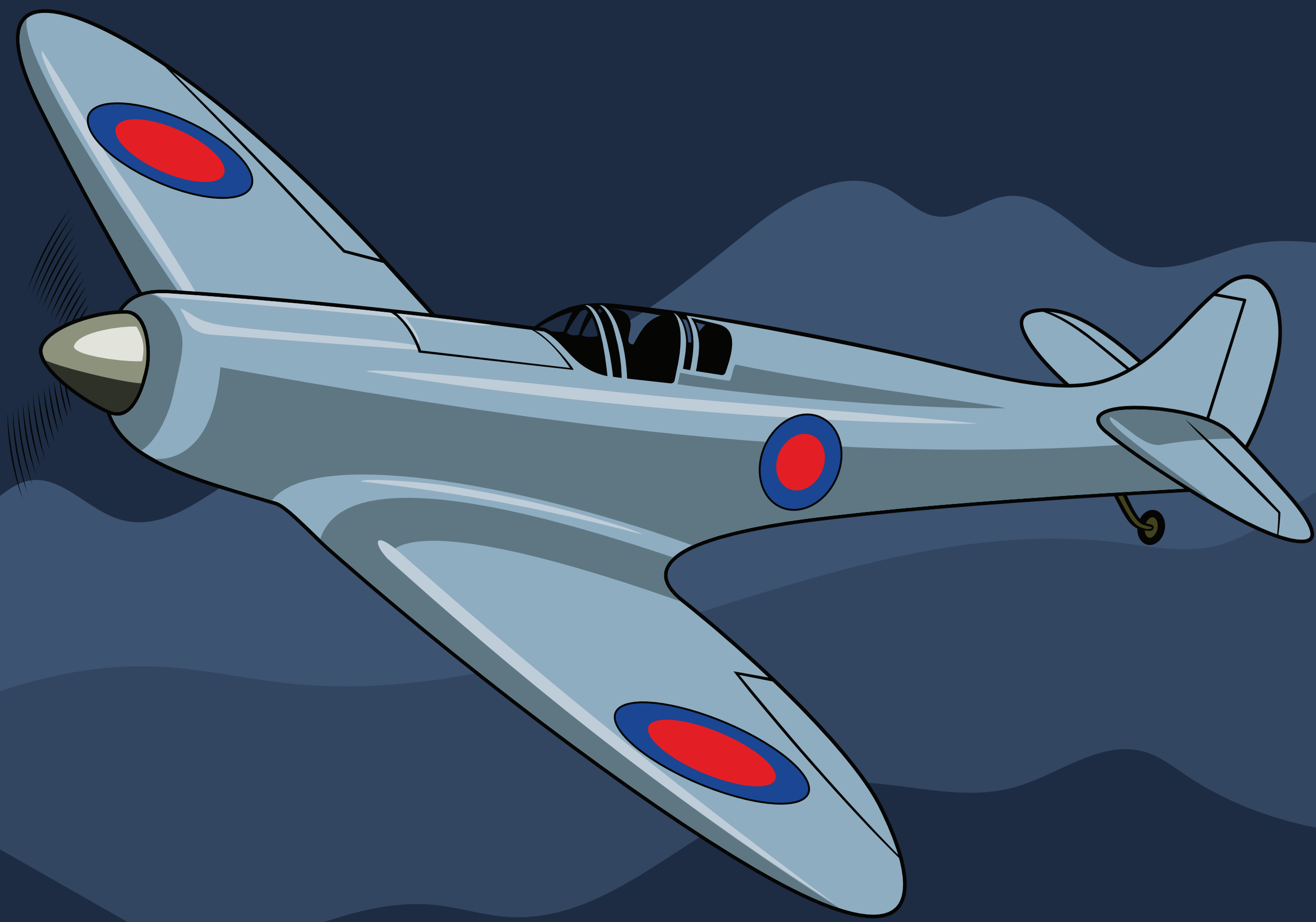
JET ENGINES

ACTIVITY WORKPACK 4



ROYAL AIR FORCE Youth STEM

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SPITFIRE AA810

FOR FACILITATORS / TEACHERS

ABOUT THESE MATERIALS

This resource pack provides students with the opportunity to explore the science and history underpinning the development and deployment of Spitfire AA810 during WWII. The materials form part of a suite of five resource packs exploring a particular area linked to Spitfire AA810. These resources concentrate on the **development of jet engines**. Curriculum links for KS3 learners are provided below to support embedding the content within your structured delivery or teaching sessions.

