal with unfamiliar contexts drawing on learning and information provided.
3.5 Opportunities are provided to support the following skills, the great majority of which will be assessed directly in coursework in valid contexts. Projects expose and develop skills to work with design and advanced manufacturing processes, iteration and development, in order to give a practical taste of the skills and competencies that underpin a range of careers and industries related to contemporary manufacture.

These include numeracy, literacy, engineering, design, creative arts, science and embedded software development. Further by focusing on practical applications of technology, we complement some of the more academic subjects by demonstrating the application of theory in realistic context driven projects. Through a range of design processes and prototypes, learners will design a range of items to help find solutions for user defined problems locally, nationally, and internationally. Solutions address issues of energy consumption, food and materials scarcity, social and online connectedness in an internet age. Sustainability is an embedded theme. A range of appropriate tasks follow the journey of the product including:

- analyse and interpret product design briefs
- gather information and research to support design briefs
- research and develop creative product concepts
- use CAD visualization to communicate exterior product concepts
- use CAD to carry out digital simulation such as FEA, technical feasibility, and initial review against brief
- use CAD to develop 3D Models suitable for production using additive manufacturing technology
- use and integrate smart-electronic modules to create functional prototypes
- analyse product life cycle including strategies to reduce carbon footprint, whether through the function of the product itself or through minimising waste from the products manufacture process.
- study of interdisciplinary teams.

Unit contents

3.6 The content of units is in Annexe C below with guidance in interpreting the criteria. These are available in more detail on the TLM community learning site and will be linked to progressively more free and open supporting resources and guidance as these become available.

3.7 All centres have an assigned Account Manager who will be very pleased to help at any time. Our aim is to give professional assessors, most of whom are qualified teachers, the confidence to make judgements with a minimum of bureaucracy so that they can focus their time on maintaining their professional knowledge and skills and support learning through effective teaching rather than “chasing paper”.

3.8 There is often a confusion between bureaucracy and rigour, since unnecessarily complex bureaucracy can actually detract from rigour by obscuring the importance of the outcomes in unnecessary process. We also encourage coursework to be carried out in valid and real contexts rather than as contrived simulations. Competence is best assessed in context. All assessors must sign an agreement to uphold standards and feedback from moderation/verification will support consistency.

3.9 Websites - TLM provides support through a cloud based system for evidence management linked to grading and certification. Providing assessment grades and the management of certification through the Awards Site is mandatory and all assessors are provided with training in its use. It is simply a matter of recording learner competence against the unit criteria as the evidence is collected and claiming a certificate on behalf of the learner when a unit has been fully assessed. All assessors must sign an agreement to uphold standards before they can use this site.

3.10 The use of the community learning site is optional at no additional cost. It provides facilities for learners to submit their evidence online, linking it to the assessment criteria across single or multiple units. The assessor can accept or reject this evidence and comment on it providing a full audit trail for evidence. Moderator/verifiers can get immediate access to this evidence and so it is potentially a lot more efficient than alternative methods. No paper, no emails with file attachments are necessary. There are facilities for progress tracking that can be based on criteria and/or units and reports that can be shared securely online with parents. The system can be linked as an extension to any standards compliant VLE/e-portfolio system for centres that are already committed to a specific VLE product. Training can be provided and free support is available from your Account Manager. The aim is to eliminate all paper based bureaucracy, all screen shots and referencing that draws time away from teaching. As far as possible we want assessment of real tasks in real contexts that are truly representative of a real working environment. This is a fundamental goal for the competence based assessment at the heart of the European Vocational Education and Training policy (ECVET). It is the way in which most employers will judge the effectiveness of individuals in their tasks at work.

3.11 Telephone and email support is available to all Centres. There is a general convention of firstname.secondname@tlm.org.uk for email addresses. It is usually best to email your account manager in the first instance. Google hangouts can be arranged for video conferencing support.

4. Assessment including e-assessment

Assessment summary

Coursework

4.1 Evidence has to be provided against the unit assessment criteria from practical tasks related to the learners' everyday work. This is likely to be from specialist lessons related to Design Technology but can and should include evidence from across the curriculum, for example from maths, science, computing or the creative arts. The way evidence is gathered is up to the assessor, the only requirement is that it clearly supports the judgements against the assessment criteria and the relevant learning outcomes and reflects the learner's personal competence. If on moderation the account manager finds gaps in evidence related to a particular candidate they will request more evidence before approving the award of the unit certificate. Assessors must then adjust their work to ensure all their learners are providing the appropriate level and breadth of evidence. **We encourage early submission of at least some evidence so that assessors are confident from the feedback that what they are providing is sufficient (and indeed not overkill). In this way we can maintain standards while supporting improved efficiency.**

4.2 Synoptic assessment has become a popular term. In essence all the coursework assessment is synoptic in that the evidence provided is against collectively synoptic assessment criteria underpinning the learning outcomes for the unit and mostly assessed in the context of holistic projects. Synoptic evidence of competence to a minimum value of 16 credits across the units is mandatory for both the level 1 and level 2 certificates This equates to a minimum of 160 guided learning hours.

4.3 At level 2, there are 4 units of 4 credits each. The 4 credit units each require 40 GLH (40 TQT) giving a total of 16 credits and 160 GLH (160

TQT). Dividing into a unit structure is for convenience and compatibility with international conventions for referencing national qualifications frameworks and to enable credit transfer e.g. as in the European system ECVET. It is NOT intended to determine the method of delivery. Teachers are free to cover units concurrently deciding where the elements are logically related. We encourage the use of the flexibility provided to target particular interests of learners to motivate them in persevering in difficult areas and to raise the level of expectation in cognitive development.

4.4 At Level 2, the central project within the curriculum is the design and construction of a range of items following industry standard commercial practices, which include the use of Computer Aided Design and Rapid Prototyping techniques using industry standard software or kits. This provides young learners with direct and motivating experience of the tools and skills that are in high demand in a wide range of careers not only in manufacturing industries, but also in many allied and supporting occupations. These skills are of wider use in what will become home manufacturing as advanced manufacturing devices falls in cost to a level where the equipment can be bought by DIY practitioners.

4.5 There is an obvious progression from Level 1 to Level 2 with learners gaining increasing capacity to tackle academic style questions requiring explanations and more detailed understanding and insight. Level 2 coursework requires increasing self-sufficiency. The outcomes for individuals in terms of the broad level descriptors allied to the assessment criteria, verified by the teacher/assessor and externally moderated by TLM will determine the final outcome. Grouping learners is up to the school but the design enables maximum flexibility. Some students can achieve Level 1 first for example in Year 8 and 9 and then progress to Level 2 units in Year 10 and finally to a Level 2 grade through the exam and academic revision. Others might be split into Level 1 and Level 2 in Year 10 and work over two years to the particular level with level 1 learners progressing to Level 2 post-16 e.g. through a related SVQ.

Progression and inclusion

4.6 There are some fundamental misunderstandings of unit based assessment with regards to progression and inclusion. The paragraphs below will explain how criticisms related to these issues can be rejected. Having higher levels of professional expectation and improved and lower cost CPD strategies is better than “dumbing down” to less professional approaches.

4.7 Open Systems and Advanced Manufacturing Technologies is a unique project based learning programme that introduces innovation and advanced manufacturing industry skills to students using an industry recognised progression route. We consider that students who achieve a Level 1 qualification in this qualification or something like the Level 1 Smart Product Design and Manufacture or Design Engineer Construct, will have improved their numeracy skills through applied mathematics embedded throughout the programme and will benefit through improved literacy as well as through other employability and design skills. For those schools interested in using Open Systems and Advanced Manufacturing Technologies in Key Stage 3, students progressing through similar Level 1 qualifications will receive a qualification recognised by government and endorsed by industry that prepares them for Level 2 achievement enhancing motivation through reward. Students, having enjoyed, completed and succeeded at Level 1 by the age of 14 years will be more likely to be successful at Level 2 and with higher grades. This provides an improved strategy for increasing the numbers getting the higher A*-C (9-5) GCSE equivalent grades by the age of 16, providing a much better basis for progression to Level 3.

4.8 Open Systems and Advanced Manufacturing Technologies offers an interesting and broad education experience in its own right and links to career progression in the engineering, design, creative arts, embedded software development and technology industries, enabling students to see the links between them. There are growing career opportunities focused on innovative product development that require a maintenance of curiosity and affinity with change. The provision at Level 1 and Level 2 underpins progression to Level 3 and the Level 3 qualification will have many of the characteristics of undergraduate study supporting better capacity to cope in degree courses.

4.9 It is very unlikely that any learner embarking on a TLM qualification based on these methods will not achieve at least some kind of recognition for their work at a level appropriate to their current attainment level with a progression route from where they end up to higher levels. Clearly some will take longer than others. This inclusion is achieved without sacrificing rigour for the highest attainers since the questions in the examination targeting the A/A* grades can be as difficult as necessary without risking weaker candidates dropping out of a grade altogether. Indeed able students can start Level 3 work in KS4 differentiated by outcome where appropriate. Currently there is a good argument that candidates achieving A* and A grades across all their subjects are not being adequately stretched in KS4.

4.10 Beyond Level 2 it will be possible for work supporting Level 2 units to be converted to Level 3 by candidates if they provide evidence that is clearly at the higher level. For the highest attainers this provides an accelerated route to Level 3 so that they are not just marking time at the end of KS4. This is where current systems fail the highest level attainers. Some individuals can cope with university level work in KS4, not many but these individuals matter just as much as those with learning disabilities and so we need systems flexible enough to cope with them.

4.11 Coursework, particularly at Level 2 should reflect useful and meaningful activities with practical activities useful to other people and the wider community as well as the candidates themselves. Examples might be to program their own robot or build an unmanned vehicle to monitor a local wildlife environment. We want to encourage work that reflects contemporary society using industrial tools and technologies that enable

ALL individuals to contribute not only those that can afford to. Projects lend themselves to cross-curricular work supporting raising attainment in other subjects, numeracy, literacy, science and information skills but also aesthetic subjects such as art and design. For many learners it is more motivating to learn through creating original work (or original remixes of other people's work) that has a real and practical purpose than to do simulations or theoretical exercises. This is a fundamental part of TLM's coursework philosophy and founded in research evidence.

5. Criticisms of coursework answered

Criticism 1: Coursework is too susceptible to plagiarism and other forms of dishonesty.

5.1 A Google search will have a high chance of finding any extended text that has been copied from an online source. If we are genuinely concerned about “copying from the internet” simply inform teachers of how to combat the issue using freely available tools. Require teachers to accept professional responsibility for the authenticity of their learners’ evidence. If teachers really want to cheat why would they not simply tell students the answers to an exam? If learners want to cheat why not simply forge a convincing looking certificate? There is no tradition of easy certificate authentication so there is a high probability that forgery will be successful. A complementary examination means that we can check back to see if individual teachers are “passing” student coursework for a disproportionately high number that then fail the examination. That provides an evidence source to cross-reference the quality assurance in order to better target staff development.

Work smarter not harder!

Criticism 2: Unit based assessment means that knowledge is in Compartments.

5.2 Unit structures are for administrative convenience NOT teaching plans. There is nothing to stop elements of several units being supported through one or more projects concurrently. Most academic syllabuses are divided up into sections. That is no different in practice to labelling the sections units. There is no requirement to assess units at a particular time. If most evidence is provided at the end of the course across all units why is that any different from a controlled synoptic terminal examination? If teachers do not teach unit based courses effectively, train the teachers, don’t blame the tools. If we are really worried about compartmentalised knowledge why preserve a subject based curriculum?

Criticism 3: Unit based assessment does not support progression.

5.3 On the contrary, the scope of unit based qualifications organised in a levelled framework provides a better support for progression when the unit content and structure is designed for that purpose. Where qualifications are opportunistically designed to simply target one level in a terminal examination that is only representative of a subset of the learning, there is a good argument that progression is badly supported but that is true of any qualification whether unit based or not.

Criticism 4: Competence based assessment has to be lowered to
the level of the least difficult assessment criterion.

5.4 In well designed assessment units the assessment criteria are contextualised to the general level specified in the overall level descriptors. This means all assessment criteria should be interpreted in terms of that overall level descriptor, not taken on face value in isolation.
It is impossible to measure anything with absolute precision and it is scientifically bogus to claim we can, even if it is politically sensitive to admit that there will be some uncertainty in assessment outcomes when applied to individuals. This is true of both coursework based and exam based methods. The important thing is to get a reasonably consistent set of outcomes within the expected degrees of uncertainty. The competence based component of these qualifications is intended to provide a baseline consistent with the general level descriptor and to motivate beyond basic competence by providing the flexibility to pursue contextual interests of individuals. Grading is achieved by a terminal examination. This means we can match the assessment method to the aspect of attainment such that we cover all aspects of learning but we also provided reliable differentiation that can accurately inform progression routes for individuals as well as motivate all, not just those that are good at exams.

Criticism 5: Exams have always been the tried and trusted way of assessing attainment. There is no need for anything else.

5.5 Written examinations have been widely used for academic assessments in schools and universities. However, that is largely due to their academic heritage where theory is often more important than practice. Even so, coursework is well-established where there are practical elements eg in science and medicine. Few jobs assess prospective candidates exclusively using written exams. In most practical areas from brain surgery to teaching, no-one would trust a written examination on its own to prove competence. That is not to say such examinations are not of value. The key is to use coursework and examinations intelligently together in order to provide something that is better than either treated in isolation. Ideological arguments of one method of assessment to the exclusion of another are simply political rather than rational.

6. The Examinations

6.1 Examinations at Level 2 are primarily for grading. They are externally set and externally marked. The details of the way grades relate to marks are provided above in section 2. The examinations also provide a cross-reference in order to increase confidence in the validity of the coursework component.

Weightings

6.2 There are two classes of objectives. AO1, AO2, AO3 are generic assessment objectives:

> AO1 – Recall, select and communicate knowledge and understanding.
> AO2 – Apply knowledge and understanding through analysis, reasoned judgements and drawing conclusions.
> AO3 – Demonstrate practical and technical skills related to applying skills knowledge and understanding in context.

6.3 Additionally, the qualification units each specify subject specific learning outcomes. The qualification design draws on both classes of objective to ensure balanced representation and that the assessment is a valid representation of what has been learnt.

6.4 The assessment objectives provided by the unit learning outcomes are evenly weighted in the coursework element since all must be achieved in order to pass.

6.5 The synoptic examination is directly related to the unit learning outcomes and assessment criteria underpinned by the content definitions in section 3 and the guidance in the unit descriptions. This is designed to be broadly representative of the knowledge and understanding associated with the learning outcomes, testable in a synoptic terminal controlled examination related to the learning outcomes. This enables grading the qualification to inform progression to higher levels whereas the coursework ensures that there is basic competence in their practical implementation in real and relevant contexts.

6.6 At Level 2 the assessment objectives will have the following weightings

Level 2	A01	A02	A03
Exam	40%	40%	20%
Coursework	20%	20%	60%

6.7 The Grade A* candidate must produce more evidence of analytical skills and show why they are applying their knowledge under examination conditions and is likely to be better suited to the more theoretical approach of future academic study whereas the Grade C candidate is likely to find it difficult to cope with courses highly dependent on academic testing and is probably better suited to a more practical approach.

Learner entry and costs

6.8 The TLM subscription model enables schools to enter learners at times convenient to them. There are no late entry fees and no additional fees should a learner fail to produce evidence at a particular level but can meet the criteria at a lower level. This can reduce costs to the school by more than 50% when compared to GCSEs and teacher time is taken into account, significantly more than this when compared to some GCSE alternatives. Examination entry will depend on whether or not learners meet the coursework criteria. This again saves money because the school is not paying for examination administration for learners that are unlikely to be successful or for whom there is little or no benefit in taking an exam.

There are no fees for replacement certificates or verification of certificates because all certificates can be directly authenticated against a secure database. For details of current subscription costs please contact us or refer to the web site.

Online examination and e-assessment

6.9 The examinations can be delivered in a traditional paper based format or online. There is a surcharge for paper based examining reflecting the extra cost involved. The online versions have a secure web user interface and require no software installation. They can run through any standards compliant web browser on any type of computer.

The user is restricted to an area in the centre of the screen during the examination and has no access to the internet, or any other storage device without moving the mouse pointer out of the secure area and this will set off a warning. Persistence will result in disqualification from the examination. Since the Level 2 online exam contains open-ended questions it has to be physically marked and so the results will not be immediately available but we will aim to have these ready within 2 weeks of taking the exam. For those taking the examinations in the traditional paper based format it is likely to take 4 weeks to finalise results.

6.10 TLM provides optional on-line tools for managing coursework evidence through the community learning site at www.tlm.org.uk
This is a free service because it will reduce time and hence costs for both the Awarding Organisation and the Centre. To optimise efficiency, self and peer assessment validated by the assessor are supported. Not all centres are ready for this and it is therefore not a mandatory requirement.

6.11 It is mandatory for all assessors to record grades in the online mark book. This is because to access the Markbook all assessors have to sign an agreement to uphold standards and so any grade recorded by an

assessor is effectively subject to that agreement. All grades must be recorded and in place before and award can be requested.
Once an award is requested evidence samples will be sought. If the Centre uses the on-line evidence management system, Markbook grades are transferred automatically and the account manager has immediate access to all the evidence and any assessor learner dialogue associated with the award. This is clearly more efficient and it is what we are working towards for all centres. We always welcome feedback so we can continue to improve the systems to reduce the bureaucratic overhead and support better formative as well as summative assessment as a strategy for raising standards.

