# L2 - Unit 1 - The Understanding and Appreciation of Rocket Science

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# Overview

**Understanding and appreciation of rockets** at Gold Level requires the candidate to show a good understanding of the main principles affecting rocket flight, in particular some of the physical forces and restrictions.  They will also need to show that they understand how these factors affects their designs.  They will need to use this knowledge and understanding when designing and building rockets, paying particular attention to what materials are used and why.  The candidates will need to build a rocket or participate in the building of a rocket and understand the construction and testing process, as well as the health and safety concerns. All of this practical and theoretical understanding will need to be demonstrated in trying to recommend further uses for this kind of technology.

**A work activity will typically be 'non-routine or unfamiliar' because** the task or context is likely to require some preparation, clarification or research to separate the components and to identify what factors need to be considered. For example, time available, audience needs, accessibility of source, types of content, message and meaning, before an approach can be planned; and the techniques required will involve a number of steps and at times be non-routine or unfamiliar.

**Example of context** – using some design software and hardware (i.e. a 3D printer) to build a rocket or part of a rocket for testing.  It could also be created and tested in a virtual way using advanced software such as Kerbal [3].

# Example of work at this level (coming soon)

## Assessor's guide to interpreting the criteria

***General Information***

**RQF general description for Level 2 qualifications**

- Achievement at RQF level 2 (EQF Level 3) reflects the ability to select and use relevant knowledge, ideas, skills and procedures to complete well-defined tasks and address straightforward problems. It includes taking responsibility for completing tasks and procedures and exercising autonomy and judgement subject to overall direction or guidance.
- Use understanding of facts, procedures and ideas to complete well-defined tasks and address straightforward problems. Interpret relevant information and ideas. Be aware of the types of information that are relevant to the area of study or work.

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- Complete well-defined, generally routine tasks and address straightforward problems. Select and use relevant skills and procedures. Identify, gather and use relevant information to inform actions. Identify how effective actions have been.

- Take responsibility for completing tasks and procedures subject to direction or guidance as needed.

***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 the INGOTs.org 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 e-portfolios and on-line 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. L indicates some capability but some help still required. S indicates that the candidate can match the criterion to its required specification. H indicates performance that goes beyond the expected in at least some aspects. Candidates are required to achieve at least a S on all the criteria to achieve the full award.