CURRICULUM LINKS

History / STEM

- ✓ **Science in Society:** Exploring the role of scientific advancements in historical events.
- ✓ **Working Scientifically:** Encouraging students to research, analyse, and present scientific concepts related to aviation technology and jet engine development.

Physics

- ✓ **Forces:** Understanding how jet engines generate thrust by applying Newton's Third Law of Motion (for every action, there is an equal and opposite reaction).
- ✓ **Energy:** Exploring how jet engines convert chemical energy (from fuel) into kinetic energy, producing thrust to propel aircraft.
- ✓ **Light and optics:** Understanding how light and optics are used in reconnaissance photography to capture high-resolution images and track enemy positions.

ABOUT SPITFIRE AA810

Spitfire AA810 is a famous aircraft from the Second World War. It is known for its important role in taking photographs of enemy areas. This particular Spitfire was used by a special group that flew deep into enemy territory to gather information through aerial photography. Unlike regular Spitfires, AA810 had no guns but instead carried lots of extra fuel and cameras. This allowed it to fly 2,000 miles to complete some of its missions. Today, there is a project to restore Spitfire AA810 so it can fly again. This project helps remember the brave pilots who flew it and it teaches people about their contributions during the war. You can find out all about this by **clicking here**.

FOR FACILITATORS / TEACHERS

GUIDANCE NOTES AND ANSWERS

This pack has been designed so that it can be comfortably delivered in a 1-hour facilitated session with secondary pupils. This pack forms part of a series of resources designed to explore the history and science linked to Spitfire AA810 aircraft. Each pack in the series contains web-links and QR codes to suitable background and contextual information to inform your delivery of the content. Answers to tasks and activities, where relevant, are provided below:

PAGE 7: Using the labels below, can you match the definition to the correct area of the jet engine?

1 = Fan: The part of the engine that draws in air and pushes it towards the compressor, increasing airflow for combustion.

2 = Compressor: It squeezes the air drawn in by the fan, increasing its pressure and delivering it to the combustion chamber.

3 = Combustor: The area where fuel is mixed with compressed air and ignited, producing high temperature, high-pressure gases for powering the turbine and generating thrust.

4 = Turbine: A part of the engine where the expanding gases produced by combustion are used to drive the compressor and fan, as well as to generate thrust.

5 = Nozzle: The exit point of the engine where high-speed exhaust gases leave, creating forward thrust to propel the aircraft.

PAGE 8: How fast can they go? Jet vs. propeller aircraft

Scenario 1:
1. The propeller aircraft is travelling at an average speed of 150 mph. How long would It take to travel a distance 300 miles? (Distance ÷ Speed) 300 / 150 = 2 hours.

2. The jet aircraft is travelling at around 500 mph. How long would it take to travel 300 miles? (Distance ÷ Speed) 300 / 500 = .6 hour (36 minutes).

3. Compare the times they take to complete the journey – which is faster? Jet aircraft is faster by 84 minutes (120 minutes - 36 minutes).

FOR FACILITATORS / TEACHERS

GUIDANCE NOTES AND ANSWERS

Scenario 2:
1. The propeller aircraft takes 3 hours to travel 250 miles. What is its speed in mph? (Distance ÷ Time) 250 / 3 = 83.33 mph.

2. The jet aircraft takes 1.2 hours to cover the 250 miles. What is its speed in mph? (Distance ÷ Time) 250 / 1.2 = 208.33 mph.

3. Work out the difference in speed between both aircraft. Jet aircraft is travelling 125 mph faster than the propeller aircraft (208.33 - 83.33 mpg).

Page 9: Aircraft comparison: Spitfire vs jet aircraft?

Spitfire AA810: Max speed (mph) = 416 mph, Max rate of climb (m/s) = 15.9, Max range (miles) = 2,000, Service ceiling (metres) = 1,200, Max take-off mass (kg) = 3,719, Max thrust (kN) = Like other Spitfires, this model had a piston-driven engine. It used a Rolls-Royce Merlin 70 engine producing 1,710 horsepower, so no thrust in kN (jets).

