**ROYAL CANADIAN AIR CADETS**

**PROFICIENCY LEVEL TWO**

**INSTRUCTIONAL GUIDE**

**SECTION 5**

# EO C232.01 – IDENTIFY THE CHARACTERISTICS OF GAS TURBINE ENGINES

Total Time: 60 min

## PREPARATION

### PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-802/PG-001, Chapter 4. Specific uses for said resources are identified throughout the Instructional Guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides or photocopy the handouts located at Annexes A, B, C and D for each cadet.

### PRE-LESSON ASSIGNMENT

N/A.

### APPROACH

An interactive lecture was chosen for TP1 and TP3 to TP5 to introduce the characteristics of gas turbine engines and give an overview of them.

An in-class activity was chosen for TP2 and TP6 as it is an interactive way to provoke thought and stimulate an interest among cadets.

## INTRODUCTION

### REVIEW

Review EO M232.01 (Identify Types of Aircraft Engines), to include:

- turbojet engines,
- turbofan engines, and
- turboshaft engines.

### OBJECTIVES

By the end of this lesson the cadet shall identify the characteristics of gas turbine engines.



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**IMPORTANCE**

It is important for cadets to know about the characteristics of gas turbine engines because this knowledge will enable them to recognize a variety of propulsion applications and to recognize reasons for the performance differences between various classes of aircraft.

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**Teaching point 1** **Explain That a Jet Engine Is a Reactive Engine**

Time: 5 min Method: Interactive Lecture

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A jet engine is a reactive engine, which propels itself by ejecting material to create a force, as described by Newton's third law of motion.

Newton's third law states that for every action there is an equal and opposite reaction. All propulsion systems rely on this fact in some way. A jet engine propels itself in one direction by ejecting a fluid (hot gas) in the opposite direction.

The amount of thrust developed by ejecting hot gas depends on the mass and velocity of the material ejected. To develop a lot of thrust, a lot of material must be ejected or else it must be ejected at high velocity. Most of the mass ejected by a jet engine comes from the air, which is scooped up from the atmosphere that the jet is passing through. That scooped air is raised to a high velocity by burning fuel.



Since the jet engine can always get more air, its thrust duration is limited only by the amount of fuel that it has available.

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**CONFIRMATION OF TEACHING POINT 1**

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**QUESTIONS**

Q1. What is Newton's third law of motion?

Q2. What determines the amount of thrust developed by a jet engine?

Q3. What determines the possible duration of a jet engine's thrust?

**ANTICIPATED ANSWERS**

A1. Newton's third law of motion states that for every action there is an equal and opposite reaction.

A2. The mass and the speed of the ejected material determine the amount of thrust.

A3. A jet engine's thrust duration is determined by the amount of fuel that it has available.

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**Teaching point 2** **Make and Operate a Pop Can Hero Engine**

Time: 15 min Method: In-Class Activity

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**ACTIVITY**

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**OBJECTIVE**

The objective of this activity is to have the cadets build and operate a pop can Hero engine to learn that an equal and opposite reactive force, as described by Newton, can cause an object to spin.



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## RESOURCES

- Instructions for making a pop can Hero engine located at Annex A.
- Empty pop can with the opener-lever still attached (one per group of four cadets),
- Common nail - one per group,
- String (very light, or dental floss), and
- Bucket or tub of water (one per group).

## ACTIVITY LAYOUT

This activity is to be carried out in an area with a waterproof floor covering.

## ACTIVITY INSTRUCTIONS

1. Fill tubs half-full of water to refill an empty pop can.

2. Give each group one empty pop can which still has the opening lever attached and bent straight up from the centre.

3. Give each group a metre of very fine string or dental floss.

4. Lay the pop can on its side as shown at Annex A.

5. Using a nail, punch a hole in the side of the pop can near the bottom as shown in Step 1 of Figure A-1 (ensure the holes are punched straight).

6. Rotate the pop can and punch one hole every 90 degrees, making four equally spaced holes.

7. Thread the string through the pop can opener-lever.

8. Have the cadets fill their pop can Hero engines with water and suspend them above the tub of water so the water drains into the tub.




The pop can Hero engine is unfinished at this point. The pop can Hero engine should not rotate as the water drains.