Examinations

6.12 The exam will be available by giving 6 weeks notice or more and paying the exam fee at least 1 week prior to the exam being sat. It is the Centre’s Examination Officer’s responsibility in line with the agreement signed with TLM to ensure that security is maintained for the examination. No candidate should have prior access to the questions in an examination paper either directly or indirectly, before they sit the paper. We will have several versions of the examination available and if there is any suspicion of compromise of security, the Principal Assessor should contact TLM to work out a solution. Assuming there is no malpractice, it might simply be a matter of scheduling an alternative paper. Papers will be planned to be of similar difficulty. Candidates can retake an examination once if they have not claimed a qualification based on a previous result. Once the result is finalised they must wait 6 months before re sitting the entire qualification. In order to gauge readiness for the examination the centre can request a “mock” examination. This will be conducted identically to the real thing and will cost the same amount. It will just not count in the qualification. Mocks should be requested in the same way as the real exam.

Internal standardisation of coursework

6.13 The Principal Assessor has the ultimate responsibility for consistency in assessment standards within a centre and has signed an agreement to that effect. All assessors have signed a contract agreeing to uphold standards and should therefore co-operate with the Principal Assessor and Account Manager at TLM to ensure that standards across the centre are consistent. It is advisable to send work samples to TLM early to check that evidence is at the right standard so that there is time to make any adjustments necessary to the course and learner expectations. TLM will generally check a higher quantity of work from new assessors and feedback to ensure that they are confident to make appropriate judgements over time. This reduces risk and improves efficiency in the longer term.

Authentication

6.14 All assessors must take reasonable steps to ensure that any coursework evidence submitted by candidates is a true reflection of the candidate's' competence. This is in keeping with the assessor undertaking to uphold and maintain standards in the contract with TLM.

6.15 Certificates can be authenticated directly online using the certificate number or by scanning the QR code on the certificate. There is no charge and it makes it more likely that certificates will be checked and that in turn improves security. Certificate forgeries are a significant problem when authentication is not simple and straightforward because convincing forgeries are easy to achieve with recent technologies and will get easier as time goes on.

7. Other considerations

Access arrangements and special requirements

7.1 All TLM's qualifications are intended to be accessible, as widely as possible. There is an extensive policy documented on the web site at https://theingots.org/community/RQF G6

The Ofqual guidelines are here:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/529394/general-conditions-of-recognition-june-2016.pdf
Page 67

Centres should contact TLM if they have any questions related to accessibility issues.

Language

7.2 The language for provision of this qualification is English only. This will only change if we have a significant demand in another language that is sufficient to cover the additional costs involved and some cultural alterations will be needed. TLM will actively support any work in this line that can be shown to cover costs.

Malpractice

7.3 TLM has comprehensive policies and procedures for dealing with malpractice. These are documented with links on the web site at https://theingots.org/community/RQF A8 Assessors should be familiar with these policies and make them clear to candidates.

The Ofqual guidelines are here:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/529394/general-conditions-of-recognition-june-2016.pdf
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Assessors should inform their account manager if they suspect any instance of malpractice that could have a material effect on the outcome of any assessments, either for themselves or colleagues. This is part of the upholding of standards that is part of the contract with TLM.

Equality of opportunity

7.4 TLM promotes equality of opportunity through policies and procedures. These are again documented in detail on the web site at https://theingots.org/community/RQF D2

The Ofqual guidelines are here:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/529394/general-conditions-of-recognition-june-2016.pdf
Page 35.

8. Resources, support and training

8.1 A clear goal of these qualifications is to enable learners to support their own learning and to reduce dependency in order to become “lifelong learners”. The IT revolution makes this progressively easier. As far as possible we encourage the use of technology and up to date methods, especially those based on empirical evidence.

8.2 TLM encourages the use of free and open source applications to reduce costs and to further inclusion. Many of the key software applications needed to support the assessed units are available freely from a range of open source platforms. Even though it is not Open Source, Sketchup, a free package offered by Google, is one of the world’s most popular design software applications and can be used without charge. It has capability ranging from beginner to professional, including 3D modelling, visualisation and export to manufacture functionality.

8.3 Integrated aspects of the Open Systems and Advanced Manufacturing Technologies programme ensure that teachers and learners receive a fully supported, expertly enhanced, stimulating and challenging learning experience. It is anticipated that teachers will soon grow in confidence, develop their own networks of industry based support and be able to develop new projects of their own – ones that may be unique to their local context or that offer specific targeted challenges. If this acts as a catalyst for better teaching associated with assessment for learning methods, it is likely that the effects on staff development and better use of technologies to support learning will go far beyond the product design sector.

8.4 The curriculum introduces new areas of learning that include close engagement with the world of work and academia. Teachers and learners alike will find it rewarding, challenging and exciting – a combination that guarantees successful outcomes and a learning environment that is happy, productive and fun.

8.5 Open Systems and Advanced Manufacturing Technologies qualifications are designed to support learning that enables progression to Further Education, Higher Education and employment for a wider range of young people. They also provide a focus for low cost and sustainable staff development that can keep teachers up to date with the technologies that can enhance the capacity for learners to gain the competencies required to make them employable as well as academically knowledgeable.

9. Grade Descriptions

At Level 2 **grade A** candidate will exhibit most the following characteristics.

9.1 Candidates demonstrate a high level of independence in using their knowledge and understanding to support activities beneficial to themselves and others in everyday contexts. They recall, select and communicate a thorough knowledge and understanding of the general competences needed to support lifelong learning and personal well-being.

9.2 They apply knowledge, understanding and skills to a variety of situations, selecting and using knowledge and information efficiently to solve problems and produce effective support for their own learning as well as the needs of others. They relate these to comparable activities in the world of work. They manipulate and process data efficiently and effectively based on objective criteria. They interpret information and transfer knowledge and understanding from familiar to unfamiliar contexts. They work creatively exploring and developing ideas. They adopt systematic approaches to safety, promoting secure and responsible practices.

9.3 They use scientific methods to analyse problems such as control of variables and observations to identify needs and opportunities. They set hypotheses in relevant contexts and critically analyse and evaluate the knowledge they gain. They review their own work and that of others making supportive and constructive criticism where appropriate. They communicate effectively, demonstrating a clear sense of purpose and audience.

A **grade C** candidate will exhibit most of the following characteristics

9.4 Candidates demonstrate the ability to select and use relevant knowledge, ideas, skills and procedures to complete well-defined tasks and address straightforward problems.

They take responsibility for completing tasks and procedures and exercising autonomy and judgement subject to overall direction or guidance.

9.5 They use understanding of facts, procedures and ideas to complete well defined tasks and address straightforward problems in supporting their learning. They interpret information and ideas related to the social and commercial impact of their actions, showing awareness of the types of information that are relevant to their areas of study. They identify, gather and use relevant information to inform their actions and make judgements about how effective their actions have been.

9.6 They work safely and securely, identifying key risks, taking reasonable actions to avoid them. They collaborate in reviewing their work evaluating the way they and others use their construction knowledge and skills and they take positive actions to improve. They use standard English and IT to communicate effectively, demonstrating some consideration of purpose and audience.

Annexe A - Example examination Level 2

The following principles will apply to the design and structure of each exam.

Questions will vary in the general area of the required learning outcomes specified in the units and cover all the assessment criteria in the approximate proportions presented in this document. Questions will reflect a balance of the content listed and explained in the guidance in keeping with Level 2 as defined by the EQF global level descriptors.

Questions

1. Which of the following heights above ground would be considered a Low Earth Orbit

a) 16,000 metres
b) 1,600 metres
c) 26,000 metres
d) 160 metres

(b) 3.5

Low Earth Orbit (LEO) is between 800 and 2,000metres above the ground.

2. Which of the following would NOT be a design consideration for a UAV?

a) Potential operational height
b) Safe speed
c) Height of operator
d) Legal restrictions

(c) 2.4

The height of the operator is not really important in the design, though the control functions of the control console or device would be.

3. Which of the following would be a cost saving consideration when designing a new robot?

a) Extensive use of rare earth metals
b) Construction with newly developed polymers
c) Employing leading programmers in the field
d) Using open source software such as ROS

(d) 4.2

Robot Operating System (ROS) is a free, community supported and developed operating system designed specifically for robots.

4. Which of the following is not a recognised microsatellite form?

a) Kilosatellie
b) Picosatellite
c) Nanosatellite
d) Femtosatellite

(a) 1.4

5. What temperature does liquid oxygen burn at when used in rockets?

a) 100°C
b) 300°C
c) 1,000°C
d) 3,000°C

(d) 2.2

6. What metal powder is now used in rocket launch fuel because it is very reactive with oxygen?

a) Lead
b) Aluminium

c) Magnesium
d) Neptunium

(b) 3.3

Aluminium is used in Aluminium-ice or ALICE.

7. Which of the following statements is one of the laws of robotics devised by science fiction writer Isaac Asimov?

a) A robot may not injure a human being or, through inaction,allow a human being to come to harm
b) A robot may not work as a television presenter on news programs because of the serious nature of news
c) A robot may never stand as the President of the United States of America
d) A robot must not be allowed to feel pain as it will then be too human like

(a) 1.5

8. Most UV devices are constructed with a material called FRP. This stands for:

a) Freon Regulated Plastic
b) Fibre Reinforced Plastic
c) Fibre Reinforced Polymer
d) Fully Redundant Polymer

(b) (2.3)

9. The radio frequencies most suitable for communication with microsatellites are?

a) 3Hz to 30Hz
b) 300MHz to 30GHz
c) 30GHz to 3THz
d) 30MHz to 30GHz

(d) 4.2

10. Which of the following is a reason for UAV's propellers to be based on a KV of 500-1,000?

a) Save battery power
b) Kill less insects in the blades
c) More flight stability
d) Make less noise in sensitive areas

(c) 3.3

11. An engineer wants to create a large complicated 3D model of a rocket to test some ideas. Explain how he might design the model so he can try out his ideas and make changes efficiently.
(1 mark)

3.1 Some idea of using a 3D modelling software that allows for different views and easy changes.

12. Materials used for most of the devices in this qualification are required to be both light and strong. Give two clear reasons, with examples, why you think this is the case.
(2 marks)

Candidates should appreciate that "most" devices here, other than robots, require the ability to fly and that flight is difficult due to various forces, especially gravity. If a material is light, it will require less energy to move. (1) However, it will be subject to heat and distortion from various forces such as pressure, so it also needs to be strong to withstand these forces (1). Something similar to these examples will suffice.

13. Many companies now sell software packages to schools that use an artificial intelligence based on learning methods to schools, particularly in teaching subjects like maths. These systems fine tune

themselves to give each students their own detailed learning programme.

Briefly describe two advantages and one disadvantage of this type of AI system.
(3 marks)
1.5 Candidates should be able to apply their own knowledge of AI to this particular example. They should be able to show that they understand the advantage to AI is it is constantly working to improve itself and will analyse all aspects of a student's learning to make sure it gives more examples to areas where the student's learning is weaker (1). Another advantage is that it is not personally involved so will only positively reinforce the students and not tell them off, which could be negative in its impact (1). A possible disadvantage is linked to the previous point as the AI will not know the student personally so may not help them learn effectively so that when they take an exam they might fail as they work the way the machine has trained them, rather than answering the questions. (1) Any similar example that shows the lack of human touch in this process. Someone who is excellent at a computer flying game could not step into the cockpit of a real plane and fly it easily.

14. A UAV manufacturer is building a UAV and looking for excellent flight stability. They have an input motor running at 6.75 volts and the motor is rated at 850KV. What will be the resulting rpm of the motor?
(1 mark)

3.3 The formula is V x KV, so the answer would be 6.75V x 850rpm/V or 5,737.50rpm

15. Briefly discuss two things that affect microsatellites while in space and what adjustments need to be made to lessen their impact.
(2 marks)
4.2 There are 3 main things listed in the specification: atmosphere, solar power and debris. Candidates need to pick two of these and give clear

examples of what can be done. For example: the drag of the atmosphere means the satellite gets pulled closer to earth, so thrusters need to be fired a few times a year to keep it at the right distance (1). Lots of space junk is flying about in the atmosphere in LEO, so the satellite needs to be moved, if possible, to avoid these objects. (1)

16. It is estimated that there are currently 500,000 pieces of space debris in the lower levels of the Earth's atmosphere. Describe two potential problems with this material.

(2 marks)

3.6 The main problem with this debris is damage to existing devices that are still in use. (1). The International Space Station has lots of small holes in its solar panels from debris smashing into it and the control centre needs to move it frequently from larger objects. The other problem is that some of this may well come back to earth and can be very destructive if it survives burning up in the atmosphere. (1). Something similar as long as it is clearly explained.

17. A UAV has a single propeller with a rotational speed of 1,500rpm. It has a battery with enough power to fly for 2.5 hours. How many revolutions will the propeller make with the life of the battery before it runs out? Show your working or reason.

(2 marks)

3.3 Candidates should be able to do some basic mathematics. The answer here is essential 1,500 X 60 (revs per minute, per hour) X 2.5, so 225,000 revolutions. 1 mark for an idea of working it out, 1 for the answer.

18. If your school decided that it wants to launch large rockets using combustible fuel material, what sort of license would the teacher in charge of launches require and why?

(2 marks)

3.4 Large rockets tend to use materials similar to the high explosives used in large public fireworks, at least in terms of danger (1), so the person in charge would need to have a license to handle explosives (1). Candidates should give a clear reason of what licenses is required and why. It is not specific to the question, but they could get 1 mark for discussing health and safety.

19. Why are many robots built using open source software? (1 mark)

3.2 Open source allows the creators of the robots more flexibility to design their own features and actions and not be restricted by the features built in to a proprietary software that can't be altered.

20. If a school was able to launch and control it's own microsatellite with an onboard camera and was able to ensure that it was pointing at the school for most of the day, what subjects in school could use the data available and for what purpose?
(2 marks)
The geography students could use the images to track changes in the flora and fauna at the school over the course of the school year (1). They could also use it for a detailed map to add to the school website for parents (1). Other subjects could be for art, to use for collages or for photography to practice modifying the images with digital software. The data could also be used by science to look for environmental changes over the seasons, or maths to collect data about pupil/staff movements to generate statistics.

21. In a recent experiment, seeds were sent to the International Space Station to be grown and others returned to earth for primary school students to plant and monitor. What is the purpose of this type of experiment?
(2 marks)
4.1 Many people see the exploration and colonisation of space as important for the future of people. If the world becomes too hot or polluted, we need to be able to move on. Growing seeds in space is to see whether or not they will be affected by the forces in space and so see if we can grow what we need to eat (1). Sending seeds back to earth after being in space is to

check if that impacts on them, should we need to send material back from space once grown on other planets (1). o.e

22. Give an example of a privacy concern relating to UAV and how it can be minimised.
(3 marks)

4.1 No real right or wrong here, but candidates need to show an awareness of the issue. They need to say that people can be photographed from great heights without their knowledge (1). They can give a reason for this in that cameras now have very high resolution, even though very small (1). Some idea of a solution, perhaps a law to license people who own these devices and regular police checks of their data collected (1).

23. Most microsatellites are used for GPS. What does this stand for?
(1 mark)
3.5 and others Global Positioning System

24. AI is now being used in almost every area of work and is replacing people at different levels. AI has been proven to be better at driving cars with less accidents, making money for investors, teaching people and even flying planes. Discuss, with some examples, some of the ethical and social concerns you have with this progress of AI.
(5 marks)
1.5/2.5 There is not necessarily a correct answer here as it will depend what each centre has taught for this topic. Candidates will be given marks for showing that they understand some ethical issue. For example, if they were planning to train to be an investment manager or even a lawyer, they may well not have a job once they are trained (1-2 marks). They need to show that they appreciate the ethical and social impacts, so society will be getting less "human" (1), if the AI devices can do people's work better, what will people do to live (1). 1 mark can be given for clarity and overall writing

if candidates can show a good understanding and can get their argument across clearly. This is an A/A* level question.

25. A company in Japan called Softbank manufactures a robot called Pepper that has been programmed to react like a human to emotions. It has a range of human type emotions and will respond by laughing and crying to inputs.

Identify and discuss three possible problems with this type of device related to the way it works with human emotions.
(6 marks)

1.6 This is a question to allow candidates to explore their ideas and there may not be explicitly right and wrong answers and markers will need to use their professional judgement. Some examples of answers that it is hard to make judgements on what an emotion should be (1), someone might laugh at something that others find offensive (1). They could talk about the danger of over attachment (1). If the device is used by people with emotional issues they may become too attached which could cause problems if the device does not act as expected (1). Related to this, they could discuss the wider problem of de-humanisation (1). If people rely on these machines, rather than real people, we could end up with a very poor society where people avoid each other as machines are far better (1)

26. Describe, with an example, one strength and one weakness of using 3D design software for developing a device such as a robot or microsatellite.
(4 marks)
AI 3.2 and others - candidates should show a strength in terms of their specified program (1 mark) being able to use POV (Point of View) features (1) to be able to see their design from every angle, so something similar (1). A weakness is likely to be that it is over complex as it is designed for professional use and has too many features, so perhaps has a feature to program in complex physical relationships to materials that require A level

maths understanding or similar (1). I mark each for naming the feature they are describing.

27. Many microsatellites are built using aluminium panels that employ a honeycomb sandwich structure between the plates. Explain what this is and how it helps the design.
(3 marks)
2.2 Candidates should be able to explain that this feature comes from the observation of bee hives which gives it the name of "honeycomb" (1). The hexagonal shaped tubes are placed between the two sheets add strength as they are harder to crush (1) but are significantly lighter than having a solid plate of the same thickness (1).

