# Aeronautical Engineering Teacher Guide

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# Introduction

This set of resources provides schools with information and activities to help pupils understand the roles and impact of mechanical engineering, with a focus on the aerospace industry.

It includes eight video case studies of engineers working in the sector to allow pupils to understand their roles and the work they do, and to consider their options when thinking about career choices.

Each of the engineers is also presented as a cartoon-style character introducing activities that teachers can adapt to suit their Key Stage 3 classes. The challenges in the activities can be adapted and developed into research, design-only, or design and make projects to suit your school and pupils.

**Presentation tips**

**Using video**

General tips: Run through videos with a timer and note the points at which you might like to pause to make a point or ask questions. You may also want to add your own commentary. You may need to point out that some of the views expressed by interviewees or the originator will be their own opinions and may need to be considered.

**Using PowerPoint presentations**

The PowerPoint presentations contain instructions and activities for students and may contain links to videos. Ensure you have YouTube enabled in school to allow these to load correctly.

**Challenges**

The materials with each of the activities are in PowerPoint format and can be adapted to suit your teaching requirements.

**Online links**

To get the best from online resources ensure your web browser is updated and that you have YouTube enabled to allow videos to load correctly. Online CAD systems may have minimum systems requirements.

# What is aeronautical engineering?

Aeronautical engineers research, design, make and test parts for aircraft, including rockets and space vehicles. This often involves understanding new technologies that may affect the weight, thrust and stability of aircraft such as drones, helicopters, jets, rockets and satellites.

An aeronautical engineer will study aerodynamics, propulsion, materials, structures, stability and control mechanisms.

Aircraft components are often designed and made in separate, but linked companies, so a manufacturer may concentrate on engine parts, wings, fuselage bodies etc.

Career opportunities exist in civil, commercial and defence establishments. The separate areas and components require overall knowledge but a good understanding of maths and physics as well as materials and structures is essential. Design and testing is largely carried out using CAD systems on computers, but also using models and test aircraft.

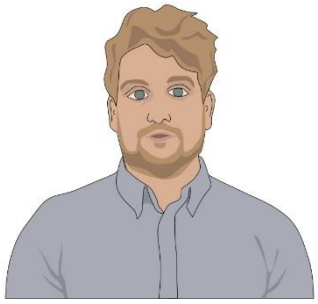
While this focuses on aeronautical engineering, much will apply to manufacturing in general, including the automotive and nuclear and civil engineering industries.

# Salaries

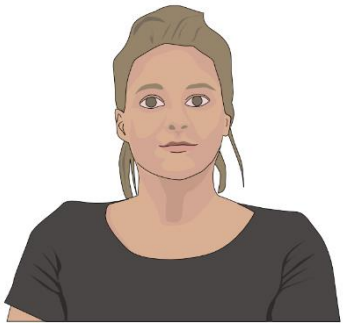
The average graduate starting salary for engineers is £24.5k. Average salaries for senior managers is in excess of £45k.

# Case studies

Included are profiles and video interviews with engineers working in an aeronautical engineering manufacturing company that manufactures a range of components for civil and defence aircraft; and from apprentices and a technical coordinator training in mechanical engineering.

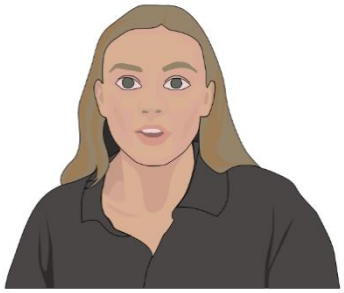


**Ben Lavender** is a manufacturing engineer working at JJ Churchill where he is part of a team developing aircraft parts. He did design and technology at school, then became an apprentice and completed his HNC. He moved from the shop floor to the design office where he uses design drawings to help develop processes for developing new parts. He finds it satisfying seeing the final product as an outcome of the work that he has helped develop, and finds the role varied, changing and interesting.



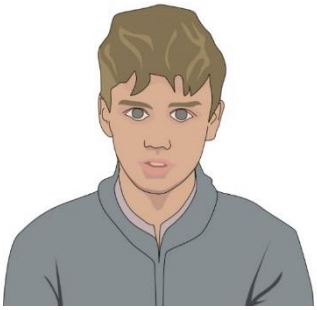
**Chloe Reeve** works for the Engineering Technology Group training operatives and apprentices on existing machinery and on new machinery following installations. She spends a lot of time travelling to different sites to coordinate programming and operator training courses and enjoys the variety of work that his offers and the satisfaction of seeing successful end products. Her family included a draftsperson and an engineer, and she gained good grades in her A Level Product Design which gave a good insight into engineering and helped her decide to do an apprenticeship. One day she would like to manage a team of engineers.