9. Now, have the cadets insert the nail back into each hole and bend each hole as shown at step 2 of Figure A-1. The holes should all be bent in the same direction, either clockwise or counterclockwise, so that the pop can Hero engine will spin under the equal and opposite reaction of the water draining.

10. Have the cadets refill their pop can Hero engines with water from their buckets and suspend the pop can Hero engines above the buckets with string. This time, while the water drains, the pop can Hero engine will spin.



The velocity of the spin should increase as long as the water continues to drain, if very fine string is used for suspension.

## SAFETY

Avoid spilling water on the floor as it may become dangerously slippery.



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## CONFIRMATION OF TEACHING POINT 2

The cadets' participation in the activity will serve as the confirmation of this TP.

**Teaching point 3** **Describe the History of Reaction Engine Development**

Time: 10 min Method: Interactive Lecture

### A SHORT HISTORY OF TURBINE ENGINES

**150 BC – Hero.** An Egyptian philosopher and mathematician, invented a toy (Aeolipile) that used steam to rotate on top of a boiling pot of water. The escaping steam caused a reaction that moved several nozzles arranged on a wheel.

**1232 – Battle of Kai-Keng.** Chinese soldiers used rockets as weapons to repel the Mongols at the Battle of Kai-Keng. Burning gunpowder and the reaction principle were used to propel the rockets. After Kai-Keng, the Mongols used rockets and it is believed that they brought the technology to Europe.

**1500 – Leonardo da Vinci.** He drew a sketch of a device, the chimney jack, which rotated due to the movement of smoke and hot gases flowing up a chimney. This device used hot air to rotate a shaft, which turned a spit. The hot air from the fire rose upward to pass through a series of fanlike blades that turned a shaft, which turned the roasting spit.

**1629 – Giovanni Branca.** He developed a stamping mill for bending metal. His stamping mill used jets of steam to spin a turbine, which rotated a shaft to operate the machinery.

**1872 – Dr. F. Stolze.** He designed the first true gas turbine engine. His engine used a multi-stage turbine section and a flow compressor. This engine never ran under its own power.

**1930 – Sir Frank Whittle.** He designed a gas turbine for jet propulsion in England. The first successful use of this engine was in April, 1937. His early work on the theory of gas propulsion was based on the contributions of most of the earlier pioneers of this field.

**1939 – Heinkel Aircraft Company.** This company flew the first gas turbine jet, the HE178.

**1941 – Sir Frank Whittle.** He designed the first successful turbojet airplane, the Gloster Meteor. Whittle improved his jet engine during World War II and in 1942, he shipped an engine prototype to General Electric in the United States. America's first jet aircraft was built the following year.

**1942 – Dr. Franz Anslem.** He developed the axial-flow turbojet, which was used in the Messerschmitt Me 262, the world's first operational jet fighter.

After World War II, the development of jet engines was directed by a number of commercial companies. Jet engines soon became the most popular method of powering high-performance aircraft.

## ACTIVITY

### OBJECTIVE

The objective of this activity is to have the cadets construct a simple gas turbine that will convert axial gas flow into rotary motion.

### RESOURCES

- Instructions for making a single-element reaction turbine located at Annex B,



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- Scissors,
- Straight pin, and
- Pencil with eraser.

**ACTIVITY LAYOUT**

N/A.

**ACTIVITY INSTRUCTIONS**

1. Cut out the rectangle shown in Figure B-1. Next, cut along each dotted line stopping about two centimetres from the hole in the centre of the square.

2. Take a straight pin and punch a hole in the top left corner of each of the four flaps. (No two holes should be next to each other.)

3. Pick up a flap at a punched corner and carefully curve it over toward the centre hole, securing it with the pin. Repeat this for the other flaps.

4. When all four flaps are held by the pin, carefully lift the paper without letting the flaps unfurl.

5. Lay the pencil flat on a table and carefully push the point of the pin into the side of the eraser.




Cadets can make the turbine spin by blowing directly into the centre of the blades. This action converts the axial movement of the air into rotary motion of the turbine blades.



The rotary motion of the turbine can be used for many purposes such as operating an air compressor or an electrical generator.

**CONFIRMATION OF TEACHING POINT 3**

**QUESTIONS**

Q1. What was the earliest known use of hot gases to produce rotary motion?