Typhoon: Max speed (mph) = 1,550 mph (or Mach 2.0 at altitude), Max rate of climb (m/s) = 315, Max range (miles) =1,800, Service ceiling (metres) = 19,812, Max take-off mass (kg) = 23,500, Max thrust (kN) = Each of the two Eurojet EJ200 engines produces 90 kN (kilonewtons) of thrust, giving a combined total thrust of 180 kN.

F35B: Max speed (mph) = 1,200 mph (or Mach 1.6 at altitude), Max rate of climb (m/s) = classified but estimated around 230, Max range (miles) =900, Service ceiling (metres) = 15,240, Max take-off mass (kg) = 27,200, Max thrust (kN) = The Pratt & Whitney F135-PW-600 engine provides 191 kN of thrust with afterburner, and around 128 kN in vertical lift mode.

Atlas C.1: Max speed (mph) = 485 mph, Max rate of climb (m/s) = 10.7, Max range (miles) =up to 4,500 depending on payload, Service ceiling (metres) = 12,200, Max take-off mass (kg) = 141,000, Max thrust (kN) = Powered by four Europrop TP400-D6 turboprop engines, each providing about 8,200 kW (11,000 horsepower), which corresponds to around 108 kN per engine. Total thrust would be approximately 432 kN.

FOR FACILITATORS / TEACHERS

GUIDANCE NOTES AND ANSWERS

Service ceiling: is the maximum altitude at which an aircraft can maintain a steady rate of climb, typically around 100 feet per minute (30 meters per minute), while still carrying a normal load. Beyond this altitude, the aircraft's performance diminishes, making further ascent impractical or inefficient.

Max thrust (kN): refers to the maximum amount of force, measured in kilonewtons (kN), that an aircraft's jet engine(s) can produce to propel it forward. This value represents the engine's peak power output under optimal conditions, usually during take-off or combat situations.

Page 13: Using the information provided about Frank Whittle add some key dates and events to the timeline below. We've added one in for you.

Born (1907), accepted into an Officer Training course at RAF Cranwell (1923), qualified as a pilot (1928), went to University of Cambridge (1928), developed initial ideas about jet propulsion (1928), took out patent for his jet engine idea (1930), graduated from University of Cambridge (1936), built a working prototype of his jet engine (1937), resigned from his company (1946), received a knighthood (1948), died (1996).

WHAT IS A JET ENGINE AND HOW DO THEY WORK?

A jet engine is a machine that converts energy-rich liquid fuel into a powerful pushing force called thrust. It works on the principle of Newton's third law of motion: for every action, there is an equal and opposite reaction.

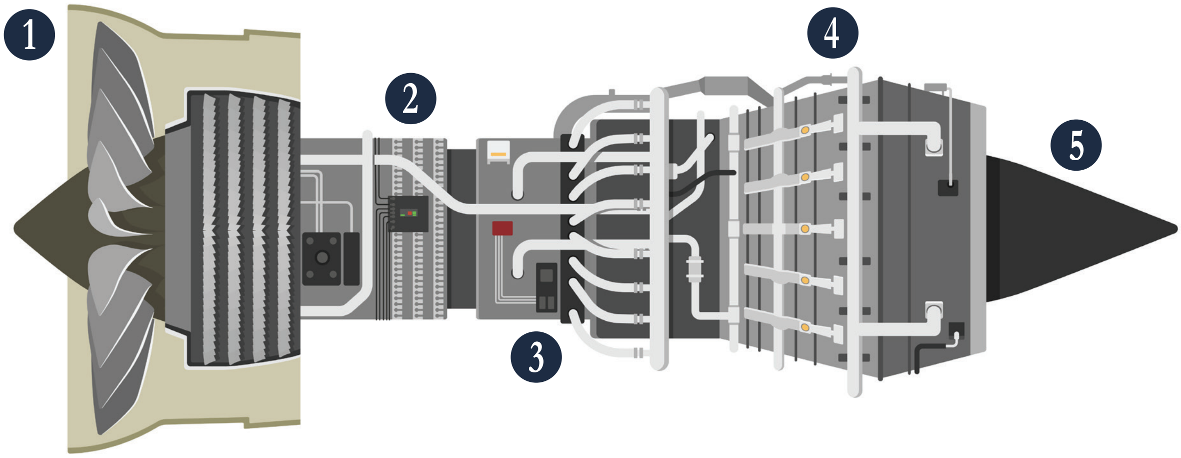
In an engine, air is drawn in, compressed, and ignited. The resulting high-pressure gases are expelled out the back, creating thrust to push the plane forward.