**Craig Milner** was a manual tool room milling apprentice at the Midland Group Training Services and is now a qualified tool maker and oversees tool making in the workshop. His main role is to organise the tool room and make sure everything gets done on time and to a good standard. He likes the variety of work and finds it satisfying producing a quality product with a function and a purpose, working in a small team of engineers. One day he plans to become a designer and help develop new products.

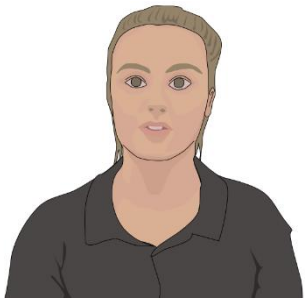


**Ella Jones** works for Grainger & Worrall and is in her first year of a four-year apprenticeship in mechanical engineering, attending college three days a week. She enjoys the diverse range of activities, including customer visits, quality control and new and emerging technologies. She aims to choose an area to specialise in but will make a choice when she has more experience. Ella feels it is inspiring and important that there are more women engineers now and they are bringing change to the industry.

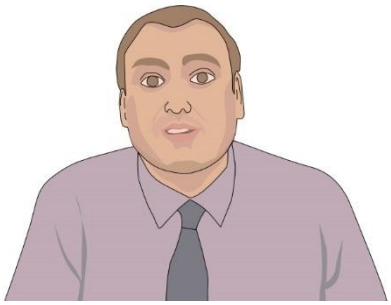
**George Kersey** is a second-year craft apprentice in tool making at JJ Churchill. George has always had an interest in engineering, through family links, and took GCSE Engineering and A Level Physics, then on to an apprenticeship. He likes being hands-on and seeing all the components come together in a final assembly and uses manual skills and CNC milling, turning and grinding to make, modify and repair fixtures. He sees new technologies and materials moving the industry forward, in particular green and nuclear energy.



**George Robertson** is a third-year apprentice from the Manufacturing Technology Centre, where he is studying Metrology which is the science of measurement. He is learning different aspects of mechanical engineering, particularly in machining, and enjoys the range of new things that this brings. He'd like to specialise in the inspection of parts, ensuring they meet standards and finds new developments such as 3D printing particularly interesting.



**Lauren Ball** is an apprentice studying at the Marches Centre of Manufacturing and Technology where she is learning aspects of mechanical engineering. She did D&T Product Design GCSE at school and quickly realised that she wanted to follow the apprenticeship route into engineering. At college she is learning a wide range of skills which she applies at her job at Caterpillar where she would like to specialise in quality control. She enjoys learning new skills and seeing herself making progress towards her goal.



**Matthew Smith** is a manufacturing engineer at JJ Churchill who has progressed from apprenticeship and now designs tooling and fixturing for manufacturing, working closely with the tool room supervisors and engineers who oversee their manufacture. He works on computers using CAD to design drawings that the tool room manufactures. Matthew mainly works independently but as part of a team of engineers, and visits suppliers off-site too. He particularly enjoys problem-solving and works predominantly in aerospace, but also in the automotive, defence and nuclear industries.

# Activities

In each activity the character introduces the challenge and provides tips to help guide pupils when they research and design solutions to meet the needs of users. The challenges are based around the principles of flight, powered flight, a drone challenge and technical drawing skills, including CAD and CAM. These are linked to activities that typically take place in delivering school projects and to National Curriculum content. There is a strong STEM component in the challenges, including maths in particular. Each activity challenge can be adapted to suit the level of your pupils' skills, knowledge and prior learning.

The activities can be used with individuals or as group-based tasks and include opportunities for research, discussion and written work looking at the impact of engineering on society and the environment, and the way these feed back into the industry. Through the challenges offered there are opportunities for pupils to investigate and explore careers, operations and technologies in aeronautical engineering.

Depending upon your school's priorities and available teaching time these can be developed into practical hands-on challenges around:

- designing only projects
- making only projects
- designing and making projects

# D&T across the curriculum

These activities provide opportunities to include cross curricular work, particularly in engineering, maths, science, computing and English. Check with colleagues in other departments to ensure that the correct levels are being addressed.

The maths component of the GCSE is 15% and pupils should be encouraged to get into the habit on incorporating number, measurement, ratio and proportion, algebra, geometry and statistics, including showing working out, in their design planning.

Materials, structures, electrical systems, forces and physics are all relevant areas of science that are used in aeronautical and manufacturing engineering applications.