***Expansion of the assessment criteria***

## 1. Candidates will show an understanding of 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.

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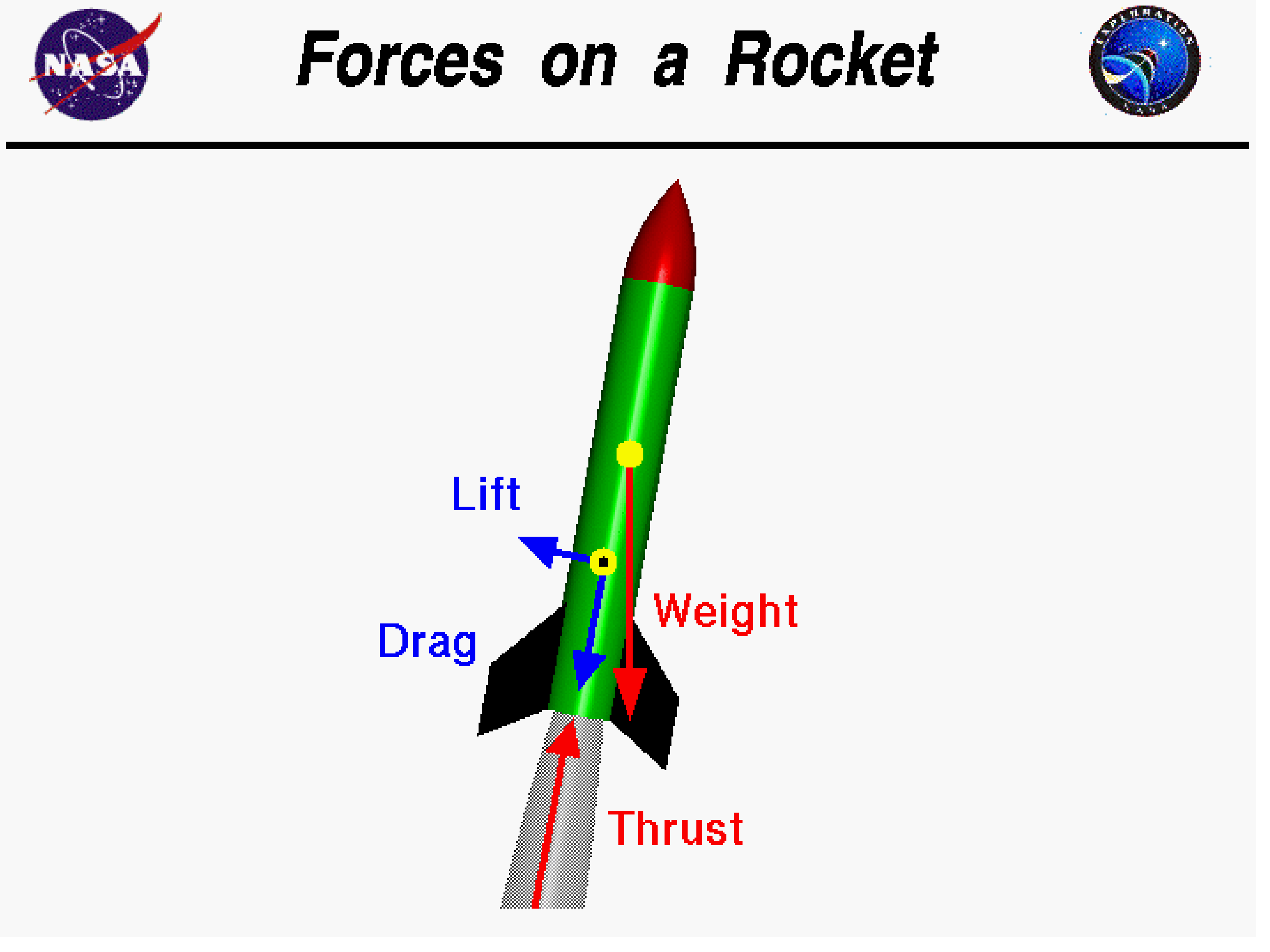
**Additional information and guidance**

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 [4]

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.**

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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.

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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

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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$^{o}$C and is highly reactive and dangerous. When it burns, it burns at 3000$^{o}$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

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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 Open Rocket [5] or Kerbal [3] 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

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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.