Q2. What did Leonardo da Vinci use hot gases to produce rotary motion for?

Q3. What aircraft was the first to fly with a gas turbine jet?

**ANTICIPATED ANSWERS**

A1. In 150 BC, Hero, an Egyptian philosopher and mathematician, used hot gases in a rotary toy.

A2. Leonardo da Vinci used hot gases to produce rotary motion for cooking food on a spit.

A3. The Heinkel HE178 was the first to fly with a gas turbine jet.



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**Teaching point 4** **Explain the Advantages of Using a Turbine**

Time: 5 min Method: Interactive Lecture




Show the cadets a slide or distribute a handout of Figure C-1.

The earliest jet to fly was a ramjet, the simplest jet engine, which has no moving parts. The speed of the aircraft forces air into the small volume of the engine, increasing air pressure and density. Ramjet application is restricted by the fact that its air compression depends on forward speed. The ramjet develops no static (stationary) thrust and very little thrust in general when travelling below the speed of sound. As a consequence, a ramjet vehicle requires some form of assisted takeoff, such as another aircraft, and so it has been used primarily in guided-missile systems.

In 1930, Sir Frank Whittle's ingenious idea of placing a turbine into the stream of hot exhaust gases allowed the operation of a compressor to solve the problem of running the engine at low speeds or static conditions. This is the secret of the turbojet engine and of all other refinements of the design, such as turboprops, turbofans and turboshafts.




Point out to the cadets the turbine shown in Figure C-2 and the absence of a turbine in Figure C-1.

Another benefit of turbines in jet engines is that they provide power for all sorts of ancillary flight instruments and other systems. In a modern airliner, turbine power provides everything from radio communications with the air traffic control tower to hot water for the passengers.

**CONFIRMATION OF TEACHING POINT 4**

**QUESTIONS**

Q1. What was the first type of jet to fly?

Q2. What is the principle difference between a turbojet and a ramjet?

Q3. What additional use has been found for turbine power on aircraft besides compressing air?

**ANTICIPATED ANSWERS**

A1. The first type of jet to fly was a ramjet, which relied on high speed to compress air for combustion.

A2. A turbojet can run at low speed or even under static conditions but a ramjet cannot.

A3. In addition to compressing air, turbines are used to power ancillary systems such as radios.



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**Teaching point 5** **Identify and Describe the Parts of a Gas Turbine Turbofan Engine**

Time: 5 min Method: Interactive Lecture




Show the cadets a slide or distribute a handout of Figure D-1.

The four basic parts of any gas turbine jet engine are the compressor, combustor, turbine, and nozzle, all of which process air, or core air, which travels through the engine. In the most common gas turbine aircraft engine, the turbofan, there is also the fan, which provides bypass air as well as core air, and a mixer, which combines the core airflow with the bypass airflow. The reduced engine noise levels and the excellent fuel efficiency of the turbofan engine have made it the engine design of choice for most modern commercial applications. Examples of varied turbofan applications are the CF-18's two GE F404 low bypass turbofan engines and the A380 Airbus's four Rolls-Royce Trent 900 high bypass turbofan engines; two dissimilar applications that both favour turbofan technology.

**PARTS OF A TURBOFAN ENGINE**

**Fan.** The fan is the first component in a turbofan. The fan pulls air into the engine. The air then splits it into two parts. One part continues through the "core" or centre of the engine, where it is acted upon by the other engine components. The second part "bypasses" the core of the engine, travelling through a duct to the back of the engine where it produces much of the force that propels the aircraft forward.

**Compressor.** The compressor is the first component in the engine core. The compressor squeezes the air into a smaller volume, increasing its pressure. The air is then forced into the combustor.

**Combustor.** In the combustor the air is mixed with fuel and ignited, producing high temperature, expanding gases.

**Turbine.** The high-energy airflow coming out of the combustor goes through the turbine, causing the turbine blades to rotate. The task of the turbine is to convert the linear gas motion into rotary mechanical work to drive the compressor, which then feeds the combustor with high-pressure air.