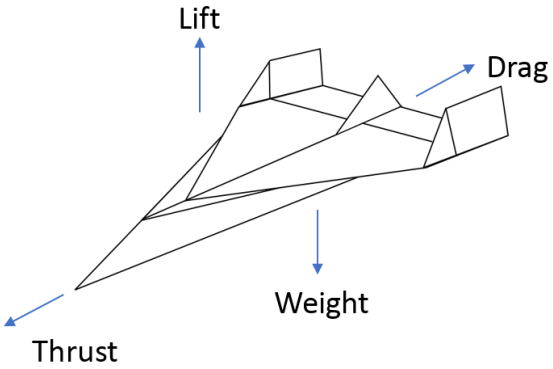
CAD, CAM and software for e-portfolios are aspects of computing that apply.

Opportunities for developing speaking and listening through team work, discussions, negotiations and presentations are plentiful as well as written work.

# The challenges

## Challenge 1: Flight

*Make a glider that flies the furthest*




Pupils learn about and understand the principles of flight: how flying machines work, before going on to design, make, test and improve paper gliders.

They are encouraged to test paper planes using adaptations from their own and others' designs to see how the changes they introduce affect flight paths.

The principles of flight and forces that act upon aircraft are considered including: Centre of gravity, Centre of lift, Angle of attack, Forces, Mass, Weight, Lift and Drag. Tips on plane design include changing the centre of gravity to affect how lift, drag, roll stability, the stall point and other factors affect how planes fly and can be changed. Trimming the flight surfaces by introducing ailerons, elevators and rudders also affects flight and is included.

Accuracy in measuring, cutting and folding is central to developing models that perform consistently and give reliable feedback.

Consistent launching using a mechanical launcher will help validate results, but hand launching can be used if monitored carefully to ensure a fair test. Measuring the flight path from launch to landing also needs to be consistent.

It may be useful to make and test exemplar model planes that pupils can adapt or use as inspiration to try and 'beat the teacher' in the challenge.

**Associated resources from the Design and Technology Association**

- Learning about structures and mechanisms at KS3
- Materials and their properties - Papers and boards

# Challenge 2: Powered flight

*Add some power to your glider to make it fly further and allow you to test other factors.*

This looks at adding power to model aircraft to extend the range of flights. Pupils need to consider how to introduce a motor and how the introduction of thrust and additional weight will affect performance.

The resource briefly looks at speed, torque and direction of rotary movement, all of which can be adjusted in DC electric motors through polarity, varying the input voltage and introducing gearing. These aspects are not covered in depth but should be supplemented through teaching of electric motors and gear ratios elsewhere.

Fuselage and wing shape can be modelled in CAD and cut from foam blocks.

If you have the budget to invest in powered paper planes there are some USB-based power units that can be controlled by a smartphone. These offer consistent thrust so that adjustments to flight surfaces can be tested accurately.

Where space is limited pylon flying provides a solution: flying a model plane tethered to a wire around a pole.

Where possible make and test models prior to introducing them in the classroom.

**Resources from the Design and Technology Association**

- Learning about structures and mechanisms at KS3

# Challenge 3: Drone mountain rescue

*Rescue some figures trapped on a mountain and bring them back to base.*

This uses model figures (Lego or similar) trapped on a ‘mountain’ (which can be an upturned bin or a piece of furniture) and asks pupils to programme a drone to fly from base to rescue them and return them to safety, or to drop rations and first aid.

If time and resources allow you might also want to make a landscape and figures that are appropriate to your school’s situation.

Programable mini-drones that include cameras and use Scratch programming such as Tynker are widely available now and are becoming more affordable. An example of programming drones can be viewed here. The planning and structured thinking that comes with programming is an important element in developing designing skills.

Pupils will need to think about:

- how the drone might pick up the figures
- how far to programme the drone to fly before it can hover above the figures. (Programming is usually done in terms of seconds rather than distances, so a good calculation and some trial and error testing will be needed.)

Some videos that show the use of programmable drones can be viewed here and here.

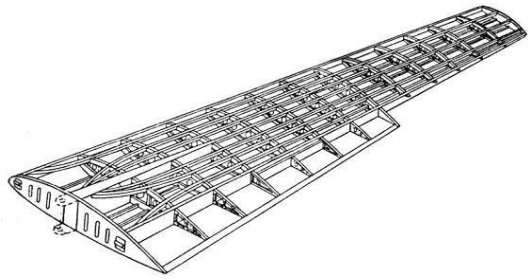
The resource also introduces drones and gives the opportunity to consider and discuss the positive and negative sides of their use, including firefighting, disaster relief, spying and transporting illegal payloads. Pupils are also prompted to research and design drones for other uses such as floating drones, carrying lights or heavy weights, etc. There is a link to some innovative drone-based inventions including some of these ideas.