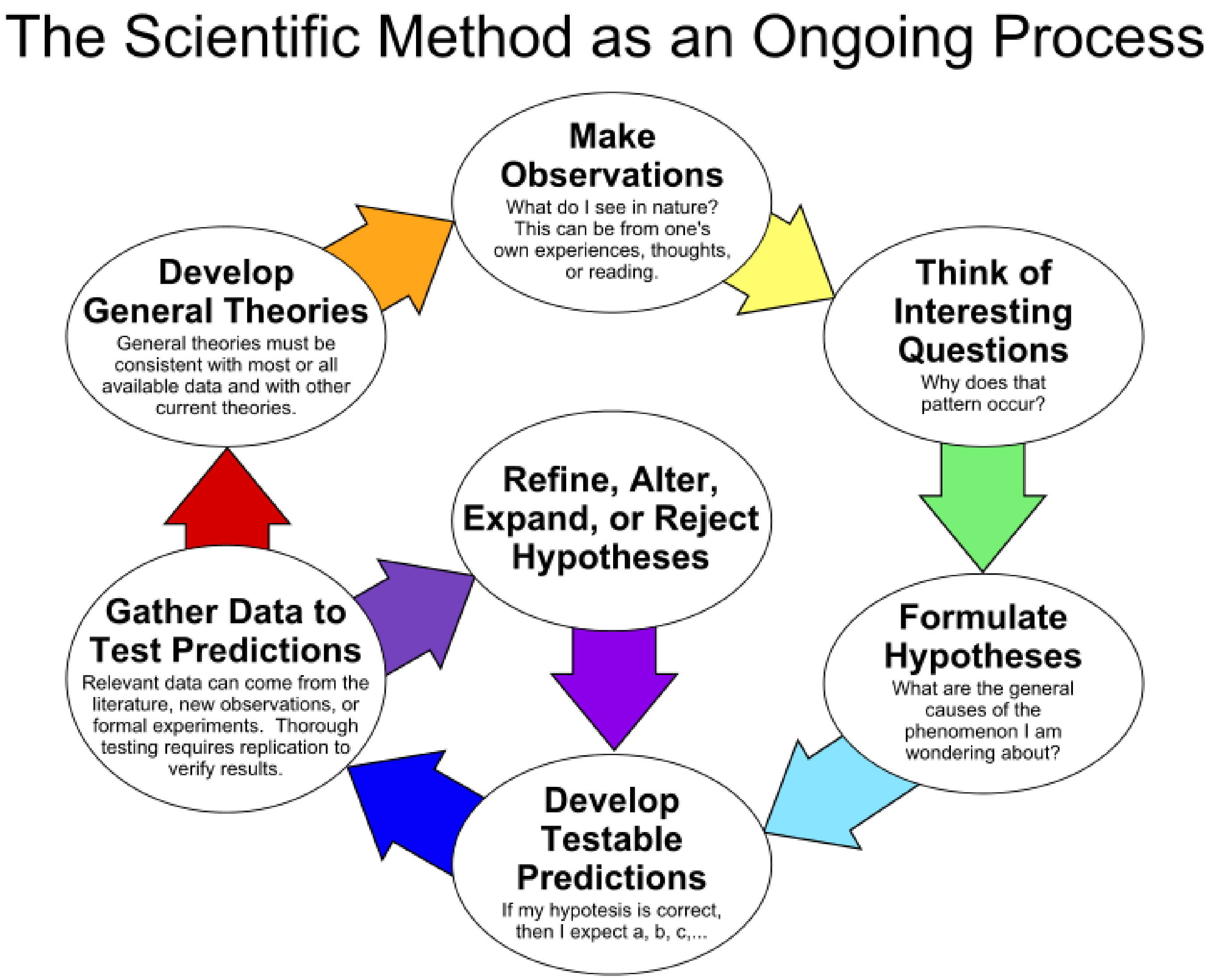


Image from https://en.wikipedia.org/wiki/Scientific_method#cite_note-Garland2015-1 [6] by https://commons.wikimedia.org/wiki/User [7] : ArchonMagnus

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.

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Rockets and Things [8]

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.

Get some help from Starchaser here [9].

See what they are up to here [10].

### 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 [11].
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.

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### 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 [12].

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 requirements 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

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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.

Space Debris [13]

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.

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### 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.

### Moderation/verification

The assessor should keep a record of assessment judgements made for each candidate guided by the above guidance. Criteria should be interpreted in the context of the general descriptors of QCF Level 1 qualifications.  They should make notes of any significant issues for any candidate and be in a position to advise candidates on suitable routes for progression. They must be prepared to enter into dialogue with their Account Manager and provide their assessment records to the Account Manager through the on-line mark book. They should be prepared to provide evidence as a basis for their judgements through reference to candidate e-portfolios. Before authorising certification, the Account Manager must be satisfied that the assessors judgements are sound. In the event of missing evidence, the assessor will be requested to gather appropriate information before the award can be made.

**Source URL:** https://theingots.org/community/osamtl2u1x

**Links**
[1] https://theingots.org/community/rocketry
[2] http://thelearningmachine.co.uk/tlm-l2-osamt-handbook/
[3] https://kerbalspaceprogram.com/en/
[4] https://spaceflightsystems.grc.nasa.gov/education/rocket/rktfor.html
[5] http://openrocket.sourceforge.net
[6] https://en.wikipedia.org/wiki/Scientific_method#cite_note-Garland2015-1
[7] https://commons.wikimedia.org/wiki/User
[8] http://www.rocketsandthings.com
[9] https://starchaser.co.uk/contact-us/
[10] https://www.youtube.com/embed/rAFQo9KLCYc
[11] http://www.ukra.org.uk
[12] http://www.esa.int/Our_Activities/Human_Spaceflight/Research/Tiny_animals_survive_exposure_to_space
[13] http://www.satellitedebris.net/Database/LaunchHistoryView.php

(function(i,s,o,g,r,a,m){i['GoogleAnalyticsObject']=r;i[r]=i[r]||function(){ (i[r].q=i[r].q||[]).push(arguments)},i[r].l=1*new Date();a=s.createElement(o), m=s.getElementsByTagName(o)[0];a.async=1;a.src=g;m.parentNode.insertBefore(a,m) })(window,document,'script','//www.google-analytics.com/analytics.js','ga'); ga('create', 'UA-46896377-2', 'auto'); ga('send', 'pageview');