28. Some unmanned aerial vehicles (UAV) have been increasingly used by criminals for various illegal activities. The devices and their use are so new that there is no law currently to deal with them.

What kinds of legal actions or practices can be taken to deal with the use of UV in illegal activities?
(3 marks)
4.2 - This question is looking for candidate's ability to synthesize what they know about the laws to come up with answers. The range of possible answers will be quite wide, but should show a clear understanding of the legal aspects. They could recommend something that was used to reduce tagging in cities by checking on who is buying the equipment, forcing shops to register the details. (1). They could suggest that a new law is passed by government just for UV. (1). Other issues might be similar to a neighbourhood watch scheme so that local people police their own skies, or similar answers. (1).

29. What is the difference between data collected by microsatellites and the information that is used as a result?
(1 mark)

This is a generic question for all the units based on an understanding of the difference between data and information. The answer should be something along the lines of: data is the raw numbers collected by the device, such as temperatures in space, information is using charts and graphs from those numbers to present a diagram of the changes in temperature so that decisions can be made. (1)

30. List and describe three key safety checks that should be carried out before launching an explosives based rocket.

(3 marks)

3.3 The first real check should be that you have notified any local airports due to the potential invasion of airspace. (1) Since there is a danger of explosion, you should also have someone on hand with fire extinguishing equipment or have notified the fire services. (1). Other checks would be to have the appropriate safety equipment or experienced people with this knowledge (1). Other examples might be to check the launcher has their explosives license or to make sure there are no people nearby who are not aware. Any other suitable examples.

31. Why is it important to work to a detailed specification when assembling a robot or unmanned vehicle for usage?

(2 marks)

This is a generic question to test candidate's application of their general knowledge. The key consideration is that the specification should provide details of how and where to use the device which is useful for guidance purposes (1). It should also be a good guideline to the limitations of the device so that people using it will not endanger themselves or others by operating it outside the recommended safety limits. (1) other answers related to working within safe limits would be accepted.

32. Most devices created using advanced manufacturing technology tend to use open source software. What is open source software and how would you describe its main attributes?

(2 marks)

2.5 Open source software is created using more liberal licenses such as ShareAlike which allow people to use someone else’s code to speed up development (1). It is community based which means that it is well supported and problems get seen and fixed quickly. (1). They could also say that it is free.

Name one open source license that could be used for advanced manufacturing and describe one of its attributes.
(2 marks)
2.5 They could name a number of licenses such as Copyleft (1) and say that it can be used and modified, but has to then be shared back with the community if any improvements are made (1).
(4 marks total)

33. According to recent research, the power of AI is such that the devices and machines built using it will not only replace “low level” jobs, such as factory assembly, but also “high level” jobs such as legal advice or analysis.

Describe the impact of this type of development on the future workforce, both positively and negatively, giving examples of the impact where appropriate. Draw a conclusion using the possible impact on you personally.
(5 marks)

1.5/2.5 - The main danger with this type of future is an over-reliance on machines (1). If machines control our electricity or food, any failure of the device will lead to huge impacts on the world (1). The other main concern is social unrest (1). If these devices take away all of our jobs, what will people do to earn money to pay for the food and other services the A devices are supplying (1). Any example they can give of the impact on themselves, such as loss of career opportunities will earn a 5th mark. Any other reasonably dangers or benefits, plus an example, for the marks.

Annexe B - Level 2 Units

Level 2 Unit 1 - The Understanding and Appreciation of Rocket Science 40 TQT, 4 credits

1: Understanding the basic physical forces involved with rocket flight	**2: Applying aspects of construction and development for rockets**	**3: Building, testing and launching a rocket with further development**	**4: Investigating further applications and exploratory topics**
1.1 I can describe the physics involved in rocket flight	2.1 I can identify materials used in the construction of rockets and explain why they are useful.	3.1 I can make rough designs ,test and evaluate versions of my final rocket	4.1 I can investigate and explain the application of rockets for science and experimentation
1.2 I can identify and explain limitations on rocket flight created by physical elements	2.2 I can describe the properties of materials that make them suitable for rockets	3.2 I can explain test procedures and potential outcomes	4.2 I understand the basic physics in relation to space exploration
1.3 I can explain principles of physics which make flight possible	2.3 I can describe the forces which enable rocket flight and which determine material selection	3.3 I can design and build a rocket for flight	4.3 I can describe the range of uses for rockets, as well as their limitations
1.4 I can explain environmental factors which will make flight possible	2.4 I can explain historical construction techniques and developments	3.4 I can describe the procedure for launch, including safety and legal aspects required	4.4 I can select potential subjects from scientific discussions which would be suitable for rocket based projects
1.5 I can explain how to incorporate an understanding of physics into the final designs	2.5 I can identify the materials needed for my test rocket and explain their suitability for the job	3.5 I can select an appropriate launch venue, taking into consideration local guidelines and legal requirements	4.5 I can discuss and describe the importance of scientific discovery for the wider society

1.6 I can use simulation to minimise problems in my final tests		3.6 I can carry out a launch and document the findings for further development	

Assessor's guide to interpreting the criteria

General Information

RQF general description for Level 2 qualifications

To demonstrate achievement at RQF level 2 (EQF Level 3) the candidate

- Has knowledge and understanding of facts, procedures and ideas in an area of study or field of work to complete well-defined tasks and address straightforward problems.
- Can interpret relevant information and ideas.
- Is aware of a range of information that is relevant to the area of study or work.
- Select and use relevant cognitive and practical skills to complete well-defined, generally routine tasks and address straightforward problems.
- Identify, gather and use relevant information to inform actions.
- Identify how effective actions have been.

Requirements

- Standards must be confirmed by a trained Gold Level Assessor or higher
- Assessors must at a minimum record assessment judgements as entries in the on-line mark book on tlm.org.uk certification site.
- Routine evidence of work used for judging assessment outcomes in the candidates' records of their day to day work will be available from their eportfolios and online work. Assessors should ensure

that relevant web pages are available to their Account Manager on request by supply of the URL.

- When the candidate provides evidence of matching all the criteria to the specification subject to the guidance below, the assessor can request the award using the link on the certification site. The Account Manager will request a random sample of evidence from candidates' work that verifies the assessor's judgement.
- When the Account Manager is satisfied that the evidence is sufficient to safely make an award, the candidate's success will be confirmed and the unit certificate will be printable from the web site.
- This unit should take an average level 2 learner 40 hours of work to complete.

Assessment Method

Assessors can score each of the criteria N, L, S or H. N indicates no evidence and it is the default setting. L indicates some capability but some help still required to meet the standard. S indicates that the candidate can match the criterion to its required specification in keeping with the overall level descriptor. H indicates performance that goes beyond the expected in at least some aspects.

Candidates are required to achieve at least S on all the criteria to achieve the full unit award.

Once the candidate has satisfied all the criteria by demonstrating practical competence in realistic contexts they achieve the unit certificate.

Expansion of the assessment criteria

Level 2 Open Systems and Advanced Manufacturing Technologies

Unit 1: The Understanding and Appreciation of Rocket Science

4 credits (40 GLH)

1. Understanding the basic physical forces involved with rocket flight.

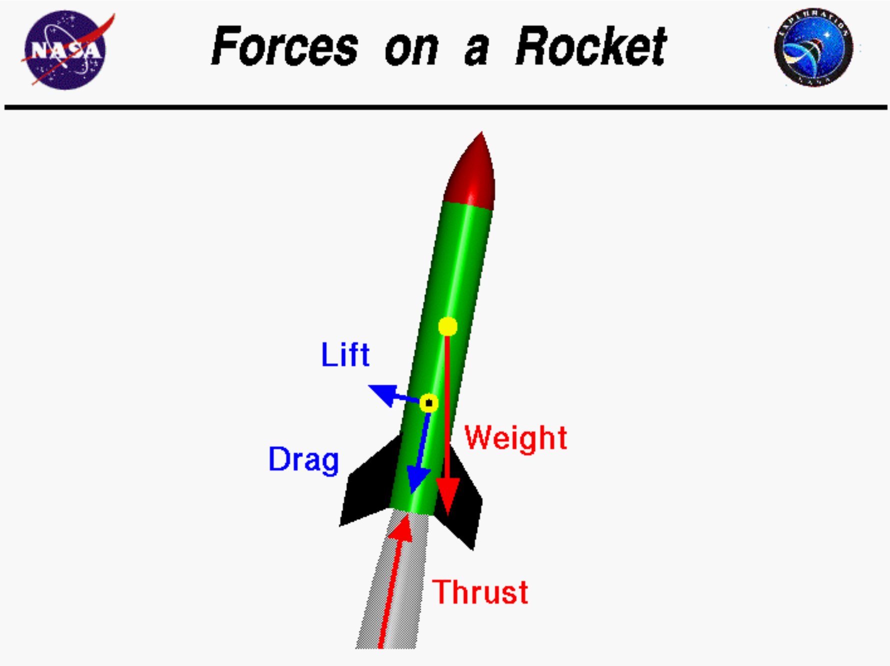
1.1 I can describe the basic physical forces involved in rocket flight.

Candidates should be able to describe a number of forces that act on rocket design.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
In order to design and build rockets, candidates need to have a basic grasp of some of the elements that make this task harder. They need to be shown the main concepts and show that they have a rudimentary grasp, at least so they can go on to a higher level as they progress through their studies. The main aspects here will be physical forces such as gravity and friction, both of which make a rocket struggle to get higher. They should also be able to show an understanding of lift and thrust which help the rocket on its way.

The weight of the rocket will act as a counter or opposite force to the thrust, which is the force pushing to rocket up into the sky. The other two forces are the lift, which is the force pulling the rocket upwards, which is countered by the drag, which is the force of the air and other elements such as pressure.



https://spaceflightsystems.grc.nasa.gov/education/rocket/rktfor.html

Understanding these basic ideas will help them appreciate the design and manufacturing process and engineering involved in the building of rockets. The same forces that affect their own test rockets are the same ones faced by the ESA (European Space Agency), just of a much higher order. Some of these concepts can easily be tested by using Kerbal in order to make changes and see the effects. This gives the candidates a safe and reproducible way of experimenting with their understandings. It will also help them appreciate what they see in their test flights should there be any issues such as lack of height.

1.2 I can identify and explain limitations on rocket flight created by physical elements.

Candidates should be able to add some more detail to their list of forces and give some more concrete examples.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Candidates should be shown as many examples of different elements as possible in order for them to understand the full range. While they can explore them through simulation software, some hands on examples will always be more effective in making the concepts stick. Even something as simple as making adjustments to paper airplanes in still and windy conditions will show some of the direct effects of drag and resistance in the air. If centres are able to build basic rockets, or slightly more advanced ones using something like Raspberry Pis, they can assess what affect some of these forces have on the rocket on something like height attained. If they add elements to the rocket that introduce more drag or weight, what impact will this have. They can create tables and graphs to see these differences and discuss ways to reduce or eliminate them.

1.3 I can explain principles of forces which make flight possible.

Candidates should be explore more forces and environmental factors which will affect successful flights.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Candidates need to be introduced to some of the ways that previous engineers have overcome some of the main forces which affect the basic aspects of flight. They can also explore how other creatures have worked on this principle. How is it that a bee can fly, given the size and structure of

its wings and the overall weight of the animal. Candidates can explore items like bird wings and look at how birds manage flight, comparing the way that a swan might get into the air compared to something like a sparrow. All of these investigations will help with their overall appreciation of the ways that basic forces can be overcome, or in some cases used, as in the way that birds can fly for hours without flapping using air thermals.

1.4 I can explain environmental factors which will make flight possible.

Candidates should be able to make judgements about suitable flight times and places based on their understanding.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Candidates should explore some of the historical evidence for rocket flight over the years and in particular look at the environmental conditions. Where do most launch sites reside and what factors were made to determine their use? Many launches have been cancelled due to the conditions on the day and even something not seen by the visible eye can affect this. For example, changes in air pressure and temperature will have large effects on rockets and their fuel as well as make their launch velocity, something which is critical, perhaps not achievable. The speed and direction of the wind at the launch site will have an affect on the way the rocket can move through the air and the amount of lift and drag it will experience. The air temperature will affect the materials in the rocket as well as the way that the fuel is burned. Candidates need to show that they understand these environmental forces and can give clear examples of the way they might affect a rocket, either in launch or in flight.

1.5 I can explain how to incorporate an understanding of physical forces into the final designs.

Candidates should be able to use their knowledge of forces and environmental elements to come up with some designs.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Candidates should have a good enough understanding of the main forces and structures to be able to come up with workable designs, whether for real or in simulation. They can recommend certain shapes and materials based on their suitability as far as reduction of drag or temperature resistance. They should also be able to recommend certain aerodynamic forms, while still appreciating that structures such as stabilisers might be important, even though they will create resistance and drag. As part of this process, candidates can experiment with different designs to see what impact drag and friction might have on them.

1.6 I can use simulation to minimise problems in my final tests

Candidates should be able to use simulation software and applications effectively.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Given the expense of rocket based devices and the high level of danger, even at the small scale of rockets used for educational purposes, it makes sense to test things in a simulated way first. Most organisations that manufacture rockets will carry out extensive simulation tests before going to production and launch. It is much better to find problems in a software simulation than to launch and lose millions of pounds of hardware. Candidates should be able to manipulate aspects of their rocket designs in

simulation software such as Kerbal and be able to predict some of the consequences. They should understand some of the basics of rocketry to be able to see that adjustments of fuel and speed will have specific impacts on success. They should be encouraged to test out their theories as this will underpin and reinforce their overall understanding. Can they adjust the weight of the materials to get maximum upward life, but still retain structural integrity, for example.

2. Applying aspects of construction and development for rockets.

2.1 I can identify materials used in the construction of rockets and explain why they are useful.

Candidates should be able to identify a number of material that could be used for rocket construction.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
It is unlikely that candidates can get their hands on real rockets, but they should be able to be introduced to the ideas through videos and experimentation to see what different materials do. There is plenty of information on rocket and plane design which can be used as guidance when gathering their understanding. In most cases, the need for rockets, given the enormous forces exerted on them, will be towards lightweight but strong materials. In most cases this will be aluminium, but they can also be constructed of titanium or lithium as well as other alloys. In some cases they may use steel, though this is comparatively heavy compared to its strength, it does have a high melting point so probably useful in the boosters since these burn at very high temperatures. Candidates should be encouraged to experiment with materials where appropriate. Many kits can be purchased for water based rockets and candidates can swap out parts of the rockets for other materials, perhaps via the use of 3D printers,

to see what affect these materials have. How much higher does a smooth rocket go compared to lighter one with a rough surface, for example.

2.2 I can describe the properties of materials that make them suitable for rockets.

Candidates should be able to create a table of properties with comments.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Having found and explored the different potential materials, candidates can now go into a bit more depth about their properties. It does not need to be very detailed, but they could explore the different properties of plastics used or the composition of metal alloys and how they are designed. If something like a titanium alloy is used, what properties does each element in the alloy posses and why was it chosen. What measurements are required for different materials and does it depend on their usage? Materials used in proximity to the fuel will need to be capable of withstanding the huge heat generated and will need to be rigid enough not to bend when heated, but it will also need to be resistant to the liquid chemicals as well. One of the main fuels used is liquid oxygen which is stored in a liquid form at around -200°C and is highly reactive and dangerous. When it burns, it burns at 3000°C. This huge range of temperatures and dangerous character make the choice of materials very important. Other propellants are made of other chemicals such as nitrates. These are slightly easier to manage, but do not generate as much force as the liquid varieties. These considerations will affect the final designs.

2.3 I can describe the forces which enable a rocket flight and which determine material selection.

Candidates should be able to show and understanding and appreciation of how materials are chosen for different purposes..

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Candidates can summarise some of their main findings and understandings in this criterion and show that they know what different materials are used and why. For each material, they should be able to identify and describe the force it is designed to overcome, or other factors such as heat or distortions. Each part of a rocket will be chosen with the right materials for the job and they can also consider aspects beyond getting the rocket into space, such as getting back. The capsules that carry people back to earth have to be made of a light but heat resistant material because the friction caused by re-entry to the earth's atmosphere makes the surface of the vessel get extremely hot. What materials should be used in the capsule in order to make the journey safe and comfortable. Given that once they get outside the earth's atmosphere they are no longer subject to gravity, what materials might be best for this state?

2.4 I can explain historical construction techniques and developments.

Candidates should be able to show an understanding of the main milestones of rocket development.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The understanding of rockets goes back to the early 1900s, but the first serious rocket to get any height from the ground was developed in the Second World War by Germany. It was not until the 1950s that a satellite made it into space for the first time and then developed increased rapidly. The "Space race" between the old Soviet Empire and the United States of America meant that developments were well funded and rapid. The Soviets had the first satellite Sputnik 1 launched in 1959 and Yuri Gagarin in space by 1961. The United States then had numerous efforts with the

first moon landing in 1968. These days, we have thousands of satellites orbiting earth, a permanent space station and any number of probes, some of which have left our known solar system. All of these have been possible due to advances in materials and designs. Candidates need to be able to give a flavour of some of these.

2.5 I can identify the materials needed for my test rocket and explain their suitability.

Candidates should be able to use their understanding in determining the best materials for test rockets.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The rockets used can be water or other propellent based, depending on the individual centres, and can also be simulations such as with Kerbal. Candidates need to show their awareness of the correct materials in choosing and building their rocket for flight purposes. It would be useful if they can produce a diagram of their rocket and label and describe the different materials and why they were chosen for the tasks. This will clearly show their understanding of the materials used in the manufacturing process.

