Take off

Several BAE Systems employees working on the next generation of Queen Elizabeth Class carriers were involved in the development of this activity and you can read some of their profiles on page three.

During this activity students will explore the design and development of aircraft carriers and apply these ideas to build their own models.

Introduction

This class of aircraft carrier will be the biggest and most powerful surface warships ever constructed for the Royal Navy (you can visit the Aircraft Carrier Alliance at www.aircraftcarrieralliance.co.uk for further information).

The sheer scale of the project is breathtaking!

What you need

(Per group, with students working in pairs)

- Materials to build a launch mechanism, flight deck and "jet" plane. These can all be recycled materials: paper, plastic pots, plastic straws, string, cardboard, wooden planks, folders (to build ramps), different surface materials etc
- Elastic or Elastic Bands
- Paper Clips
- G Clamps
- Scissors
- Tape, glue, blu tack
- Tape measure or metre rule
- Cardboard
- Computer with internet access

Note for STEM Ambassadors: schools will have many of the items you need, so check with the teacher before your session.

Remember that a risk assessment should be done before beginning this activity - see the Hazards information sheet that accompanies the EEnP resources.

Aircraft are heavy. The take off mass of an aircraft can be 14,000kg. How many people of an average mass of 70kg would this be?

The new aircraft carriers can carry up to 40 aircraft. What additional forces are acting on the deck at take off? We also need to consider the undercarriage of the aircraft. Will it be strong enough to withstand all of the forces acting upon it at take off?

The deck needs to be long enough to give the aircraft enough space and distance to actually take off. However if it is too long this becomes expensive or impractical to make.

Aircraft can take off using either a catapult or a ramp.

Visit www.aircraftcarrieralliance.co.uk/media/video-library.aspx for videos of the aircraft carrier.
What to do

Using this resource you will be able to guide a group of students through the design and development of a launch system for an Aircraft Carrier.

Visit www.youtube.com/watch?v=XcLxJhAkk8E to see an aircraft take off from a carrier.

Part One

Firstly the students must think about the factors involved in achieving a successful launch of an aircraft from the deck of an aircraft carrier.

Discuss the following questions (the picture on page 1 may help provide some answers):

9 What does an aeroplane need in order to take off?
9 What problems do you think a plane might have when taking off from a boat at sea?
9 How would you design an aeroplane runway; does it need a ramp?
9 Can the deck and aircraft withstand the thrust (force) and speed at take off?
9 How can we design the undercarriage of the aircraft to ensure safe take off?

Use the internet to look at previous examples of carrier ships and aircraft to help you.

Part Two

Now you are ready to design, make, and test a launch system:

1 Design and make an aeroplane. Why not make one in paper and one in card and compare how the two work?
2 The undercarriages of your aeroplane need to be strengthened. Choose appropriate materials and attach to your aircraft.
3 Devise a Launch system. For example a ‘hook’ to attach to a launch cable (for example paper clip attached to the undercarriage).

4 How long does your deck need to be? Build your deck using available materials. Remember to attach the deck to a strong base for example cardboard or plastic pot.
5 Devise, position and install a launch cable and tensioning device (for example an elastic band across the flight deck) at one end of the carrier deck.

You are now ready to test the system:

1 Launch the aircraft.
   - To do this place the carrier deck on the end of a table (you may wish to use G Clamps to help).
   - Attach the hook to the launch cable.
   - Ensuring the launch is repeatable, gently pull back the aircraft (you may wish to give the students a set distance) and then let go.
   - Remember to follow safe launch practices: all students must be behind the aircraft at launch and the aircraft should never be launched towards anyone.
   - Alternatively you might be able to launch your aircraft outside.

2 Make adjustments to your design to optimise launch capability.
   - Try launching using different thicknesses of launch cable.
   - The aircraft will fly better if you:
     (a) add more weight to the front in the form of paperclips
     (b) reinforce the hook and undercarriage
     (c) Release the aircraft on a ramp

3 Re-test.

4 What is the maximum flying distance achieved? Does the aircraft clear the carrier deck?

Some extras

You may want to build more sophisticated launch mechanisms in your Design and Technology workshop (see picture below for example):

There are many other additions you could make to this session. The design element can be extended:

- change the design of the aircraft (e.g. increase wing lift, or devise a new folded paper aircraft)
- change the design of the launch mechanism
- create a scale model of your plane with wheels (you will need extra materials)

You may also wish to design, build and test an aircraft landing system for the aircraft carrier.

You can use the same aircraft and deck but perhaps you could add light beams to provide a glide path guidance beam? Can the students develop a circuit to light the aircraft carrier and provide the guidance?

Handy hints

Add a societal context to this activity by discussing the need for the aircraft carriers and the jobs that they (and the aircraft) do. How does the development of these ships benefit the wider society?

For example are there drawbacks or benefits for employment, economic, security and technological developments?

It is also useful to discuss the engineering and cost trade-offs e.g. around carrier length. Sometimes decisions are made because they are the best compromise in terms of cost, efficiency, materials and man power. You can demonstrate this by adding a procurement dimension to the activity. Give each group a budget and apply costs to the materials they can use. Make it a competition: the winning team’s aircraft will have travelled the furthest using their launch mechanism and the whole design will have the lowest cost.