**Nozzle.** The nozzle is the engine's exhaust outlet. The hot, high-pressure gases that have passed through the turbine, combined with the colder air that bypassed the engine core, produce a force when exiting the nozzle that acts to propel the engine, and therefore the aircraft, forward. The nozzle may be preceded by a mixer, which combines the high temperature air coming from the engine core with the lower temperature air that was bypassed in the fan. The mixer results in a quieter engine.

**Afterburner.** In addition to the basic components of a gas turbine jet engine, one other process is occasionally employed to increase the thrust of a given engine. Afterburning consists of the introduction and burning of raw fuel between the engine turbine and the jet nozzle, utilizing the unburned oxygen in the exhaust gas to support combustion. The increase in the temperature of the exhaust gases further increases their velocity as they leave the propelling nozzle, which thereby increases the engine thrust. This increased thrust could be obtained by the use of a larger engine, but this would increase the weight and overall fuel consumption.



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## CONFIRMATION OF TEACHING POINT 5

### QUESTIONS

Q1. What are the four basic parts of any gas turbine jet engine?

Q2. In addition to the four basic parts, what two parts are found in a turbofan jet engine?

Q3. What are two features of the turbofan that make it attractive for modern commercial aircraft?

### ANTICIPATED ANSWERS

A1. The four basic parts of any gas turbine jet engine are compressor, combustor, turbine, and nozzle.

A2. In addition to the four basic gas turbine jet parts, a turbofan has a fan and a mixer.

A3. Two features of the turbofan that make it attractive for modern commercial aircraft are noise reduction and fuel efficiency.

**Teaching point 6** **Conduct a Crossword Game Based on Jet Power**

Time: 15 min Method: In-Class Activity

## ACTIVITY

### OBJECTIVE

The objective of this activity is to provide the cadets with an opportunity to use the terminology and definitions that have been learned in this lesson.

### RESOURCES

- Coin,
- Flip chart, and
- Markers.

### ACTIVITY LAYOUT

In the centre of a flipchart, print the word “combustion”.

### ACTIVITY INSTRUCTIONS

1. Divide the cadets into two teams.

2. Determine the order of play by flipping a coin.

3. The first team must make a word from terminology presented in this lesson, using a letter from the word “combustion” written on the flipchart in crossword manner.

4. For each letter in the new word the team will get one point.

5. Before the word can be written on the flipchart, the definition for the word must be provided by the team and the instructor must accept both the word and the definition.

6. Subsequent plays can utilize any letters on the flipchart.



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7. Any letter reused is worth two points.

8. The object of the game is to get the most points for the most letters in the time allowed.




Ensure that both teams get an equal number of turns.

**SAFETY**

N/A.

## CONFIRMATION OF TEACHING POINT 6

The cadets' participation in the activity will serve as the confirmation of this TP.

## END OF LESSON CONFIRMATION

**QUESTIONS**

Q1. What determines the amount of thrust developed by a jet engine?

Q2. What is the principle difference between the operations of a turbojet and those of a ramjet?

Q3. What are the four basic parts of any gas turbine jet engine?

**ANTICIPATED ANSWERS**

A1. The mass and the speed of the ejected material determine the amount of thrust.

A2. A turbojet can run at low speed or even under static conditions but a ramjet cannot.

A3. The four basic parts of any gas turbine jet engine are the compressor, combustor, turbine, and nozzle.

## CONCLUSION

**HOMEWORK/READING/PRACTICE**

N/A.

**METHOD OF EVALUATION**

N/A.

**CLOSING STATEMENT**

The gas turbine engine has proven so effective and adaptable that it has become one of the most popular solutions for aviation; Air Cadets will see gas turbines used in many applications.

**INSTRUCTOR NOTES/REMARKS**

N/A.