3. Building, testing and launching a rocket with further development.

3.1 I can make rough designs, test and evaluate versions of my final rocket.

Candidates should be able to use their understanding of forces and materials to design a basic rocket and evaluate their design.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
It is not necessary for candidates to design a rocket that will be built, though they need to show enough of an understanding to show that they have thought carefully about the design and the materials and how these will affect the device. They can either draft a design on paper, or if they are comfortable, they can use a drawing programs such as Inkscape or Google SketchUp, or any that they know how to use or can learn how to use. An understanding and competence with these types of applications will be useful as they study higher levels of manufacturing, so it is worth spending some time investigating them now. They can also use packages such as http://openrocket.sourceforge.net or https://kerbalspaceprogram.com/en/ which will have pre-built designs which they can adjust and manipulate to their needs. Testing of these will come later and can be evaluated, but for now they need to be familiar with the process of design and manufacture. It would be good for candidates to show a progression of designs towards their final versions and some explanation of why they modified earlier designs.

3.2 I can explain test procedures and potential outcomes.

Candidates should be able to explain the main purpose of test procedures and show a basic understanding of possible outcomes of those tests.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
At Level 2, candidates should begin to understand the design cycle in engineering and be guided through why testing is an important part of this process. They should be shown how to design tests and what outcomes should result and use this guidance to develop their own tests. Using the suggested simulation software, it will be relatively easy for them to make changes to their designs and run the simulations to see what the outcomes

might be, but it would also be useful to do some hands on experimentation so that they can see directly what happens.

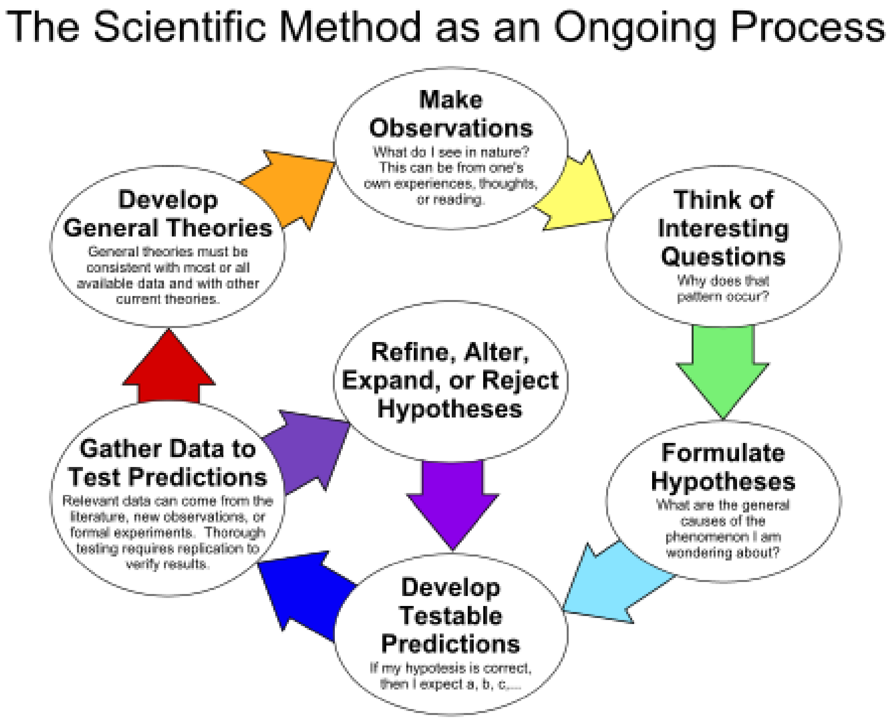


Image from https://en.wikipedia.org/wiki/Scientific_method#cite_note-Garland2015-1 by https://commons.wikimedia.org/wiki/User:ArchonMagnus

As you can see from the above image, there is a repeat cycle where the solution does not meet the requirements with testing and has to be adjusted until it does. This is a very important element of engineering and design of any system or product. Candidates can be shown how to develop a basic testing table and can work through the process as a group or with the class. At Level 2 they can then design and maintain their own test procedures.

3.3 I can design and build a rocket for flight.

Candidates should be able to carry out simple tasks and instructions to build a rocket for flight.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Various rocket kits of varying complexity are available on the market and centres who have the facilities such as engineering equipment can build their own. This gives a great deal of flexibility in the actual design and build of a working rocket.

http://www.rocketsandthings.com

The key thing here is to give candidates the experience of different applications and materials so that they can have a clear idea of how rockets are engineered and what factors are important for a successful launch, regardless of the actual rocket used. They should understand the common factors in all rocket engineering. All of this will lead to them being able to launch their own basic rocket.

3.4 I can describe the procedure for launch, including safety and legal aspects required.

Candidates should be able to describe the key factors to a successful launch and be aware of the dangers.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Centres offering this course who wish to launch fuel based rockets will need to be fully compliant with legal issues and regulations, as well as hold safety certification from something like the UKRA http://www.ukra.org.uk. There are clearly legal issues in flying objects into airspace and candidates need to understand these and also the risks associated with combustible elements and fast moving objects. Most candidates will be familiar with the detailed health and safety requirements that come into play with fireworks and rockets are no less dangerous if operated the wrong way. If your centre is going to launch relatively large rockets, the centre, or the person in charge, will need an explosives licence. This will also apply to how and where the explosives are kept. While we would not discourage this, it might be easier to stick to water based rockets and simulations until more experience has been gained.

3.5 I can select an appropriate launch venue, taking into consideration local guidelines and legal requirements.

Candidates should be able to participate in the choice and checking of a launch site.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
It is expected that candidates can show some competence in determining the place and characteristics of the proposed launch site and time, and that this will demonstrate their understanding of some of the physical forces and materials studies in other sections of this unit. The type of rocket used will determine how many of the environmental and health and safety factors they will need to consider and apply. In most cases at Level 2 they will be guided by their assessor or third party, but will need to demonstrate their own understanding through some checklists and write-ups. The local

environment will also be a key factor for the launch site. Candidates in rural areas far away from commercial airspace will find sites much more easily than those in urban settings or near to airports.

3.6 I can carry out a launch and document the findings for further development.

Candidates should be able to launch their own rocket.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The rocket they launched can be a simulation or the real thing. The key here is that the act of launching should give them some valuable data about the launch and allow them to contemplate what might be improved for further launches. How affected were they by the weather or other uncontrollable elements. Was their design suitable for the conditions and the objectives they set themselves. Is there any room for improvement at all, or are they already as far as they can go with their existing designs. Candidates can use this to begin the process of development and improvement which is an important aspect of manufacturing. The launch will probably create more questions for them to answer which is a good thing as it means they have more development and improvement ahead of them.

4. Investigating further applications and exploratory topics.

4.1 I can investigate and explain the application of rockets for science and experimentation.

Candidates should be able to demonstrate a wider understanding of the use of rockets and their place in science and engineering.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The criteria in this section of the unit are all about investigating the wider use of rocketry and some of the implications (both good and bad) of these. The amount of hardware in LEO these days is almost beyond comprehension, but most young people would be lost without them as the satellites drive their smartphone habits that are seemingly indispensable for their lives. Recent satellites have been used to explore out into space in order to investigate the fate of the universe, while others have been turned inwards to look at the effects on our climate. Many primary schools are currently (2016) growing seeds that have spent time on the ISS (International Space Station) to see what effect this has had in space. Other experiments have been equally as challenging, such as the testing of **water bears** http://www.esa.int/Our_Activities/Human_Spaceflight/Research/Tiny_animals_survive_exposure_to_space . Candidates can find and explore some of these examples and extend their understanding of the research and engineering options available to them through studying this field.

4.2 I can understand the basic forces and materials in relation to space exploration.

Candidates should be able to discuss the characteristics of space in terms of the forces they have explored and materials.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Having looked at the requirments down here on Earth for rockets, candidates can now look outside of the atmosphere and into the dark and quiet of space. How can we determine what is required once the rocket we built gets outside of Earth’s atmosphere. What are the implications of the radiation exposure, temperature and lack of gravity. What other forces are at play and how might this affect some of the materials used. In most cases, candidates can produce a table or a database of the various

elements and some comments about their characteristics. They will not be expected to know a great deal of detail at Level 2, but should know the main composition of the atmosphere and aspects of forces that work in different layers of the atmosphere as applied to launching rockets. They should also be introduced to some of the developments in materials for space based equipment and be able to understand how the materials are chosen for different tasks in space. One much overlooked aspect of rocketry is the amount of noise generated. There are many ways to overcome this noise, but in large rockets for space exploration which carry people, it can be a real issue as sound levels reach dangerous levels.

4.3 I can describe the range of uses for rockets as well as their limitations.

Candidates should be able to show an understanding of the main uses for rockets currently.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Candidates should be guided on researching and collecting data about different types of rockets and the application of these rockets. In most cases this will be for civil and industrial applications, but they can also investigate the military uses of rocketry and the history of the industry. The main one which will engage them at this level will be their own rockets they build and fly for this course, but they need to have a good understanding of the wider use of rockets.

The main categories to explore will be:

1. Military - missiles and other rockets for delivering explosives or destroying other rockets or machines, as well as fighters
2. Science and research - weather equipment and atmospheric checks, as well as transportation (rocket sleds)

3. Communication - launching and maintaining satellites
4. Spaceflight - communication devices and exploration
5. Rescue - sending ropes to stricken ships or ejector seats on planes
6. Hobby, sport and entertainment - rocket cars and hobby rockets

In all of the above instances it is likely that candidates can identify and explain some of the possible limitations. For example, the number of satellites in space is now reaching a high density. There must be a limit to how safely a rocket car like the Bloodhound SSC might be able to go?

http://www.satellitedebris.net/Database/LaunchHistoryView.php

At what point would there be so many satellites that they begin to crash into each other and will we see them raining from the sky?

4.4 I can select potential subjects from scientific discussions which would be suitable for rocket based projects.

Candidates should be able to think of areas of research that rockets could help with.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Level 2 candidates may need some help with this criterion, but should have enough information from other areas of this unit to think about how rockets could be used. They may be able to find areas of interest that they have discovered through this course and think of imaginative ways that rockets could assist. Candidates will not be expected to come up with completely new ideas, but will need to be able to show enough understanding of the science and application of rocketry to be able to identify plausible uses for rockets, either as a new field or as an extension of an existing one. They

might also be able to discuss ways in which identified limitations might be overcome.

4.5 I can discuss and describe the importance of scientific discovery for the wider society.

Candidates should be able to present and discuss their ideas to an audience.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The final piece of any project of engineering and development is to present your designs and ideas for peer review. Candidates need to opportunity to be able to present their ideas and views to their peers, in order to get some feedback and be able to implement improvements. It would be useful if candidates could present some ideas to local engineering forms or interested parties where appropriate and centres are encouraged to make these relationships possible as part of the process. Even if they present their material to their colleagues in the centre this will be a useful experience. Better candidates can reference some of the more interesting scientific elements they have discovered in their journey and link these to the problem solving powers of engineering and how they think it has benefited the wider community or society.

Level 2 Unit 2 - The Understanding and Application of Microsatellites 40 TQT, 4 credits

1. Understand the current place in the market of microsatellites	2. Review and define the key issues in making a microsatellite	3. Understand the key issues in space deployment	4. Investigate the control, data use and end of life issues related to microsatellites
1.1 I can review the current status of microsatellites in terms of global production and main countries involved	2.1 I understand the need for size reduction in satellite technology	3.1 I can appreciate the cost implications of getting equipment to space	4.1 I can describe how microsatellites are controlled from earth
1.2 I can list and define the key uses of microsatellites	2.2 I can describe some of the key materials used in construction and say why they are used	3.2 I can describe key terms such as “piggyback” in terms of deployment and give examples of how it is used	4.2 I can describe how microsatellites are controlled while in space
1.3 I can describe the main launch vehicles used for deployment and their characteristics	2.3 I can describe the main forces acting on satellites in their life-cycle and how this affects their manufacture	3.3 I can list and define the main propellants used by microsatellites	4.3 I can review the types of data collected by microsatellites
1.4 I can define the main versions of microsatellites including nanosatellites, picosatellites and femtosatellites	2.4 I can describe the main forms of communication used in microsatellites and give examples of their usage	3.4 I can describe the strengths and weaknesses of the main propellants used in space	4.4 I can review the dangers of microsatellites that return to earth when they finish their mission
1.5 I can assess the current market in microsatellites	2.5 I can develop a list of requirements in the manufacture of a microsatellite	3.5 I can describe the different levels of orbit used in microsatellite systems	4.5 I can assess the impact of microsatellites and recommend a possible future use for them

	2.6 I can devise my own basic design for a microsatellite and define its purpose	2.6 I can describe the main legal issues relating to microsatellites	

Expansion of the assessment criteria

Level 2 Open Systems and Advanced Manufacturing Technologies

Unit 2 The Understanding and Application of Microsatellites

4 credits (40 GLH)

1. Understanding the current place in the market of microsatellites.

1.1 I can review the current status of microsatellites in terms of global production and main countries involved.

Candidates should be able to show they understand the most current state of the market for microsatellites.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
From 2000-2015, there were about 20-30 launches per year, on average, of microsatellites, but it is estimated that there will be 500+ launches in the next 5 years.

https://en.wikipedia.org/wiki/Miniaturized_satellite#Microsatellites

Though the satellites themselves do not have to be hugely expensive, some of the equipment on them and the fact that they are required to be launched into space (which is expensive, most launches cost upward of £6,000,000 per device) means that the countries involved tend to be the more developed and wealthy nations. The above wiki page cites a small number of countries involved in the deployment, The main countries are the USA, UK, Spain, Germany, Japan, Canada and Mexico, though there are others. Candidates can explore a particular country and gather some information about how many devices are launched by the country. They can contact the companies to get some first hand data. If all students work on different countries, they can compile all the data for the group and have a better collective understanding. Candidates do not need a detailed understanding of the market, but should be able to show that they appreciate the key players and have a sense of specialisation from each.

1.2 I can list and define the key uses of microsatellites.

Candidates should be able to demonstrate they understand the range of microsatellite use.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The primary use of most satellites is for the purpose of communication and we are increasingly dependent on them for things such as GPS tracking. Many candidates will be familiar with the use of GPS in cars and also that their smartphones can tell them exactly where they are. All of this information is possible because satellites are circling the earth and bouncing data back and forth. Candidates will also use tools such as Google Maps to look at locations. The detailed maps are a combination of GPS data, satellite images and images taken by driverless cars from the ground. This data makes travel much easier and more consistent as you can explore a new venue before ever being there. The other key driver of satellite usage is for research. Large and powerful satellites are used by national weather services to track the weather as it has a huge impact on a country's economy, such as knowing if the harvesting of food will be

damaged by Summer storms or tracking hurricanes to minimise damage and loss of life. These types of systems can also be used on a smaller scale for something like University departments. Most Universities could not afford to build or launch low earth orbit microsatellites in order to carry out investigations about something like pollution levels or checking for different particle elements in different layers of the atmosphere, however, since the research is so important, national government tend to pay the bills.

Candidates can explore this area and find a number of different uses for microsatellites and as with the previous criterion, if they work in teams in different areas, they can share and compile their findings.

1.3 I can describe the main launch vehicles used for deployment and their characteristics.

Candidates should be able to describe a number of launch vehicles.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Microsatellites are sometimes launched as secondary devices in main satellite deployments, but this does not always address the need for specialised orbit levels and flight paths, so increasingly there is a need to develop launch vehicles specialised for small satellites. The companies that are currently working on this are from the UK, US, Switzerland and Spain.

UK - Virgin Galactic
US - DARPA, Garvey and Boing
Switzerland - Swiss Space Systems
Spain - PLD Space

Each of these companies has a different approach to getting devices into LEO (Low Earth Orbit) and are possible trying to make themselves special in the market place.

Candidates can investigate these different companies and describe some of the USP (Unique Selling Points) of each of their launch solutions. They can list some of the characteristics such as: what height or range of heights do they operate in; what is their payload; what is their general cost etc.

1.4 I can define the main versions of microsatellites including nanosatellites, picosatellites and femtosatellites.

Candidates should be able to show they understand the basic differences between the main microsatellites.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The most obvious difference between these devices is in their weight. Candidates will know from earlier units on rocketry that the more weight involved in a lauch, the more expensive it becomes in terms of the fuel needed to get into orbit. Due to their weights and size, they should be capable of different tasks and carry a range of equipment. As technology evolves and more miniaturisation occurs, these may become blurred. It does not seem like much technology can be packed into a 100g femtosatellite, but when you consider that a Raspberry Pi Zero only weighs 31g and is a full blown computer, it does give some sense of the possibilities.

Candidates need to list the main characteristics of each device and give some broad examples of the type of equipment they might carry, perhaps with some images and descriptions.

1.5 I can assess the current market in microsatellites.

Candidates should be able to show they can appreciate the reasons behind some of the market information.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The microsatellite market is an extremely exclusive one as it is very expensive to enter. As it is difficult to enter and expensive, it means that there is a lot of money to be had and not really enough people to understand it well enough. This criterion will allow candidates to use a more critical eye to look at the market place of microsatellites. Most companies that are advertising the ability to launch microsatellites are basing the ability to do this on future orders. The tell customers they "should" be able to do it, so customers give them some money in advance for it to happen, but that does not mean it will happen. As the launches and technology to launch are based on a great deal of theory, there is no guarantee involved. Virgin's launch vehicle had a setback as the first test flight ended in tragedy which would have caused some customers to cancel their orders and these orders will have been used to borrow money in order to build and test the launch vehicles. Many companies said they could launch for a certain amount, i.e. £6,000,000 for a 100kg device, but when it comes close to the actual launch time it turns out to be closer to £10,000,000 because of factors such as increasing fuel or development costs that they were unable to predict. A late 2016 NHK news bulletin about a Japanese company's attempt to launch a small rover on the moon said the cost was $1.2 million per kilogram. Many of the pieces of information saying this industry is worth millions of pounds are coming from the very companies that stand to make all of the money. How much can we believe?