Scan the QR code or click here to find out more

HOW DOES IT WORK?

1. The engine sucks air in the front with a fan.
2. A compressor raises the pressure of the air by forcing it through increasingly smaller places.
3. Kerosene (*liquid fuel*) is injected into the engine from a fuel tank.
4. In the combustion chamber, kerosene mixes with the compressed air, causing a controlled explosion and increase in temperature.
5. The exhaust gases rush past a set of turbine blades, causing them to spin.
6. The turbine blades are connected to a long axle shaft that runs through the engine. As the compressor and fan are also connected, they also spin.
7. Hot gases then leave the engine through an exhaust nozzle, travelling at high speeds.

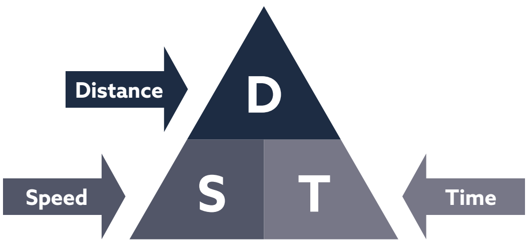
Using the labels below, can you match the definition to the correct area of the jet engine?



Part	Description
☐	**Compressor:** It squeezes the air drawn in by the fan, increasing its pressure and delivering it to the combustion chamber.
☐	**Fan:** The part of the engine that draws in air and pushes it towards the compressor, increasing airflow for combustion.
☐	**Turbine:** A part of the engine where the expanding gases produced by combustion are used to drive the compressor and fan, as well as to generate thrust.
☐	**Nozzle:** The exit point of the engine where high-speed exhaust gases leave, creating forward thrust to propel the aircraft.
☐	**Combustor:** The area where fuel is mixed with compressed air and ignited, producing high temperature, high-pressure gases for powering the turbine and generating thrust.

HOW FAST CAN THEY GO?
JET VS PROPELLER AIRCRAFT

Spitfire AA810 was a propeller-powered aircraft. It achieved movement by rotating propellers to generate thrust by lowering the air pressure in front of the propeller which pulls the aircraft forwards. Jet engines are capable of creating more thrust than propeller-powered aircraft. As a result, they can fly faster.



The speed, distance, & time triangle

The triangle helps us to work out a range of factors:

Speed = Distance ÷ Time

Time = Distance ÷ Speed

Distance = Speed × Time

Answer the questions in the scenarios below to calculate which of the two aircraft are quicker? Use the equation to help you.

SCENARIO 1

1. The propeller aircraft is travelling at an average speed of 150 mph. How long would It take to travel a distance 300 miles?
2. The jet aircraft is travelling at around 500 mph. How long would it take to travel 300 miles?
3. Compare the times they take to complete the journey – which is faster?

SCENARIO 2

1. The propeller aircraft takes 3 hours to travel 250 miles. What is its speed in mph?
2. The jet aircraft takes 1.2 hours to cover the 250 miles. What is its speed in mph?
3. Work out the difference in speed between both aircraft.

AIRCRAFT COMPARISON?
SPITFIRE VS JET AIRCRAFT

Carry out your own research on a number of different jet aircraft and compare them to Spitfire AA810.