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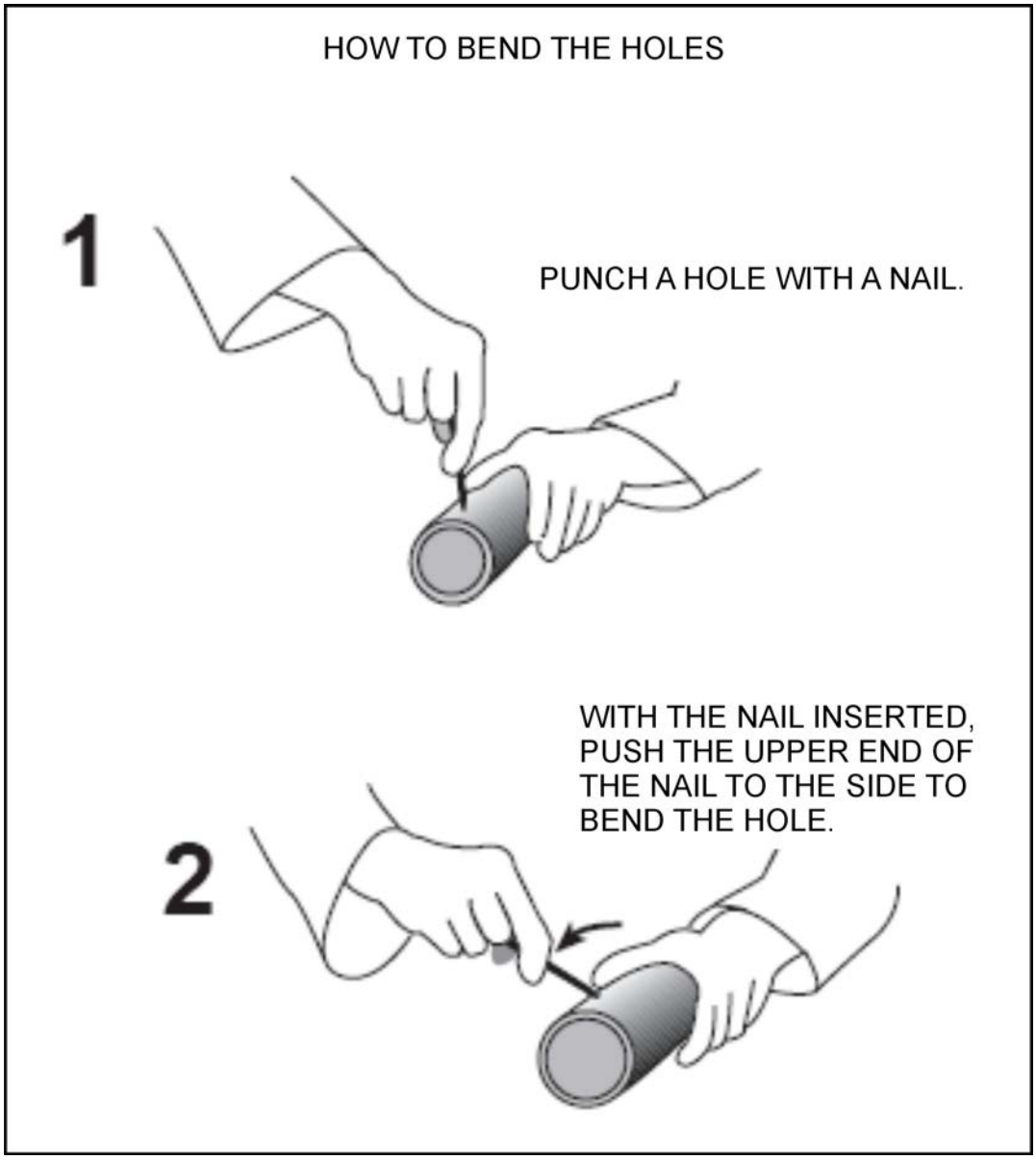
**MAKING A POP CAN HERO ENGINE**




*NASA, Rockets: A Teacher's Guide with Activities in Science, Mathematics and Technology, NASA (p. 30)*