**Safe use of drones**

From July 2018 restrictions on the use of drones flying outdoors have been introduced, and safety precautions should be introduced and risk assessed prior to their use, indoors or out. A hall or gym is perhaps the best space to use, but pupils’ movements should be restricted away from the flying zone. See: http://dronesafe.uk/

# Challenge 4: Modelling structures / Engineering drawing

*Draw and model an aircraft wing*



This covers drawing skills and emphasises the need for accuracy and an understanding of the principles behind the object to be drawn to ensure a good result for a portfolio to show what pupils are capable of.

Pupils will need to think about identifying appropriate materials and using drawing tools suitable for the level of detail and accuracy they require.

Different approaches are briefly covered: illustrative drawing, including sketching, rendering, orthographic and isometric; and engineering drawing, following scale, line thickness and dimensioning, and CAD programmes.

CAD files or engineering drawings can be used to make parts or whole structures and there are links to model sites where those who wish to can take this further. Your school may have a model or engineering club where this can take place.

**Resources**

- Learning about structures and mechanisms at KS3
- Metals materials handing pack
- Google SketchUp

# Applying the National Curriculum at Key Stage 3

**The National Curriculum for Key Stage 3** states:

*Through a variety of creative and practical activities, pupils should be taught the knowledge, understanding and skills needed to engage in an iterative process of designing and making. They should work in a range of domestic and local contexts, such as the home, health, leisure and culture, and industrial contexts, such as engineering, manufacturing, construction, food, energy, agriculture (including horticulture) and fashion.*

*When designing and making, pupils should be taught to:*

***Design***

- *use research and exploration, such as the study of different cultures, to identify and understand user needs*
- *identify and solve their own design problems and understand how to reformulate problems given to them*
- *develop specifications to inform the design of innovative, functional, appealing products that respond to needs in a variety of situations*
- *use a variety of approaches, such as biomimicry and user-centred design, to generate creative ideas and avoid stereotypical responses*
- *develop and communicate design ideas using annotated sketches, detailed plans, 3-D and mathematical modelling, oral and digital presentations and computer-based tools*

***Make***

- *select from and use specialist tools, techniques, processes, equipment and machinery precisely, including computer-aided manufacture*
- *select from and use a wider, more complex range of materials, components and ingredients, taking into account their properties*

***Evaluate***

- *analyse the work of past and present professionals and others to develop and broaden their understanding*
- *investigate new and emerging technologies*
- *test, evaluate and refine their ideas and products against a specification, taking into account the views of intended users and other interested groups*
- *understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists*

***Technical knowledge***

- *understand and use the properties of materials and the performance of structural elements to achieve functioning solutions*
- *understand how more advanced mechanical systems used in their products enable changes in movement and force*
- *understand how more advanced electrical and electronic systems can be powered and used in their products [for example, circuits with heat, light, sound and movement as inputs and outputs]*
- *apply computing and use electronics to embed intelligence in products that respond to inputs [for example, sensors], and control outputs [for example, actuators], using programmable components [for example, microcontrollers].*

**Progression**
The age-related expectations for pupils are laid out in the Design and Technology Association's Progression Framework which lays out ways in which progress should be cumulative, developing on earlier learning in the areas of designing, making, evaluating and technical knowledge. Pupils who have learned about frame and shell structures and simple electrical circuits at KS2 can apply this knowledge to projects and prototypes at KS3 by, for example, developing more complex structures and developing circuits or gearing systems.
The Progression Framework is freely available from the Association's website.

**Links to maths and science**
With the GCSE having 15% of its marks for maths, preparatory work at Key Stage 3 using realistic scenarios is a valuable way of getting students used to its inclusion. Estimating material quantities and developing plans for aircraft designs include maths and this is often an easier way for some pupils to absorb the concepts of number, place value, fractions, geometry and ratios.

Science links include understanding the principles of forces, including gravity, velocity and motion, and properties of matter and materials. (NC)

# Useful Links

Links to resources are included in each of the challenge outlines. The following will be of help for general Design and Technology guidance and information on engineering.

Design and Technology Key Resources is a bank of 45 units aimed at Key Stage 3 pupils across different aspects of D&T. It includes a free Learning Planner and Assessing Without Levels Teacher Guide to help teachers plan effective learning at KS3.

The Design and Technology Progression Framework is a free resource covering progression from Key Stages 1 to 3.

**Born to Engineer** offers classroom toolkits and outlines the range of things engineers do in their daily work. www.borntoengineer.com

**Aerospace Engineer** job profile at the National Careers Service.
**Mechanical engineer** job profile at the National Careers Service.

**Aeronautical Engineering** at Wikipedia.
**Mechanical Engineering** at Wikipedia.

**RAF** Careers in Engineering

The D&T Association's Skills for Industry programme includes free teaching resources that teachers may find useful.

# Acknowledgements

Our thanks for their help and participation to all the people featured in this resource and to the following for their invaluable help in developing it:

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