Aircraft		Spitfire AA810
Max speed (**mph**)		
Max rate of climb (**m/s**)		
Max range (**miles**)		
Service ceiling (**metres**)		
Max take-off mass (**kg**)		
Max thrust (**kN**)		

Aircraft		Typhoon
Max speed (**mph**)		
Max rate of climb (**m/s**)		
Max range (**miles**)		
Service ceiling (**metres**)		
Max take-off mass (**kg**)		
Max thrust (**kN**)		

Aircraft		F35B
Max speed (**mph**)		
Max rate of climb (**m/s**)		
Max range (**miles**)		
Service ceiling (**metres**)		
Max take-off mass (**kg**)		
Max thrust (**kN**)		

Aircraft		Atlas C.1
Max speed (**mph**)		
Max rate of climb (**m/s**)		
Max range (**miles**)		
Service ceiling (**metres**)		
Max take-off mass (**kg**)		
Max thrust (**kN**)		

Aircraft		Hawk T2
Max speed (**mph**)		
Max rate of climb (**m/s**)		
Max range (**miles**)		
Service ceiling (**metres**)		
Max take-off mass (**kg**)		
Max thrust (**kN**)		

Conversion table:

1 metre = 3.281 feet

1 mile = 1.609 kilometres

As part of your research write short definitions of some of the key terms used.

Service ceiling (your definition) ...

____

____

____

____

Max thrust (kN) (your definition) ...

____

____

____

____

WHO WAS FRANK WHITTLE?

Read about Frank Whittle, the inventor of the jet engine, and then add key dates and events to his career timeline on the next page.

Frank Whittle (1907 - 1996) was the pioneering figure behind the invention of the turbojet engine. Whittle faced much adversity through his career, beginning at a young age when he was rejected by the Royal Air Force due to his lack of height. His determination led him to train harder, and he was accepted into an Officer Training course at RAF Cranwell in 1923.

The training he received at Cranwell highlighted his intelligence. He became an accomplished pilot (qualifying as a pilot officer in 1928) and was accepted into Peterhouse College at the University of Cambridge (graduating in 1936). Through his studies, he developed his initial ideas behind the turbojet. Whittle initially proposed his ideas on jet propulsion in 1928, but these faced scepticism by the government as they were perceived as improbable. Not giving up on the idea that would innovate aviation, Whittle took out a patent for the idea in 1930. His tests proved successful in 1937 when he built a working prototype. The success of the prototype created interest and supplied funding for more engines to be built.

The stress of the business caused Whittle to resign from the board in 1946, and then retire from the RAF shortly afterwards - however his efforts were not for nothing. He received a knighthood in 1948 and continued to work in other fields for many years, including working with Shell as an engineer. After a long and productive life, Frank Whittle died in August 1996.

FILL IN THE TIMELINE

Using the information provided about Frank Whittle add some key dates and events to the timeline below. We've added one in for you.

1907

1923 — Accepted for Officer Training (RAF Cranwell)

1996

AERIAL RECONNAISSANCE
JETS AND FLYING ROCKETS

During WWII photographic interpreters at the RAF's image analysis centre (RAF Medmenham) proved that Nazi Germany's scientists had achieved jet and rocket propulsion in their prototype Luftwaffe aircraft.

A German Me 262

These jet-powered aircraft included the Me 262 and the Me 163, which flew very few missions towards the end of the war. More worrying to the image analysts were the powerful V1 'doodlebug' and V2 rockets. These ballistic missiles had the potential disrupt the D-Day landings and could cause significant damage to British cities.

During WWII photographic interpreters at the RAF's image analysis centre (RAF Medmenham) proved that Nazi Germany's scientists had achieved jet and rocket propulsion in their prototype Luftwaffe aircraft.

Constance Babbington Smith was an expert image analyst working at RAF Medmenham. Her detailed analysis of hundreds of images helped to identify the location of the V1 and V2 rockets - in preparation for an RAF bombing mission to destroy the launch sites. Constance's work was so impressive that she was sent to the Pentagon in Washington to support the US military after the war ended.

Scan the QR code or [click here] to watch British wartime footage of a V2 rocket.

RESEARCH TASK

Create a short PowerPoint presentation on the impacts of the jet engine and other important aviation technology and innovations in WW2 such as:

1. Radar technology.
2. Aircraft Carriers.
3. The deployment of the Spitfire and its use for reconnaissance.

Scan the QR or click here to see the use and development of radar in WW2

Scan the QR or click here to see radar & WW2 technologies (British Defence Section)

Scan the QR or click here to see how the Spitfire was used during WWII

Scan the QR code or click here for Information on the UK's giant aircraft carriers