Figure A-1 Making a Pop Can Hero Engine



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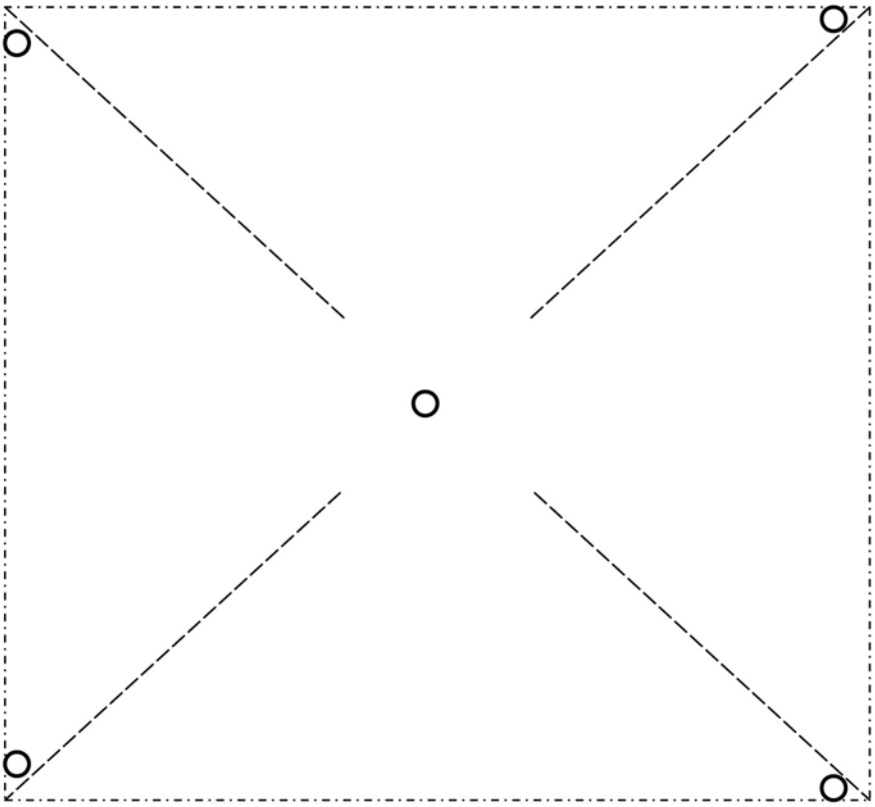
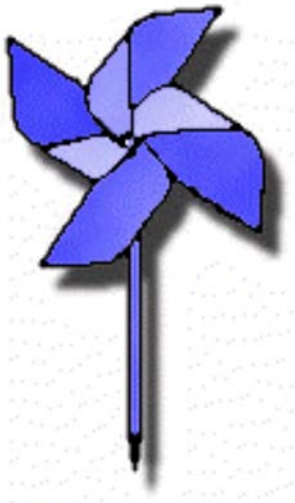
**SINGLE-ELEMENT REACTION TURBINE**



*D Cdts 3, 2007 Ottawa, ON: Department of National Defence*

Figure B-1 Single-element Reaction Turbine Template



*The Franklin Institute. "Resources for Science Learning" Pinwheel Wind Collector. Retrieved 21 February 2007, from http://sln.fi.edu/tfi/units/energy/pinwheel.html*

Figure B-2 Single-element Reaction Turbine



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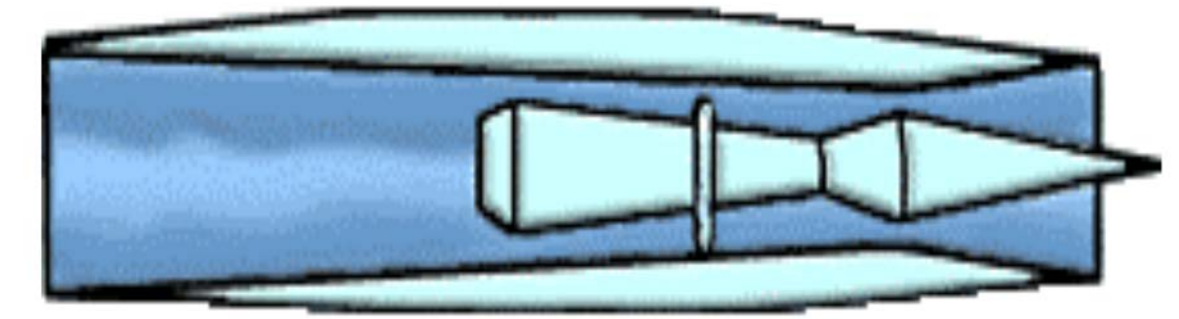
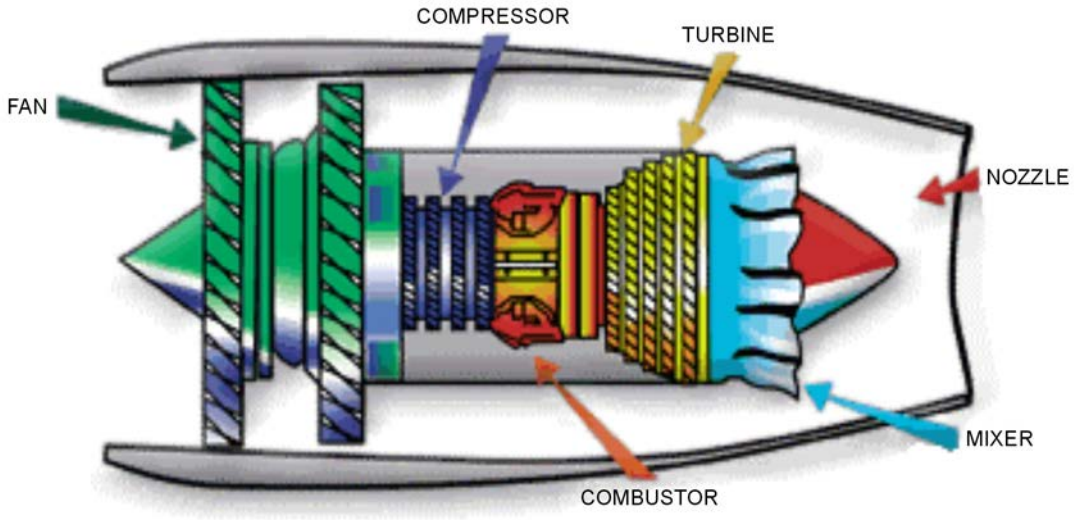
# A RAMJET ENGINE