Candidates don't need to be shrewd market traders, but should be able to get enough information, with guidance, to be able to see what is hype and what is possible in this volatile and fast moving market.

2. Review and define the key issues in making a microsatellite.

2.1 I can understand the need for size reduction in satellite technology.

Candidates should be able to show they understand the implications of size and weight on the success of satellite technology.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Candidates may already have explored issues about size and weight in the unit on rocketry and should appreciate the relationship between some of the forces involved. The energy required to get a 100 kg satellite into orbit is considerably more than a 1 kg one. Some of this need for size and weight reduction is driven by improvements in technology and miniaturisation of components, but also by the drive for efficiency. The cost of launch will always be relatively expensive so manufacturers will always be trying to save weight and therefore cost. It might also mean additional business as companies that do have the capability to launch a 100kg payload can launch several smaller satellites and therefore make more money as they can charge each company and the sum of all companies may well be more than the total of the one.

Candidates need to show, with examples, that they understand some of these issues and that they have a good understanding of how and why manufacturing companies and designers of satellite technology will try to go for smaller systems and designs.

2.2 I can describe some of the key materials used in construction and say why they are used.

Candidates should be able to list and describe a number of the main construction materials used, giving reasons for their choice.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Demonstrate the various forces and pressures on devices as they pass through different layers of the atmosphere and in their journey there will determine some of the material needs required. Once the devices are in orbit, there will be different forces and pressures on their components. As they accelerate through the atmosphere there will be gravitational forces and pressures as well as temperature changes working on them. Each material will need to be capable of withstanding some of these extremes. The temperature at launch will probably be 20-30°C, this will increase to 100s or 1000s of degrees during flight, but by the time it is in orbit this could be as low as -269°C. Candidates should appreciate that this range of temperatures will cause large extremes of expansion and contraction of materials. Materials need to be considered for this range of extremes. The other issue, once the satellites are in orbit, is they are no longer protected by the Earth's magnetic field or atmosphere and will be subject to higher levels of solar radiation. Many scientists are working on ways to reduce the damage and disruption caused to satellite technology due to these. What materials might be used to reduce or deflect these damaging waves?

2.3 I can describe the main forces acting on satellites in their life-cycle and how this affects their manufacture.

Candidates should be able to show they understand the basic forces that satellites need to endure.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
This criterion ties in with the previous one in looking at the forces working on satellites from "cradle to grave". What materials can be used to not buckle and warps at temperature extremes. How can engineers choose materials that will not be damaged beyond repair once they are bombarded with different types of radiation. If the satellite is at the end of its life and reenters the atmosphere, what materials need to be used that will disintegrate and not fall back to earth to cause other issues. These are some of the issues that candidates need to explore and think about solving.

2.4 I can describe the main forms of communication used in microsatellites and give examples of their usage.

Candidates should be able to show they understand the ways that engineers control their devices.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Depending on the purpose of the satellite, it will doubtless have a range of functions and these will need to be controlled from Earth. Some of the functions will relate to how the satellite works in the environment, so moving and adjusting its flight, perhaps twisting to keep facing the sun or down towards Earth etc. The instructions required to keep the satellite functioning effectively will need to be sent to the device and it will need to be able to send back signals that it has acted on these or not. As with any computerised system, if there are any problems, or potential problems, it needs to transmit these so that some action can be taken. Once it is in orbit, there is little that can be done, but there are likely to be some self-healing functions to try and make sure it can carry out the tasks it needs to. If the satellite is constantly transmitting information, the engineers need to work out the best way to do this. Transmissions of any description will require a transfer of power, albeit this may be small, so how might this be managed efficiently? What are some of the limitations of different

communication and transmission system in terms of distance and data volume that can be carried? How can these be used effectively?

2.5 I can develop a list of requirements in the manufacture of a microsatellite.

Candidates should be able to use their knowledge and understanding to put together a simple shopping list of requirements.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The candidates have explored some of the key ideas in microsatellite design and manufacture and considered carefully the impact of forces and the environment on their devices. They should not be able to put together some of their findings in terms of a list of possible elements. This will include some of the manufacturing materials required, some of the communication devices and types etc. This is bringing together all of their findings from earlier sections of this unit. In the case of materials, they should evidence some of the characteristics that have informed their choice, so for example, they would recommend a certain alloy for the frame of the device because it does not distort with extremes of temperature, or some type of plastic shielding for the communications elements as the material is not as badly affected by gamma rays.

2.6 I can devise my own basic design for a microsatellite and define its purpose.

Candidates should be able to construct a basic diagram of their microsatellite with labels for key components.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The candidates can draw their designs on paper or use some computer assisted design software if they are able. They should use their acquired skills and knowledge to put together a basic design of their own microsatellite and label some of the main parts. The labelling will reflect what they understand about materials and if they want to, though it is by no means a requirement, they could write a detailed summary of the main parts with some descriptions of the materials used and why. This is likely to cover other criteria in this unit. In order to differentiate their satellite purpose from more general purpose satellites, they might include a short description of what data the device will collect and how that might be used. This information could be part of another criterion in the qualification.

Some guidance may be necessary from other subject areas, such as some explanation of the use of GPS data or temperature fluctuations as used in modelling such as weather or travel issues.

If their device is for high resolution photographs for a specific purpose, they may include the dimensions and specifications of the camera to be used.

At this level, it is not expected that candidates are experts in their field, but should be able to demonstrate a good depth of understanding around their chosen topic and show that they understand how the equipment used, such as a camera, will impact on how the device is made and any weight considerations.

The following site lists a number of uses for a specific satellite, showing some of the range.

http://www.nesdis.noaa.gov/jason-3/spacecraft.html

3. Understand the key issues in space deployment.

3.1 I can appreciate the cost implications of getting equipment to space.

Candidates should be able to show they understand the relationships between weight and size and cost of deployment.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The science behind this is quite complex to explain, but a basic understanding of power to weight ratios should be enough here. Candidates can use the Kerbal program to test out their theories as it will output some data to tell them how much power is being used and they can see if they can get into space with a certain weight of object. It might be worth searching the Kerbal forums or posting a question there.

http://forum.kerbalspaceprogram.com

Current estimates (using quora.com) are that a payload of 454g (1 pound) would cost £7,600 ($10,000). This is the total cost of the rocket and the fuel. The rocket is the expensive bit and the fuel is about 1/10th of the cost.

More details might be available through sites such as NASA's resources for schools.

http://www.nasa.gov/education/resources
The criterion only states an "appreciation", so there is no need, unless interested, to go into huge amounts of detail.

3.2 I can describe key terms such as "piggy back" in terms of deployment and gives examples of how it is used.

Candidates should be able to show they understand some key terms used and show their understanding with clear examples.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The above criteria should demonstrate that getting stuff into space is not a cheap undertaking. Different ways of minimising the cost need to be explored, though as the criterion suggests, the most common is probably the use of a piggy back. This is a straightforward criterion to allow candidates to explore the different methods and give examples of how they work and why.

Given the cost of deployment and the increasing need of devices, there is not enough capacity so there are many satellites waiting to be launched but can't be for several years. This might not be too big of an issue, but what happens if an important satellite suddenly malfunctions and needs replacing?

One possible solution here is to use jet aircraft to at least get some launcher close to space so that the energy needed to make the final step is not huge. This is not quite a piggy back in the traditional sense of being on the "back", but is the same idea. The jet travels as high as possible and then launches a device like a rocket from its undercarriage. Like all of these ideas, there is an acronym for it, which is ALASA (Airborne Launch Assist Space Access).

https://youtu.be/BOaJWoVLhAc

A more well known example of this might be the US Shuttle which used to be launched on top of a rocket.

Candidates can explore this technology and possibly comment on how effective they think it might be.

3.3 I can list and define the main propellants used by microsatellites.

Candidates should be able to document some of the propellants used in satellites and their characteristics.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
This will tie in with the rocketry unit to some degree, but the propellants used for getting devices into orbit may not be the same as the ones used once there. In most cases a device will not need to move around that much once it has achieved its orbital place, and most of its direction and placement can be controlled through the use of solar panels delivering energy supplies. However, there may be occasions when the device needs to adjust more radially or move to a different location and for this it needs slightly more power. Most devices will be built with small thrusters, depending on overall size and purpose, and most of these thrusters will be propelled by some chemical based on Hydrazine. There are various compounds based on this base product, depending on the requirements and other factors. The main characteristic is that it breaks down in a reliable way and produces energy which means that it can be used reliably and predictably in space devices. Small amounts can create large amounts of thrust which means a small payload on a microsatellite could help it maneuver for many decades without any problems.

Students can produce basic tables listing the elements and giving some of their basic characteristics such as:

Propellant name	Main chemical (s)	Type	Comments
Anhydrous Hydrazine	Nitrogen and hydrogen (N_2H_4)	Liquid	Absorbs a lot of water from the air (hygroscopic), so hard to handle
Monomethyl Hydrazine	Carbon, hydrogen, nitrogen (CH_3NHNH_2)	Liquid	Absorbs a lot of water from the air (hygroscopic), so hard to handle. Strong hydrogen bonding.
ALICE	Aluminium	Powder	Small particles of aluminium that react with H and O in water to create energy. Can be made on moon and Mars

It is not expected that candidates understand the complexities of the chemical, but should have a good overview that there are liquid and solid variants and some of the elements involved.

Other propellants can be discovered and commented on.

3.4 I can describe the main strengths and weaknesses of the main propellants used in space.

Candidates should be able to show they understand some of the characteristics of propellants.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The key thing about propellants is that they are stores of energy and therefore, quite dangerous. The main ones used in space are also, as observed in the previous criterion, hygroscopic which means they would

leach water from anything they come in contact with, including our hands. This criterion and the previous one can be combined so that candidates can gather information about the main propellants, but also offer some descriptions of their merits. They should be able to demonstrate that one propellant might be more useful as a fuel to get into space as it works more safely in our atmosphere, but would be unsuitable in space because of the freezing temperatures there, or conversely, one works in space, but not on Earth so well. The assessors will be looking for a good overview of how candidates judge what is useful and why.

3.5 I can describe the different levels of orbit used in microsatellite systems.

Candidates should be able to show they understand the different orbits in terms of their distance and characteristics.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Most satellites and microsatellites are positioned at a certain point away from the planet in order to maximise their functionality. Some stay in a fixed position and distance, while others circle around the planet. Each of these takes a different set of equipment to manage. The closer the device is to the Earth, due to gravity, the faster it will move. There are 3 different types of orbit that are generally used.

High Earth Orbit
Satellites in this orbit are designed to match the Earth's rotation so they can map specific areas over long periods of time. An example here is a weather satellite that would be used by a specific country to know the weather for the country every day. In order to be in this position the satellite needs to be 36,000km from the surface. Although “stationary” in relation to earth, they are still travelling at 11,100km per hour, as is the Earth. As noted earlier, any closer and the device would begin to speed up

and not be synchronous with a spot on the Earth. Since they are quite a distance away from the Earth, they can also be used to monitor the Sun's activity, particularly measuring the burst of radiation that come from the Sun from solar flares as these are damaging for radio equipment on the planet.

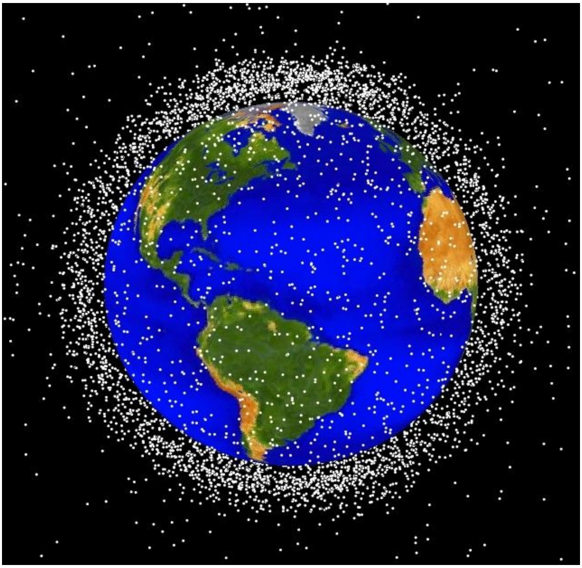
Medium Earth Orbit

Satellites in this orbit will take 12 hours to pass around the Earth and will be positioned at 2,000-20,200km from the surface. The most common use for devices at this altitude are GPS (Global Positioning System). The orbit is very predictable and constant which makes it ideal for GPS systems so they can be constantly updated on their position and speed, such as in car navigation.

Low Earth Orbit

The satellites are generally used for very specific purposes, such as specific weather checking. For this purpose, a satellite will be launched to monitor a very small region, such as the one launched to monitor only the rainfall in the tropics. Since the tropics is a specific section of the Earth either side of the equator, the satellite needs to stay in this region above the earth. The altitude for this will vary, but will generally be between 180-2,000km from the surface.

There are quite a lot of objects now in LEO, though most of them are "junk" such as debris from launches or disabled satellites. The following image is from a NASA web site that tracks the pieces.



http://orbitaldebris.jsc.nasa.gov/Photo-Gallery.html
Clearly there is a lot out there just above us.

Candidates need to show an appreciation of some of these numbers and give some examples to show their overall understanding.

3.6 I can describe the main legal issues relating to microsatellites.

Candidates should be able to show they understand some legal issues.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The main considerations about microsatellites is perhaps related to ownership. Who actually “owns” space and how can it be managed?

There are a number of potential legal issues that can be investigated including the following.

Space Activity

Anything that goes into space needs to be managed by someone, but only a certain number of countries have the resources to put objects into orbit. The US has the most objects in space, but can also put satellites up for other countries using their rocket systems, as can Europe, Russia, Japan etc. Who gives the authority to do all of this?

Telecommunications

Most countries now use satellites for their mobile phone systems and they will have a license to operate a satellite in their own country. However, many people travel to different countries and want to use their phones or other devices in those countries which means some international cooperation. How is this controlled and who is in charge if there is a problem.

Observation

At present, the governments are the only organisations that can afford to put satellites in space with advanced imaging capabilities. They can then share this image data with other organisations. However, they may only share information that is not going to cause them problems or embarrassment. With the cost of microsatellites and launches going down all the time, it could be possible that organisations like newspapers can have their own equipment and they might then be able to contradict the government, especially where governments are misleading people about military activities.

Debris

The amount of hardware in space is quite staggering. Some it will fall to Earth and some of it might cause damage to people or property. If an American device falls to Earth in the UK and damages people, how will damage compensation be retrieved. What happens if a satellite loses control and crashes into a UK communications satellite and all of the customers lose their signal for many days. Who will fix the issue and pay for the customer's inconvenience?

Some satellite uses are listed here with discussions.

https://quizlet.com/3838036/satellites-correction-legal-and-ethical-issues-computers-flash-cards/

These are some of the issues that can be explored and candidates are encouraged to think of their own examples to explore. There is likely to be a great deal of work in space jurisprudence in the years to come.

4. Investigate the control, data use and end of life issues related to microsatellites.

4.1 I can describe how microsatellites are controlled from earth.

Candidates should be able to describe some basic control mechanisms used in satellite deployment.

Evidence: Documentation in portfolios, assessor observations.
Additional information and guidance:
Once microsatellites are up in space, they tend to be control through radio transmissions or other means as discussed in the next criterion. Most companies will have computer based control centres which will monitor the devices to make sure they are collecting the right kind of data and that they are not in danger of being damaged by other space junk. As with the control centres seen in TV broadcasts of US space flights, companies will have several computers and monitors looking at different aspects of the devices needs. Some computers will be controlling the movement of the device, while others will be making adjustments to the onboard sensors to make sure they are collecting the right kind of data. In some cases, they

may need to recalibrate the collection equipment to make sure the data being collected is fit for purpose. Other pieces of equipment might run basic checks on the collected data to look for problems before processing and releasing the results.

This Inmarsat infomertial shows some of the equipment in operation: https://youtu.be/FCE27vAPd6I

4.2 I can describe how microsatellites are controlled while in space.

Candidates should be able to show they understand the basic aspects of AI.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The majority of microsatellites will be launched into a Low Earth Orbit, which candidates will have investigated earlier and will know to be 100-2,000km above the Earth. At these distances, the types of communication involved with talking to satellites and receiving their data are likely to be radio transmitter based systems. However, even this has some issues as different radio frequencies are absorbed or deflected by different parts of our atmosphere, so the usable frequencies for space are broadly 30MHz to 30GHz. This is not all usable however, since most countries use radio frequencies for various purposes on Earth, such as FM radio which operates between 88 and 108MHz. This would interfere with communications to satellites and vice versa.

http://www.spaceacademy.net.au/spacelink/radiospace.htm

Candidates can explore this in as much detail as they are comfortable with, particularly if it overlaps with an interest in another subject, but the requirement is to show an understanding that microsatellites will be tuned to respond to some form of radio signal in this range and that this signal will send messages to the device to perform some operation and the device will use this frequency to transmit data, such as images, back to the control station on Earth.

The amount of control for LEO satellites will be higher as they are effectively being pulled back to Earth by gravity. The control systems will need to make adjustments to the device to make sure it stays at the correct heights and in the correct direction to carry out its functions. There are 3 effects on LEO satellites that need to be adjusted to compensate for.