Remember there are a number of ways for you to launch the aircraft which include:

- Slingshot from the front of the desk/carrier
- Slingshot from the back of the desk/carrier
- Adding wheels to your aeroplane and creating a ramp to launch from (will need extra materials)
- Catapult on a ramp
**Who works with these ideas?**

**STEM Ambassador Profiles**

**Emma Cheshire**  
Engineering Programme Manager  
*Industry Sector:* Engineering/Defence  
*What I do on an average day:* I lead a team of engineers to deliver an end solution. A lot of my role is coordination, planning the work and setting milestones and deadlines to ensure goals are reached. I need to have an appreciation of the technical solutions even if I am not an expert.  
*How I got here:* I went to an all girls grammar school and did triple science at GCSE, followed by Maths, Physics and Geography A levels. At Loughborough University I studied Aeronautical Engineering which was hard work but a lot of fun. I did an Industrial placement year at BAE Systems where I then got sponsored for my final year at university. There was a lot of making models and testing them to destruction on my course which made it a lot of fun.  
*My favourite part of my job:* There are two parts; the first is delivering, whether it’s a product or plan or idea at the end of the day. I relish getting to that end result. The second part is leading a team of specialists who come together to deliver something and helping people to reach their true potential through their work.  
*Who is an engineer?* A problem solver. Innovative and a team player.  
*Hobbies:* I did sailing at university and I still do it now. Walking the dog and I am training for the Three Peaks challenge. I also enjoy playing golf.

**Kim Chilver**  
Systems Engineer  
*Industry Sector:* Engineering/Defence  
*What I do on an average day:* I work in developing support solutions which involves solving problems in the electronics on the ship. The programme I use tells you what needs to be done if a system fails and is a database of all the systems on the Queen Elizabeth carrier.  
*How I got here:* I did Physics, Maths and Electronics A level, plus French AS. For electronics I made a guitar tuner as my project. I read Electronic Engineering at Cardiff University – that was a lot of fun. After university I worked for a small electrics company, but joined the BAE Systems graduate programme a year later. My first project for BAE Systems was based in Preston working with the Saudi Arabian side of the company. I also spent six months looking at an unmanned aircraft project. For the last 18 months I have been working on the Queen Elizabeth carrier project.  
*My favourite part of my job:* My job is interesting and rewarding, especially when you can see what you’ve made put into action. I particularly enjoyed working on the unmanned aircraft project as I got to make and see tests on the aircraft that could be simulated on a computer.  
*Who is an engineer?* Someone who has lots of design knowledge, and theory knowledge. They are given a problem and are able to find a solution for it. Unlike a technician you don’t fix existing problems. You have to foresee the problems and solve them beforehand.  
*Hobbies:* Guitar and saxophone, I am a member of a few bands. I also play table tennis and football. I try to do as much as I can with my time.

**Explanation**

There are many challenges facing the modern aircraft carrier and sometimes mistakes happen.

The Queen Elizabeth class of aircraft carriers, due for launch in 2016, has taken many years to design. This class of aircraft carrier will be used by all three UK Armed Forces and will be versatile enough to be used for operations ranging from supporting war efforts to providing humanitarian aid and disaster relief.

Aircraft carriers act as runways and often have a flat deck for the launch and landing of aircraft. There are generally two ways of launching the aircraft:

1. A “catapult” can be used to accelerate the aircraft to a safe flying speed.
2. An upwards force is provided by a ski-jump at the forward end of the flight deck.

The Queen Elizabeth class will use an electromagnetic catapult.

Which form have the students developed today?
This is engineering

This activity highlights many principles of Mechanical Engineering as we look at applying ideas of physics and materials science for the analysis, design, manufacturing, and maintenance of an engineered system.

There are many university courses you can choose from; generally you will need STEM A levels (Advanced Highers in Scotland) including mathematics and preferably physics too. Alternatives include STEM-related Advanced Diplomas (or BTEC National Extended Diplomas) plus appropriate qualifications in mathematics and possibly physics too. See www.ucas.com for more information.

Engineering is a very wide field and there are many different apprenticeship routes you can take to becoming an engineer. For example apprenticeships in the marine industry will cover aspects of boat building, maintenance and repair; marine engineering; electrics and electronics.

Visit www.apprenticeships.org.uk for further information.

In Scotland visit www.apprenticeshipsinscotland.com and in Wales wales.gov.uk/apprenticeships

BAE Systems also offer apprenticeships visit www.baesystems.com/apprentices for more information.

Curriculum links

You may find this resource useful when studying the following at Key Stage Three:

**England Science:** Forces and motion, describing motion

**Scotland Science, Forces:** 2-07a, 3-07a – applications of friction, 3-08a – applications of gravity

**Technological developments in society:**
2-01a – using knowledge to help design and improve products, 3-02a – implications and ethical issues arising from technological developments

Next steps

Remember there are more resources at networking.stemnet.org.uk, search for Engineering.

For more information on STEM Clubs visit: www.stemclubs.net

CREST Awards are easy to run, encourage students to continue with STEM subjects, and add real value to UCAS applications. To link this activity to CREST Bronze Awards, contact your CREST Local Coordinator: www.britishscienceassociation.org/crestcontacts

Extra maths

Ignoring acceleration, if the aircraft reaches a speed of 75 ms\(^{-1}\) at takeoff after travelling for two seconds, how long does the carrier deck need to be?

Assuming the mass of an aircraft is 14,000kg, what is its weight?