*NASA "Engines 101". Ultra Efficient Engine Technology (UEET). (2001). Retrieved 17 March 2007, from http://www.ueet.nasa.gov/Engines101.html*

Figure C-1 A Ramjet Engine

# A TURBOFAN (FANJET) ENGINE




*NASA "Engines 101". Ultra Efficient Engine Technology (UEET). (2001). Retrieved 17 March 2007, from http://www.ueet.nasa.gov/Engines101.html*

Figure C-2 A Fanjet (Turbofan) Engine



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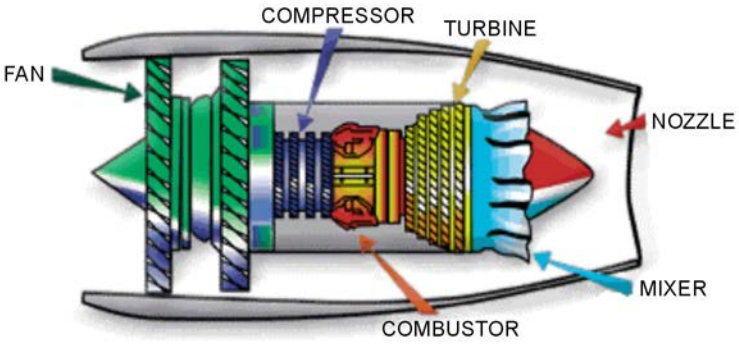
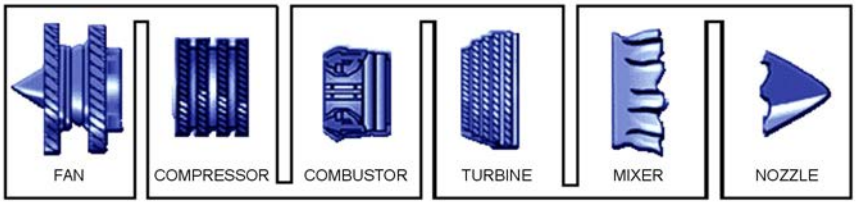
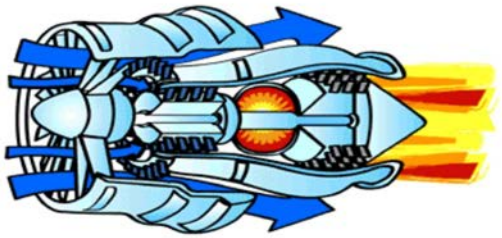
## PARTS OF A TURBOFAN (FANJET) ENGINE



*NASA "Engines 101". Ultra Efficient Engine Technology (UEET). (2001). Retrieved March 17, 2007, from http://www.ueet.nasa.gov/Engines101.html*

Figure D-1 Turbofan Parts



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