1. Atmosphere - the atmosphere, though thin, still drags on satellites so causing them to be more affected by gravity and being pulled closer and faster to Earth
2. Solar Power - when the Sun is hotter, it makes the air expand. The satellite is in a fixed orbit, so it is now moving through thicker air. Conversely, when the Sun is cooler, the air is thinner so the satellite needs to be adjusted more often.
3. Crashes - there is a lot of junk in space and all of it travelling at thousands of kilometres per hour, if there is a collision is creates a lot of extra junk. Satellites need to be adjusted to avoid this debris and not make more.

4.3 I can review the types of data collected by microsatellites.

Candidates should be able to show they understand the different types of data available.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
This criterion can be combined with 3.5 above which is looking at where the satellites are placed in orbit, as this will determine what they can do. The candidates can extend the information in 3.5 to include more detailed

examples of the different data that is collected. Some of this will be quite familiar to candidates if they watch the weather forecast on the morning news, then use GPS to get to school and then look at their school on a mapping program such as OpenStreetMap. What other data could be collected?

https://www.ncdc.noaa.gov/data-access/satellite-data/satellite-data-access-datasets

Candidates can explore the types of data available and give some examples of data that they find interesting or unusual.

4.4 I can review the dangers of microsatellites that return to earth when they finish their mission.

Candidates should be able to document some of the dangers of space debris.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Candidates earlier explored the danger to objects in space, where 500,000 pieces are flying around at 28,000km/h. However, what if some of these objects manage to survive the burn up through the various layers of the atmosphere and come to Earth? In 2014 the amount of junk in space was estimated to be 5.5 million kilograms. Some of it can be quite big when it gets back to Earth.

Most objects will burn up and lose most of their velocity as they are quite small. It is estimated that if they do not burn up they will hit the Earth at about 100m/s (6,000km/h), though this is not as fast as their speed in space, it is still more than fast enough to kill someone and cause significant damage.

Candidates can explore as part of this ways to minimise this possibility. There are plans to build satellites in space that will destroy various junk. Other plans are for ground based lasers to destroy material as it enters the atmosphere and there are already instances where surface to air missiles have been used for large objects returning to Earth.

4.5 I can assess the impact of microsatellites and recommend a future use for them.

Candidates should be able to show they can think about the future of microsatellites and potential uses based on their understanding.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Having explored what satellites can do and what equipment they might be able to carry on board in previous criteria, what additional uses might there be? Candidates are encouraged to "think outside the box" and come up with their own ideas about what these devices might be used for. As part of this criteria, though it is not mandatory, they should be able to come up with a design of their own and specify what equipment it will carry and what data it will collect and transmit.

Level 2 Unit 3 - Working with Robotics and Artificial Intelligence
40 TQT, 4 credits

1. Understand what Artificial Intelligence is and how it works	**2. Review and define examples of where robotics is used**	**3. Understand the processes of making a basic robot work**	**4. Appreciate and test the issues and challenges of robotics**
1.1 I can list the main features of an artificial intelligence	2.1 I can describe instances of robotics in industrial places	3.1 I can review the equipment required to design and create robotic devices	4.1 I can test the build quality of an assembled robot against the specification
1.2 I can describe, with examples, the main uses of artificial intelligence	2.2 I can review how robotics is used in medical applications	3.2 I can assess the design tools used to create robots and use these in a basic way	4.2 I can test the main features of a built robot in terms of hardware and software
1.3 I can review some of the expectations of artificial intelligence	2.3 I can describe how robotics is used in agricultural environments	3.3 I can work with various components of robot design and appreciate their features	4.3 I can make adjustments to a robot build or control system to improve its functioning
1.4 I can review the intended uses of artificial intelligence	2.4 I can assess the wider use of robotics in society	3.4 I can build a basic robot for testing	4.4 I can recommend additional features to existing designs based on usage
1.5 I can assess the strengths and weaknesses of using artificial intelligence	2.5 I can assess and comment on the dangers associated with the reliance on robotics in society		
1.6 I can describe any legal and ethical issues associated with using robots			

Expansion of the assessment criteria

Level 2 Open Systems and Advanced Manufacturing Technologies

Unit 3 Working with Robotics and Artificial Intelligence:

4 credits (40 GLH)

1. Understanding what Artificial Intelligence is and how it works.

1.1 I can list the the main features of an artificial intelligence.

Candidates should be able to show they understand the basic aspects of AI.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The idea of AI goes back a long way in human history, but it is only recently that it has become more realistic and achievable. It is also now debatable about what AI is. For example, is the “intelligent” device that maintains the temperature in your home and gives various alerts an intelligent device? Are the driverless cars that are now appearing on our roads any less intelligent that the drivers they have replaced? In recent news stories, another milestone has been reached with AI where a computer was able to beat the world champion Go player. Many people have said that Go is far too complex a game for machines to beat people at, though clearly that is no longer the case. Equally, a tablet device interaction system was recently able to call an ambulance and thereby save a young child’s life. Re these examples of machine intelligence or just examples of how subtle programming has now become? Most research into this area is looking at some sub-problems which define intelligence in different ways, of at least some aspects of what we feel is intelligence. These are:

Deduction, reasoning and problem solving

Most people can solve problems by taking various steps, which is relatively easy to replicate with algorithms, but people can also make judgement leaps and reach the correct conclusion even without going through the steps. AI can't not yet achieve these and the processing power to get near is currently difficult to achieve. The ability to act on probabilities for AI devices will be a large step forward.

Knowledge Representation

Much of what people reach decisions on is based on some very subtle understandings. They understand objects and their properties, the effect of these objects and properties on other objects etc as well as aspects of time and space. All of these are quite difficult to replicate in a machine working in logical steps. This also has some sub elements:

- Default reasoning - nothing is as simple or true as it needs to be
- Common sense - everyone has millions of little facts to draw on and use and some of these are applied in non similar situations
- Gut feelings - most art critics can spot fake paintings without checking

Planning

Most of us can plan as we can act on external inputs and collaborate with others to achieve shared goals. Machines often work on a simple path of one action leading to one goal. Even though we don't know the future, we can act on it. A machine might see 30% chance of rain as meaning there is no need for a coat, but most people would assume that they might be the unlucky one in that 30% zone and take a coat.

Learning

We change our behaviour through our experiences and being told by others. An AI device can not necessarily learn as effectively as it does not have that shared experience, though algorithms can be built to build upon similar experiences and actions to “learn”. Many school based VLE (Virtual Learning Environments) use simple systems to try and give students questions and support based on their wrong answers, which is a simple learning mechanism.

Communication

Many candidates will be familiar with smartphones and tablets that have devices that “talk” to you and many help centres have automated phone systems that take questions and replies and move you through various queues to get to the area you need. How much can a machine actually communicate to us naturally?

Perception

Many machines are quite capable at speech and visual perception and can have a huge bank of images or sounds available to quickly process the data to get a good response. In many cases, they may be as good as any human. For example, if a computer had every single image of skin cancer known in its database, it may be able to decide if a patch of skin was cancerous or not long before an expert was available.

Motion and Manipulation

Machines are also good at detecting and acting on motion and being able to manipulate objects. How much of this is intelligence?

Social

Many toys these days have the seeming ability to interact with us and display what we would consider emotions. These sorts of AI devices are expected to offer a great deal of relief to elderly people who no longer have close family or friends to interact with. How effective can these be at accurately interpreting a human's state and responding correctly?

Creativity

Most people who study the history of humans cite cave paintings and other decorative objects as the turning point in our intelligence. How much can machines replicate or improve on this?

General Intelligence

Putting all the above together, you have more or less what it is to be human. Therefore, it is the overall aim of AI research to reach this point. Some would argue against this as it is going to render people, in some instances, of little or no value. This then becomes a philosophical issue.

If it was at Level 1, students should be at least familiar with some of these areas of research and development and how they can be used, even in a small way, in their own engineering projects. At Level 2 we would expect a bit more independence in terms of research and understanding.

1.2 I can describe, with examples, the main uses of artificial intelligence.

Candidates should be able to describe, perhaps by creating a table, the main uses of AI.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
It is likely that candidates have come across a number of uses of AI in their lives, and may not even have been aware of the fact. Some have already been listed in the previous overview of AI. Candidates need to list and discuss some of the main features of a number of these applications and focus on the ones that interest them. This could be a useful criterion for inter-departmental collaboration as applications of AI cover most academic disciplines to varying degrees.

https://en.wikipedia.org/wiki/Applications_of_artificial_intelligence

1.3 I can review some of the expectations of artificial intelligence.

Candidates should be able to give some clear details of their chosen examples from 1.2.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
It could be useful here for candidates to put together a presentation of their examples of AI they have found. They can present this to the rest of the group for feedback as it will enhance the entire group's understanding and appreciation of the applications and uses of AI. Hopefully the group will have a wide enough range to cover all aspects. If need be, assessors can chose the areas for candidates to investigate so that the group can come back together and discuss their findings. If any companies local to the centre use any form of AI, this would be a good opportunity to get some hands on experience for the learners.

1.4 I can review the intended uses of artificial intelligence.

Candidates should be able to demonstrate a broad understanding of using AI.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
In order to fully appreciate the study of AI, it is useful for candidates to have an understanding of the wide range of uses and also future proposed uses. This overview will help them better evaluate the suitability of designs and uses and be able to make more informed judgements. Probably the closest to their own experience is the use of AI for education. Some companies claim to use AI in a benign way in order to help students learn better. For example, many companies offer maths tutor programs. Some claim that they use sophisticated algorithms to personalise the learning of each student and therefore maximise their results. Candidates can use some of these tools as a starting point to evaluate the use of AI. Do they help them achieve better results. What aspects of the AI make this work. How does this compare to a human teacher. These are important considerations for candidates to explore as we venture further into AI.

In a competition in the US in July 2016, contestants were set the challenge of making software that could fix security problems. The US government is investing a great deal of money in making self-healing computer systems and already Google and Apple use these types of systems to cut back on costs of employing people. When Instagram was purchased it had less than 100 employees, but made billions of dollars. Car companies making the same money 20 years earlier employed hundreds of thousands of people.

1.5 I can identify some of the strengths and weaknesses of using artificial intelligence.

Candidates should be able to demonstrate an appreciation for some of the good and bad aspects of using AI.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Clearly there is a great deal to be gained from the use of AI. It would be hard to dispute the benefits of using AI for checking medical photographs for particular diseases or infections, or the use of AI machines to take away some of the monotony of jobs for people so that they can carry out more meaningful tasks. However, both of these also carry dangers. An over reliance on AI for any task will always carry a certain amount of risk that the AI is not accurate enough and might miss some nuance that a trained expert would see. Can AI be used to hurt people?

http://www.bbc.co.uk/news/technology-36517340?ocid=socialflow_twitter

If AI is used in finance to help large companies make lots of money at the expense of others, is this a good use? If AI through Google and other large corporations controls how we get our information, do we still live in a democracy?

Clearly there is a need to understand some of the problems as well as the advantages of AI going forward and candidates need to show a reasonable awareness of the issues.

1.6 I can describe any legal and ethical issues associated with using robots.

Candidates should be able to describe the legal and ethical concerns.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Many people argue that the best way to make sure that AI machines do not harm people is to make them like people. However, one thing history shows us is that humanity is more than capable of extreme cruelty to others, so why would making a machine be like us stop this effect?

There are various laws that apply to AI and perhaps the most famous is from some writing by a science fiction writer Isaac Asimov. His three laws of robotics are:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

The main thing here is perhaps the intent of the designer. Anyone making a machine using AI is obviously building into the control of the machine their own interpretation of the world. If they build the AI to do harm, then that is what the machine will do, so perhaps it is here that intervention and rules need to be applied. In this instance, the development of AI needs to be open and transparent and therefore open standards and open source principles are perhaps the best to use.

Some of the legal and ethical areas that candidates can explore and discuss include (though are not limited to):

- Rights - should AI machines have the same rights as us
- Privacy - if AI can understand and report on all our conversations, what if it is used by government to control us
- Dignity - should AI devices treat the old and sick, can they be good soldiers or police
- Weapons - should AI by used in warfare
- Ethics - should AI be autonomous and make its own decisions

2. Review examples of where robotics is used.

2.1 I can describe instances of robotics in industrial places.

Candidates should be able to list, with guidance, the main industrial applications of robotics.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Robotic arms have long been used with some effect in industry. Some of the first robots were used in manufacturing as early as the 1960s, though mass deployment occurred in the 1970s, particularly in japan which today leads the world in the development and use of robotics. Candidates for this criterion need to describe a number of robot applications used in industry, such as in car manufacture or even the automation of book orders from large retail companies. There are plenty of examples to draw from.

2.2 I can review how robotics is used in medical applications.

Candidates should be able to give some examples in their own words of robots used in medicine.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The use of robotics in medicine is relatively new, having first appeared in the 1980s, but it has accelerated in the last 10 years. In 2006 a robot device assisted with a successful heart surgery and was rated better than any existing surgeon. The device had a database of 10,000 operations to call upon in order to work which is more than any surgeon would have experienced. Robots have assisted across the range of surgeries and continue to evolve and improve with feedback. Candidates need to investigate some of these examples and write what they feel about the

current status. They could also investigate and comment on the development of nanorobotics which are intended to be injected into patient's bloodstream and be able to fix people at the macro level.

https://en.wikipedia.org/wiki/Nanorobotics

2.3 I can describe how robotics is used in agricultural environments.

Candidates should be able to list, with guidance, the agricultural application and use of robotics.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The main use for robots in agriculture is in the automation of harvesting of crops, but they are also being developed to tackle weeds and other areas. In harvesting, different robotic arms are developed to deal with different fruit and vegetables. Fruit such as grapes are quite delicate and require sensitive robotic arms to cut and collect them without damage. Robotics is also used to automate things such as milking. Cows carry an identification chip in their collar which is radio enabled. As they enter the milking shed, their details are read by the milking machine. They are then cleaned and a laser pinpoints their udders to attach the milking device. They go into the shed when they feel the need to be milked and are given an appropriate food ration whilst being milked. The milk is also automatically tested and accepted or rejected. According to various farmers the system has increased yields as it is less stressful than human intervention. Other uses for robotic devices are in automated tractors and watering systems. Candidates can choose their own examples and those who live in rural areas may be able to collect direct evidence of this use from their own local farms.

2.4 I can assess the wider use of robotics in society.

Candidates should be able to show other areas of robotics use.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
This criterion is an opportunity for candidates to explore the wide range of robotic use outside of the previous more commonly known areas. They can tie this in with other units and look at the use of robotics in space and microsatellites where a robot makes a lot of sense in terms of working in zero oxygen and zero gravity. Areas might include robots around the home, such as the robot vacuum cleaners and lawn mowers used in some homes. They might also explore uses in education and sports. Candidates are not expected to go into a great deal of depth, but need to show that they are aware of the wide range of applications and uses of robotics. This will help inform their other areas of study and also any future progression in the field of manufacture.

2.5 I can assess and comment on the dangers associated with the reliance on robotics in society.

Candidates should be able to show that they understand some of the dangers of using and being reliant on robots.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Candidates in the above criteria will have looked in some detail at the various uses of robots and can now be in a position to think and comment about some of the potential dangers. While some of the dangers may appear in the realms of science fiction, there is an important point here that as robots become more successful at solving problems for us, there is a creeping reliance on them to do that work without supervision. The most

contentious developments are possibly in the field of warfare. The US are said to be developing robots to be able to go into battle in order to take away the risk from real soldiers. However, what sort of programming will they receive in terms of life and death. A famous book and film from the 1970s, Westworld, explored this very effectively, though there have been many others.

https://en.wikipedia.org/wiki/Westworld

In this book/film, robots are used to populate a theme park. The real people can go to different worlds and interact with the robots. The most popular is a Western where people can have harmless (for them) shootouts with robot cowboys. As you might expect, the robots malfunction and start turning on their "masters". This is played out in many books and films, but it plays on real fears of most people. At what point do we over-rely on robots and how can we turn them off when they get nasty.

Are we ready to have robots be teaching us in the classroom?

http://bit.ly/28Y2tDY

Candidates might be able to explore this criterion as part of their PSRE or English lessons, or during tutorials to full appreciate the social context of these technological developments more widely. In the Summer of 2016 the first driverless car was involved in a fatal accident which makes this investigation all the more important.

3. Identify the processes of making a basic robot work.

3.1 I can review the equipment required to design and create robotic devices.

Candidates should be able to show familiarity with some of the tools available to create robots.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
In many cases, there will be software tools which come with devices and candidates just need to show an awareness of some of their more understandable features. This is an exploration of what is available and centres are free to explore as much or as little as they need in order to give learners the confidence to be able to move forward. Candidates should be aware that robots are designed with software and controlled with software, so a familiarity with a range of tools will make sure they are equipped to investigate the field in some depth at a later date as they continue their studies. Some basic robots might have a hand held controller, but candidates can still explore how this might work and some of the functions that it has and see how it relates to the movement of the robot itself.

3.2 I can assess the design tools used to create robots and use these in a basic way.

Candidates should be comfortable around the various tools used to design and create robots.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Candidates do not need to demonstrate high levels of competence in the use of 3D software or programming languages, but should be able to show that they are aware of the application of these types of systems and applications in robot design and manufacture. This is also a useful point to look at other subjects that support the development of devices such as the use of smart products and design tools. If centres have access to 3D printers they can explore the functionality and usability of these devices and the software design tools that come with the devices. There are open source software and proprietary versions available that can offer either real world control and robots or virtual versions. In both cases, the candidates

will gain experience of the process of design and construction. In some instances, it might be enough to demonstrate to a group how software can be used
and some of the likely end products and as they gain confidence they can explore on their own. Software such as EZ-Builder (https://www.ez-robot.com/EZ-Builder/) may be a useful starting point, but there are plenty of packages on the market to explore.

3.3 I can work with various components of robot design and appreciate their features.

Candidates should be able to understand the main components and separate parts of a robotic device.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
This criterion is deliberately open so that centres can use whatever materials they are comfortable with and have access to. In some cases, centres will have staff experienced with robot design and construction, but in most cases it will be using pre-made kits of devices such as the following or similar:

https://www.intorobotics.com/47-programmable-robotic-kits/
http://www.robotshop.com/uk/

These types of systems can be purchased with varying levels of complexity and numbers of elements. Candidates should be able to appreciate that robots are designed to mimic human functions (for the most part) so it would also be useful to see the human equivalent so some overlap with biological sciences and physics would be useful. How does the hip joint work, how do muscles and bones work together to lift weights etc. Understanding these will help candidates better understand what is required in a robot design to make it do similar, but also to see some potential limitations. Most materials that robots are constructed from are not the same as human equivalents so there will always be limitations in something like flexibility and endurance. Understanding these will help students make better quality design decisions in their engineering projects.

3.4 I can build a basic robot for testing.

Candidates should be able to participate in building a basic robot system.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Many engineering projects involve a great deal of teamwork and people working on their own specific areas of specialism. However, it is only in being involved in the entire process do people really appreciate the project. Therefore, it is good for candidates to be involved in constructing and controlling a robot as part of a team or on their own. Centres should either build a working robot a a class based project, or as small teams, but not discourage students who are confident of their own abilities to work alone. This will ensure that candidates can appreciate all aspects of robot construction, even if they are not involved in individual aspects. Candidates should also be shown, or have the opportunity, to be able to test out some ideas about a robot's functionality. What changes can they make to the device or the control software and what effect might it have? Did the change have the expected effect? If not, what more needs to be done and what improvements can be made.

4. Appreciate and test the issues and challenges of robotics.

4.1 I can test the build quality of an assembled robot against a specification.

Candidates should be able to appreciate quality control issues in engineering.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
In most cases, unless it is an open source project, candidates will not necessarily have a detailed specification about how a device is built. There are open source projects available which are good starting points.

http://www.turtlebot.com

Some of the design features might be protected by intellectual copyright, but they can still see enough details about some of the specifications to discuss and understand with support some of the design features. It may be something relatively easy to see, for example a robot built using a 1st generation Raspberry Pi, as that was available at the time, may be far more effective with a 3rd generation board due to the improvements in processing power and control software. The rate of development in technology is very rapid and many companies will need to move on their designs even though they may find them unsuitable by the time they are ready for market. In this case, their design skills will hopefully win out. The key thing is for candidates to be able to compare and contrast finished products with their understanding of what was intended. They should be shown how to look for design details and match them to available hardware and software, even if at this point in their journey they don’t fully understand the intricacies.

4.2 I can test the main features of a built robot in terms of hardware and software.

Candidates should be able to appreciate some of the main features of hardware and software used in robotic products.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Robotic devices, as determined in earlier criteria, are built for specific purposes and usually to emulate some aspect of human action. This means that they are quite specific in what they can do and how they can do it. In manufacturing systems, there are multiple robotic arms and each one carries out one small part of the entire process. They can do this with great precision and at great speed, but they can do little else. In looking in detail at some robotic project, for example the TurtleBot listed in the last criterion, candidates can investigate how well the tools are matched. Does the hardware work in all types of conditions, or are there some obvious limitations. If the candidates want the device to do X, can it actually do it with the given hardware. Many people these days use the popular robotic vacuum cleaning devices. These can be left at home during the day to potter about and clean the house, but they can't clean the stairs or clean the cobwebs lurking in the ceiling corners. What kind of device can be used for this set of tasks? Equally, most robotic devices come with some proprietary software or with an SDK (Software Development Kit). How much knowledge is required to take full advantage of the SDK version? Is the software easy to change and understand? Many robots now use an Open Source Linux based operating systems called Robot Operating System or ROS. This has all the basic functions required to run any robot device, but is open source and community supported which allows people to build the functions they need on top of it easily and cheaply. At this level, it is enough for candidates to be shown some of the answers to these questions and show some sense that they can ask their own questions relating to the equipment available.

4.3 I can make adjustments to a robot build or control system to improve its functioning.

Candidates should be able to list a number of basic changes to a design.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
As with 4.2 above, candidates will not be expected to have the sophisticated manufacturing and development skills to be able to recommend precise adjustments, though this should be encouraged, but they will need to show an appreciation that these are possible. It may be enough at this level to work with existing examples in development kits which allow candidates to explore the ideas and see the results for themselves. This will hopefully lead them to begin thinking of their own adjustments as they start to appreciate how the hardware and software interact and what they can do to modify them.

4.4 I can recommend additional features to existing designs based on usage.

Candidates should be able to identify possible improvements.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Most of us are sold on the surface features of products and it is only after some time that we realise they might not be as good as we thought in our own situations. For example, some smartphones are made as thin as possible for carrying convenience and lightweight feel, but this means that the structural integrity is compromised and they end up having cracked screens when people sit down with them in their back pockets and they bend. This is probably an acceptable compromise as people value the convenience over the small(ish) chance of the screen damage. It is likely

that the designers of this product did not think that users would put them in their back pocket and sit down on them. This is the sort of understanding that only comes about because of usage. Candidates here need to consider some of their own observations that come about in usage and try to formulate some design improvements to try and overcome or at least minimise this. It may be something quite basic or something fundamental, the point is that they think about how they could improve some features. This type of thinking will help them in the future to design better products for manufacture.

Unit 4 - The Development and Deployment of Unmanned Vehicles (UV) 40 TQT, 4 credits

1. Understand the history and range of uses of UVs	**2. Appreciate the design and development issues related to UVs**	**3. Explore the problems and solutions of UV usage**	**4. Understand the legal, moral and ethical issues related to UV use**
1.1 I can research the history of UVs and list the key milestones	2.1 I can describe the range of designs currently in use	3.1 I can describe the main control methods used with UVs	4.1 I can describe the legal issues relating to UVs
1.2 I can list the primary uses of UVs currently in operation	2.2 I can assess the designs in terms of their use	3.2 I can assess the development constraints that apply in building UVs	4.2 I can assess the main laws and regulations that affect UVs use
1.3 I can explore the extended range of uses of UVs	2.3 I can assess the main materials used in the construction of UVs and list their strengths and weaknesses	3.3 I can describe the key requirements of endurance and reliability of UVs	4.3 I can review the ethical concerns relating to UVs in a commercial setting
1.4 I can describe the use of UVs in civil and military situations and give examples of each	2.4 I can describe the main forms of UVs based on their use and required characteristics such as range, height, speed, payload	3.4 I can design my own basic UV based on my understanding	4.4 I can review the ethical and legal concerns relating to UVs in a military setting
	2.5 I can describe the software and hardware used in UVs	3.5 I can describe the features and use of my UV	

Expansion of the assessment criteria

1. Understand the history and range of uses of UVs.

1.1 I can research the history of UVs and list the key milestones.

Candidates should be able to show an appreciation of the development of UV over time.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The majority of UV are called "drones" and this is the popular perception of these devices. The term itself is rather loaded and emotional and most people would associate this with weapons that are used in war. Though the majority of UV are used in a military setting, it is not the only use.

Various starting points are cited for UV, with the earliest being the use of hot air balloons filled with explosive being sent by the Austrian army against Italy. Using that example, the same could be cited for the flaming ships which were launched against enemy fleets in various wars from ancient Greece onwards. In the 1930s, something more akin to what we would understand as a UV was used by the British Navy. They had radio controlled planes that were used by the military for target practice, a system that was copied by the US military around the same time. These were more like the UV that we would understand in today's marketplace. These target vehicles continued to evolve but by the time of the 1970s they were beginning to carry surveillance equipment and be used to gathering intelligence in battle zones. These intelligence gathering UAV are widely used to this day. Many systems developed by the military have subsequently become part of everyday commercial use, such as mapping technologies used for items like SatNavs in cars or the weather maps on TV.

Since the early 2000s, many UAV have been developed to be weapons to either be delivered as bombs or to deliver bombs and missiles.

The history of Unmanned Ground Vehicles (UGV) has a similar timeline as it has a similar technological need. Remote controlled cars were developed as early as the 1920s. As with UAV, the main developments have been in terms of military use, though there are also radio controlled tractors in agriculture. The latest developments are for unmanned cars and buses which is being explored by a number of countries. There are also a number of cities that use unmanned trains, for example the Thames Link trains in London.

Water based vehicles are relatively new as the technology required, relating to the pressure in the sea, has been harder to overcome. The earliest versions were for underwater recovery in the 1970s and this technology as taken up by commercial companies. The most high profile of these would be in the recovery of resources or for historical interest, such as the Remotely Operated underwater Vehicles (ROV) used to film and document the Titanic wreck or other famous shipwrecks.
Other uses are for science and education as they can be controlled remotely to dive to great depths to collect specimens or in places that are difficult for people, such as under ice sheets.

Candidates can document the history in their own words and give examples of what they think were the major milestones.

1.2 I can list the primary uses of UVs currently in operation.

Candidates should be able to show the most widely used areas of UV usage.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:

Clearly the military is the biggest user of UV as they tend to be the organisation with the largest budget to be able to afford to research and develop the devices as well as use them. According to this web site: https://www.nationalpriorities.org/cost-of/drones/ the cost of "drones" for the US tax payers are $116,063 per hour! Clearly there are not many companies that can afford that sort of outlay.

Other than the military, the largest user of UV, at least in the US, is for construction purposes.

http://www.devoredesign.com/2015/07/31/for-the-first-time-ever-commercial-drone-usage-statistics/

UAV are used first of all to find good land to build houses on, so the land is surveyed and images are taken to look at the layout and the available resources such as water and other elements. Once the buildings are made, they will need to be inspected from the air to make sure they are properly constructed. The UAV will also explore the surrounding area to give precise measurements for marketing materials, "only 2km away from the nearest train station" or something similar. The aerial maps can be used in brochures to sell the housing.

UAV are increasingly used in monitoring wildlife. The devices are used as they do not tend to disturb the wildlife as much as people or other vehicles. In the BBC programme Springwatch in 2016, a UAV was used to check the numbers of seabirds on a cliff face for the first time. It was easier to send in the UAV from a boat below the cliffs than to let someone climb down and scare all of the birds away, which would have made counting them almost impossible. UAV are also used to try and track down poachers in Africa who are killing Elephants and Rhinoceroses for their tusks and horns, or even to stop poaching of Orang Utans. The devices can be operated from a remote location so are much more flexible and cause less disruption to other species. UAV are widely used in New Zealand where they are replacements for sheep dogs and they can monitor and herd the millions of sheep that live there.

Candidates can document the areas that they are interested in and have the most information they can understand.

1.3 I can explore the extended range of uses of UVs.

Candidates should be able to show they understand the most current state of the market for microsatellites.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The useage of UAV, either on land, in the air or in the seas by the military, is probably more developed, but might not get as much coverage due to the emotional impact of their use in war. Here is a list of areas where UV are used extensively, though it is not an exhaustive list.

- Agriculture
- Search and Rescue
- Films and Commercials
- Sports
- Wildlife Management
- Science/Environment
- News reporting
- Real estate
- Mapping
- Delivery
- Monitoring
- Communications

List from: http://diydrones.com/profiles/blogs/examples-of-non-military-non-police-use-of-drones-please-add-your

Candidates can explore and document some of these areas depending on their interest and career preferences.

1.4 I can describe the use of UVs in civil and military situations and give examples of each.

Candidates should be able to describe in some detail some specific uses.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
This criterion is an extension of the earlier criteria and allows candidates to go into some detail about the information they have found. If they are interested in the use of UV for wildlife management, can they give some detailed strengths and weaknesses of the use of the device to support their choice. They can provide images to show the devices in operation and perhaps label some of the ways they are used effectively, while also showing some of the limitations.

The military use is obviously a sensitive one because the statistics for their use obviously involve the loss of life. This is unfortunately a reality of this technology which candidates need to come to terms with.

2. Appreciate the design and development issues related to UVs.

2.1 I can describe the range of designs currently in use.

Candidates should be able to show some of the designs currently available.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:

Candidates can produce a table or a report to list and define some of the main designs used today. The main areas will be related to sea, land and air and if they wish they can cover all of these or some detailed examples of one particular area, for example all of the different designs for unmanned submarines. This criterion will be in conjunction with the next one which looks at the designs in terms of their intended use.

The main aerial designs tend to be either small plane or helicopter based formats, though some of these can have multiple propellers. They can vary in size depending on the range required and what they will carry, which is something addressed in a later criterion.

Most of the land based devices tend to be like small tanks, presumably since this is the most efficient and effective way to travel across any terrain. This is also useful on other plants as devices like the Mars Rover show. Some military devices are experimenting with insect like forms as the multiple legs are less likely to get stuck on small inclines.

The main underwater designs generally tend to be small version of the others. Water can sustain all types of shapes and weights so they are less restricted in their designs, though pressure is a key factor.

It would be useful for students to create a presentation or report of the different designs perhaps showing as wide a range of types as possible for examples. This will help inform them for their own ideas and possible designs.

2.2 I can assess the designs in terms of their use.

Candidates should be able to show they understand the relationship between design and purpose.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
In manufacturing terms, devices have to be made for their intended purpose and this will vary greatly. If the designs are for underwater work, then making them from flimsy plastic will be unsuitable due to the immense pressures. Equally, the use of dense metal might make a UAV very strong, but might make it impossible to get off the ground. In some cases, such as with the Mars Rover, some amount of assumption would need to be made. Although there have been missions to Mars and various probes, there is no way of knowing exactly how the device would respond when actually on the planet and how well the internal devices would work.

In most cases, the designs and materials can be tested with simulation software or through the use of practice environments. This will be easier for land based devices, though it would be difficult to replicate the deep sea pressures that ROVs might face. Air based devices can be tested in wind tunnels for aerodynamics.

Candidates need to pick a variety of devices they have found through their investigations and discuss how they think they work in their intended situations. Do they work well in terms of payload, distance for travel, on-board equipment and other factors? Is there a point where the device needs to be compromised as it can't carry enough or can't maneuver well enough? How do you decide what to leave out. Could candidates suggest improvements to a design and justify why they have done this?

2.3 I can assess the main materials used in the construction of UVs and list their strengths and weaknesses.

Candidates should be able to explore devices specifications and look for ways to improve them.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
This is tied in with the above criterion. What materials have been used and what properties do they have which make them most suitable. Could other materials be used? If so, why weren't they used instead. Candidates can investigate some of the material properties, where possible, such as strength to weight rations or cost. Some materials might be difficult to obtain or in short supply, so alternative are used. They may not be as good, but are available.

Even aluminium used in aircraft is considered too heavy for UAV as the weight would greatly reduce their operational range. Therefore, most of them are constructed with composite materials. These are generally some form of Fibre Reinforced Plastic (FRP), though early versions were Glass Fibre-Reinforced Polymers (GFRP). As the technology of materials advances, so does the use in UV increase. The most advanced, currently, is Carbon Fibre-Reinforced Polymers (CFRP). These devices are 5 times stronger than the same element made from metal. This does come at a cost however and they would be 20 times more expensive than using glass fibre based elements.

http://www.azom.com/article.aspx?ArticleID=12234

The above page has some useful links exploring the future of UV and the materials that make them.

A table listing materials and describing their relative strengths and weaknesses would be useful here.

2.4 I can describe the main forms of UVs based on their use and required characteristics such as range, height, speed and payload.

Candidates should be able to demonstrate a clear understanding of the range of characteristics of UVs.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
This criterion could be an extension of earlier ones since it is elaborating on the detail of information about specific types and forms of UVs. Candidates can fill out a report or table listing some of the attributes of the UVs they are exploring in other sections of this unit. The following is an overview of areas they can explore.

UAV
For UAV, candidates can explore what the different ranges are and how these are affected by conditions such as temperature and altitude. What can the devices carry, and how does this affect their range, speed and possible altitude. What sort of speeds can they obtain and what are the various ranges of speed. Does the speed affect their functionality so that the faster they go the less they can do. If they are too slow, does it minimise what uses they have, or is this a positive attributes. Part of this is looking at the way technology is moving. Other sections are looking at improvements in build materials, power plants and instruments. All of these should have an impact on their speed and range.

Facebook are currently developing a new UAV called Aquila which is designed to give remote parts of the world access to the Internet. The UAV will fly at an altitude of 20,000m and can stay up via solar power for 3 months at a time.

http://www.bbc.co.uk/news/technology-36855166

ROV
Are there any restrictions to the depth that the devices can submerge to. If they are attached to a mother ship, this will give them more operational time, but will it limit how deep or how far they can dive. What restrictions are there in terms of pressure they can withstand. The deeper they go, the more need there is for lighting. Lighting requires a great deal of energy,

which means they will have to carry more and more or be tethered to a power supply, which will limit their range and depth. What speed can they travel at and how much flexibility do they have. Do they need to be able to travel at great speed.

Some recent developments in underwater UV are based on swarming techniques and are designed for search and rescue in deep water. The devices work like a carpet that scours across the seafloor looking for debris or materials from shipwrecks and plane crashes, as well as resources for mining. The main issue with them is with communication, as discussed in later criteria.

UV
What are the restrictions on speed that are determined by the terrain they need to move across. Are there any restrictions to environment as far as operation. Do they work well in extremes of cold and heat, or can these be adjusted for. If they carry a great deal of equipment, what impact will this have on their range and ability to move effectively.

Candidates can answer some of these questions and their own questions to make sure they have a good understanding of the way that devices can be used in different settings as this information will help inform any designs they might have to make in the future.

2.5 I can describe the software and hardware used in UVs.

Candidates should be able to describe the control systems for UVs.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The hardware used for different UVs is going to either be with someone close to the device or very far away, but the hardware will be similar in what it is trying to achieve. If it is a UAV, there will need to be some sort of

hardware system with levers for speeding up and slowing down, as well as moving in different directions. For basic UAV, the overall control will likely be via a visual operation with the control person in sight of the device. More long range devices, especially if they are in dangerous places, will be controlled via an onboard camera which will relay film back to the operation panel for action. These devices may well have sophisticated sensors onboard for height and operating temperatures, as well as for control of attached equipment. All devices will have software programs running via embedded circuitry to relay the instructions and carry them out. They will have other hardware such as servos to move wing parts or other attachments.

The explosion, especially in terms of cost of commercial devices, has been helped by the revolution in open source hardware and software. It is now easy to get control software and use powerful embedded systems to carry out sophisticated maneuvers even on hobby based UVs.

The latest UAVs have a sophisticated software called **Hydra Fusion** which uses a system of simultaneous localisation and mapping. Sme ground based devices have a similar system. In UAV, it works by the device stitching together the video images as they are taken to create a 3D map of the surroundings in real-time. This can happen at relatively high speeds and means that the UAV can determine how to navigate complex and unknown surroundings quickly. This is made possible using the same GPU (Graphics Processing Unit) technology that game developers use.

Some UVs can now “think for themselves”. The devices use learning software which allows it to make its own decisions about the correct speed, height and direction etc. The software is also being developed in order to avoid collisions and be able to track specific items such as people or animals.

Further developments are being undertaken in using swarm based simulations. Many people are familiar with how birds and other animals manage to swarm in great numbers and not bump into each other. Tests are currently underway to allow UAV to work together and follow the lead of one UAV for guidance. Tests have been effective with several UAV navigating a wood together.

The Mars Rover has been allowed to “do as it wants” on mars by the team in control of the project. Some software on the device has been enabled which allow it to go wherever it pleases and to use its laser tools to gather data about any rocks that it “thinks” would be useful.

Devices are currently being developed to search in deep ocean places. The main problems here are with maintaining communications. The best option at present is with the use of blue light as this passes through water relatively easily. Radio communications used in other UV does not work in the density of water so well and sound would not work due to the sounds in the sea such as mammals like whales. One solution would be for one of the devices to surface to get information and location information and then re-submerge and transit this information to the rest of the swarm.

3. Explore the problems and solutions of UV usage.

3.1 I can describe the main control methods used with UVs.

Candidates should be able to show the methods of controlling various UVs.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Different types of device will be controlled in different ways. In some cases, they will be controlled with some hand-held device sending radio signals to the device. In other instances, the control will be built in via software to the device itself and a control panel will be set up remotely to control the movements and actions. As with all elements here, a certain amount will be determined by the purpose of the device. For example, in a recent

geological survey a small radio controlled helicopter was used to survey a newly forming island in the seas off the coast of Japan. The small helicopter was sent to the volcano in order to photograph and sample the eruption. The survey ship, for safety reasons, was not allowed any closer than 4 km which made it very difficult to see the device to control it, though the control system on the ship was not sensitive enough to deal with landing and takeoff from a rocking ship. The solution was to have a skilled person deal with takeoff and landing using a hand-held controller. Once in the air, the onboard camera was used in order to control the helicopter through seeing what it was doing, as well as other sensors looking at speed, height and temperature.

What other types of systems can be used. What are the basic characteristics of control software. Candidates can explore and document some features of control, again depending on devices, and show that they understand that the control needed for an ROV will have some similarities with a UAV, but also some stark differences.

3.2 I can assess the development constraints that apply in building UVs.

Candidates should be able to have an appreciation of some of the manufacturing constraints in their projects or the projects of others.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Most of the constraints that candidates will face with their own designs are likely to be related to size. Even if they use smart technology such as 3D printers to make their designs, they will be restricted by how big they can make the device and this, as they will know from earlier criteria, may affect the functionality of the device. Looking more broadly, what other constraints might be general to this type of advanced manufacture?

One high profile company used $3.5 million of kickstarter funds to develop and sell a hand sized UAV but eventually had to close before going into production. The main problems they had were buying too much stock and the failure of the hardware and software combination to "scale". The hardware and software worked well on prototypes but the tolerances used in mass production made them fail.

https://www.kickstarter.com/projects/torquing/zano-autonomous-intelligent-swarming-nano-drone/posts/1424636

Are there lessons to be learned from this failure? If so, what might they be.

One other major development constraint, which is addressed in other criterion, is the issue of privacy and safety. While these are more moral and legal concerns, they also impact on the manufacture and design stages of the process. The devices must have some systems to prevent accidents. If the UAV goes out of "line of site" of a controller, it is effectively out of control. If it then ventures outside of safe airspace, the controller is unaware and can't stop it from becoming dangerous to other aircraft. What mechanisms can be built in to prevent these issues. How can the devices be prevented from snooping on people who have not given permissions. Should there be some way to prevent them taking images without prior authorisation? How would this be achievable?

Other development constraints are related to cost and materials. The latest and greatest technologies are not always available to companies other than government agencies that can afford it and some of the testing required can be costly, especially if it results in many broken prototypes.

There are also considerations to key components such as the propellers and motors used in designs of UAV. What sort of power will they use, how stable are they, what sort of stress can they withstand for example.

http://www.robotshop.com/blog/en/make-uav-lesson-3-propulsion-14785

Candidates are not expected to come up with their own conclusions, but are encouraged to read around this topic and offer some sensible suggestions based on their understanding, no matter how basic that might be.

3.3 I can describe the key requirements of endurance and reliability of UVs.

Candidates should be able to describe what features aide endurance and reliability.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
Any device that is manufactured requires a great deal of precisions, especially with moving parts that create large amounts of friction or resistance. If a propeller on a UAV is out by a tiny amount it will not work well enough and will create wobble and wear, as well as affect the overall performance.
Some of the main considerations for UAV are likely to be related to the following, though there will be an overlap with ROV and water based UV

Motors
Most motors used in UV are based on coils and magnets. The magnets are pushed around the inside of a casing as they jump from one magnetic field to the next. This rotation is then transferred to a wheel or a propeller etc. There are different type and sizes of motors available and in designing a UV, these would need to be considered carefully. One very important consideration is how fast the motor will rotate with the amount of voltage available. For UAV, it is preferable to have a lower KV rating of 500-1,000 as this will make the device more stable and easier to control. KV is the

rpm per volt. In manufacturing the device, the voltage can be regulated to get the desired spin speed based on this KV rating, so for example:

A voltage of 6.5V with a KV rating of 550 would result in a spin speed of 3,575rpm. Increasing the voltage to 8.5V would be 4,675rpm.

A similar calculation can be made for thrust. Some motors would be rated by saying that a certain size propeller on the motor would be able to lift 400 grams. When designing and manufacturing your devices, you need to make sure that there is enough thrust to get into the air or move across the ground. One thing to bear in mind is that this value is the **maximum** thrust. Therefore, if you build a device that weighs 1.5kg, you really need to have about 3kg of thrust, or the ability to lift 3kg, otherwise your motors will be flat out all of the time and will probably burn up quickly.

Propellers

Propellers required are generally two blades and light and small so that they can spin faster and slower quickly and therefore be easier to adjust. This will be useful in trying to fly in confined spaces where precision of placement is important.

There is a great deal of complex physics involved in propeller design, but candidates just need to know some of the basic elements, such as the angle of attack, which is how much the propeller is angled down compared to where it is attached to the motor rotor arm. This helps push the air down as it spins. The other important measure is the efficiency. Most propellers are no more than 80% efficient, which means they can't use all of the power given to them to produce thrust. Also, instead of making very large and unwieldy 2 blade designs, they can use 3, 4 or more blades which reduces the radius required. This makes smaller designed vehicles easier to create.

The propeller material will be chosen based on how much weight reduction is needed as plastics will be lighter. Some vehicles require more rigid propellers, so wood is used as it will not flex as much. As the propellers spin at very high speeds, it is important to make sure they are properly balanced as they could easily spin away from their mounting and damage the device or people nearby.

Speed Controllers

Mose UV are used in very controlled ways, such as an ROV trying to collect samples of animals in a deep ravine or a UAV flying close to a cliff edge to film a particular bird. In most cases this requires very precise and fine controls of the device. This control is made possible by the connectors which attach the batteries to the powerplant (propeller, tracks etc). The regulation of the power to a device is important, but especially so with a multi-propeller device as a slight variation in the speed of one rotor will dramatically alter the way the device operates. Most UV will have an onboard ESC (Electronic Speed Controller) in order to carry out these precise controls of power to each propeller or wheel etc.

Batteries

Most UV that are operated at a distance from their operator, or remotely from a far away location, will tend to use batteries for their power. Some can have solar cells, but these are not always practical and possibly unlikely to be used by most students in their designs and use. The majority of UV batteries are made from a Lithium base. These batteries are light but powerful, so perfect for this task. Older batteries were made from Lead or Nickel.

Batteries will be measured in the amount of output voltage they generate and also the overall capacity which is measured in amp-hours (Ah). Most UAV will be able to fly for about 20-30 minutes before the battery runs out. The design consideration here is the more capacity, the heavier the battery pack will be.

Some useful details can be found on this website:http://www.robotshop.com/blog/en/make-uav-lesson-3-propulsion-14785

3.4 I can design my own basic UV based on my understanding.

Candidates should be able to show they understand the key aspects of UV by designing one with labels.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
It is not expected that all candidates will have the facilities to build their own UV, though this would be beneficial for their future studies. As a very minimum, it would be useful for candidates to design their device, whether on papers or with CAD software, so that they can show they have incorporated some of the understanding from other criteria in the unit.

Their design should show some consideration of the purpose of the device and what it is intended to do, perhaps related to some of the candidate's research on other similar devices.

3.5 I can describe the features and use of my UV.

Candidates should be able to describe their design's features.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
This is an extension of the previous criterion. There should be some labelling about what the power source will be and what characteristics this will give the device. There should be some idea of the control mechanisms and also some of the limitations of these. The main features should be related to some of the equipment or materials on the design. They might

have a multi-propeller design as it will be much easier to control in small spaces as they intend to use it to film in a cave or similar closed environment. They might label and show the specifications of onboard equipment, such as an X megapixel camera to get high definition video of events at the school's sports day etc.

4. Understand the legal, moral and ethical issues related to UV use.

4.1 I can describe the legal issues relating to UVs.

Candidates should be able to list a number of key legal issues and their main features in relation to UV.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:

Privacy
The legal issue relating to drones mostly relate to the fact that they are able to go almost anywhere. The most obvious example here is that people with small UAV with cameras onboard can easily fly the device around where they live and film their neighbours. This may all be quite harmless, but it is unlikely the neighbours have given their permissions so it is a breach of their privacy. In recent years, as UAV have become cheaper, people have been flying them more and more and going higher. For people that live near busy airports, such as Heathrow or Gatwick, this means going into space reserved for commercial aircraft. There have been increasing numbers of incidents where UAV have been close to or in some cases hit aircraft that have been landing or taking off. The developments of UAV have been so rapid that it is difficult to get laws passed in response to them as the legal process if very slow. Most property law was designed to protect people's privacy on the ground around their property, but never dealt with the air above their property.

Anyone who takes pictures of people and places will be subject to the Data Protection Act which is designed to protect people from harm. It is fine to film your own family, but you can't just film anyone. Candidates should be aware of the DPA from other subjects.

If UV are used to film public places, they might also be in violation of copyright laws. If they film a company and do not get the permissions from the company to use the image, they will be breaking this law.

Health and Safety
Other legal issues relate to personal injury. Some of these devices are quite heavy with powerful propellers. They do crash and if they crashed into someone, they could cause serious injuries. One operator of a medium sized helicopter was killed when it crashed into them. How do companies offer insurance to deal with issues such as this?

Another health related issue is that the power cells on UV are quite toxic. If the UV is operated in a publicly accessible water venue and breaks up, it will leach all sorts of poisons into the environment. How can this be regulated and controlled.

4.2 I can assess the main laws and regulations that affect UVs use.

Candidates should be able to show they understand the need for regulation.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
This criterion is an extension of the previous one and allows candidates to explore their understanding of the wider issues. Given their understanding of the laws they cited above and some of the health and safety concerns, are the laws good enough to prevent too many issues. What other laws

need to be in place to limit some of the potential for damage. Who should be allowed to build and use UV and should they be available to anyone? Candidates should be able to give some examples of how the laws they identified in the previous section can be used to protect people and property, but also examples of where they can be broken, either deliberately or by accident.

4.3 I can review the ethical concerns relating to UVs in a commercial setting.

Candidates should be able to show they understand some of the ethical issues of UV usage.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
As with some of the legal issues above, some of the ethical issues revolve around the fact that UVs can go to places where it was difficult to go previously and they can go to these areas carrying cameras. The most obvious moral issue here is with the privacy of individuals. Some UAV are so small and quiet that people being observed would have no indication of the fact. Since anyone can obtain these UAV and they are relatively cheap, this means that anyone could use them to spy on other people.

Other ethical concerns could be in relation to ROV as they explore shipwrecks. Most shipwrecks involve the loss of life and usually require permission from the families of those who died before they are observed, but with ROV it is easy for people to visit these sites without anyone really knowing about it.

In the news recently there was an incident with a gunman shooting people indiscriminately in the US. It was almost impossible to stop him and talk to him to try and stop him, so the police sent in a UV device with explosives and blew it up next to him. Many people were upset that there was no chance to find out why he did it or to punish him though the due process of law. Others would argue that he was taking other people's lives so it was the right thing to do. Was it the right thing?

Candidates can offer examples of their own to illustrate their understanding of some of the moral issues surrounding the use of these devices in a commercial setting.

4.4 I can review the ethical and legal concerns relating to UVs in a military setting.

Candidates should be able to show they understand the main issue around the use of UV in the military.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance:
The use of UV in a military setting is the most widely known and has the longest history. As noted at the beginning of this unit, UV, in this case balloons full of explosives, were used as early as the 19th Century for warfare. Warfare is a messy and dangerous business, and nations have always looked at ways of making the death of their own personnel as low as possible. However, given that war is about killing people, is there a moral case for not using machines to do it for you. If you are desensitized from the output of war, death, does this make more warfare inevitable?

One of the main concerns about the use of UV is their inaccuracy. Despite the claims of the military that they are "precision weapons", the number of civilians killed by these devices by accident is very high. As with the police example above, is there a need to capture people and make them pay for their crimes through prison time, rather than death?

Most international organisations try to protect civilians by laws which state that nations need to be at war in order to carry out any attacks and therefore cause death. However, with the use of UV, most of the targets are in countries which are not at war with the combatants and therefore not "legitimate" targets for attack. What is the legal position in this instance.

One key moral issue is in relation to the gamification of war. In many cases, the soldiers that operate the UV are people that are good at playing games as this is effectively what is happening. They are watching their computer screens and controlling a device many thousands of miles away and "taking out" the enemy. It all seems like a big computer game and has many of the same features. This is probably better than many people dying in a battle, but is it ethically or morally OK?

The cost of using UV compared to a full army on the ground is significant and as more and more of these devices are built, it is more of a temptation for people in government to use them to save money. It takes away a lot of the cost of war but also the impact as there are no deaths on the side of the people doing it.

There are probably other issues that candidates will come across and they just need to explore them and comment on what they feel is the moral or ethical case.

Annexe C – Summary of the units and their assessment.

Level 2

Unit 1 - The Understanding and Appreciation of Rocket Science
Unit 2 - The Science and Application of Microsatellites
Unit 3 - Working with Robotics and Artificial Intelligence
Unit 4 - The Development and Deployment of Unmanned Vehicles (UV)

- 4 credits - 40 GLH
- 4 credits - 40 GLH
- 4 credits - 40 GLH
- 4 credits - 40 GLH

160 GLH in total for the full certificate. Units can be assessed concurrently or consecutively enabling the school to decide how to organise teaching. The exam covers all unit and the 160 GLH content.
There is a unit certificate available for each unit and all units must be assessed as satisfactory through coursework at Level 2 or higher before an exam entry is permitted. The exam will then differentiate grades A*, A, B, C.

Annexe D - Useful links and supporting information

The TLM community learning site www.tlm.org.uk has a wealth of supporting information and practical tools for managing evidence, progress tracking and reporting. These are all free for participating schools. Contact TLM for further details or training if required. We will update and add to supporting materials as time goes on.

The TLM Learning web site supports multiple languages and it is not very difficult to provide new translations. If you want to teach in the context of a modern foreign language it is possible and we will provide support where we can.

Making the transition from existing qualifications

It is rarely necessary to abandon all of the course-ware of existing courses. The flexibility of the TLM approach means that most centres find they can map a great deal of their current learning to the assessment criteria and avoid major upheaval. This means that you can start gently and at more or less any time in the year. All we are interested in is the assessment outcome, the process to get there is up to the Principal Assessor and colleague assessors in the centre. So we can start by using evidence already available or in existing systems and you can decide for yourself how quickly you transition to TLM's evidence management if at all. We are not a software company trying to sell you technology, we are simply providing tools to make administration of our quality assurance service more convenient to users. If you think a different system is better for you, you are free to use it. All we need is ready access to evidence supporting the assessment criteria.

Annexe E - Coursework assessment flowchart