Year 1

SECTION 1

INTRODUCTION TO FLIGHT

Core Concepts in Aerospace Engineering

Fundamentals of Flight

INTRODUCTION

The flying machines you see now did not just come up. It all started from nature's inspiration through to different stages of development to where we are today. In this section, you will learn about the historical development of flights, the pioneers in aviation and the various classifications of flying vehicles and their parts, and how these parts function. This will help you appreciate the various phases aircraft design has gone through over the centuries. The way birds fly efficiently should be your primary inspiration as you consider aerospace studies. Note that you will be required to come up with your own concept of flight vehicles by the end of this section. Please follow through as your teacher guides you to this end.

At the end of the section, you will be able to:

- Trace the evolution of flight prior to powered, controlled flight.
- Describe the stages that led to the attainment of powered, controlled flight.
- Differentiate between the types of aerospace vehicles.
- Make free hand sketches of current and future aerospace vehicles and label their parts.

Key ideas:

- An ornithopters is an aircraft designed to copy the flight of birds directly.
- The pioneers of flight were people who successfully designed early working aircrafts.
- Fixed wing aircrafts are aircrafts whose main lifting surface is fixed.
- Rotary wing aircrafts are aircrafts whose main lifting surface rotates to produce lift.

WHAT IS AEROSPACE ENGINEERING?

Aerospace engineering is a field of engineering that deals with the design, construction, testing and operation of aircrafts and spacecrafts. Aerospace engineering can be broken down into two major parts.

They are

1. Aeronautical Engineering
2. Astronautical Engineering

Aeronautical engineering deals with the design and construction of aircrafts. These aircrafts fly within the Earth's atmosphere.

Astronautical engineering tackles the design and manufacturing of spacecrafts.

The aerospace industry did not begin as we have it today. The industry was developed by the collective effort and contributions of various pioneers who conducted research and worked on developing aerospace vehicles independently. We will take a look at the contributions of some notable aviation pioneers and also investigate what inspired them to pursue flight development.

KEY STAGES CHARACTERISING THE EVOLUTION OF FLIGHT

We begin our discussion with the natural ability of birds and other flying animals.

Flying Animals

For millennia, birds have ruled the skies with their remarkable ability to fly. Yet, many other animals possess adaptations that allow them to also achieve flight, either for brief moments or sustained periods. A variety of species, including some invertebrates or insects (such as butterflies, bees, etc), and even a few mammals (such as bats, flying squirrels) and fish (Exocoetidae or flying fish), have evolved the capability to glide or fly. Inspired by the graceful flight of these creatures, humans have long sought to conquer the skies, drawing directly from nature's aerial masters.

The mastery of birds in flight is a particular marvel. Scientists and engineers have tried to imitate birds directly to achieve higher flight efficiency. Among other things, birds have the following features that make flight convenient and efficient:

- Hollow bones that are extraordinarily strong but at the same time light in weight.
- Very light features that produce high aerodynamic lift to sustain flight.
- Very efficient lungs that can sustain respiration for a long time without stressing its muscles.
- Consumption of high energy foods that can sustain the bird for a long time in the air.
- A broad breastbone or sternum that supports their skeleton and muscles.
- A streamlined body that reduces their air resistance.

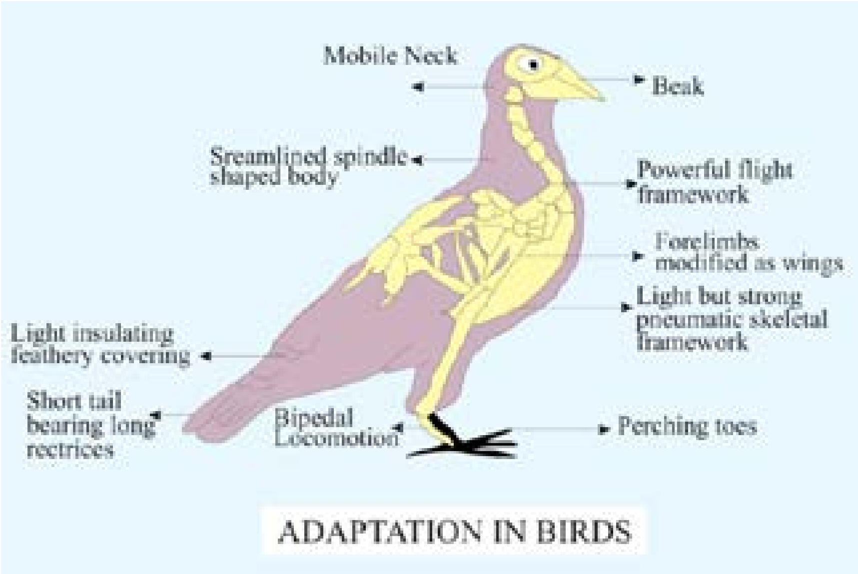

Fig 1.1 Features of birds that enable flight

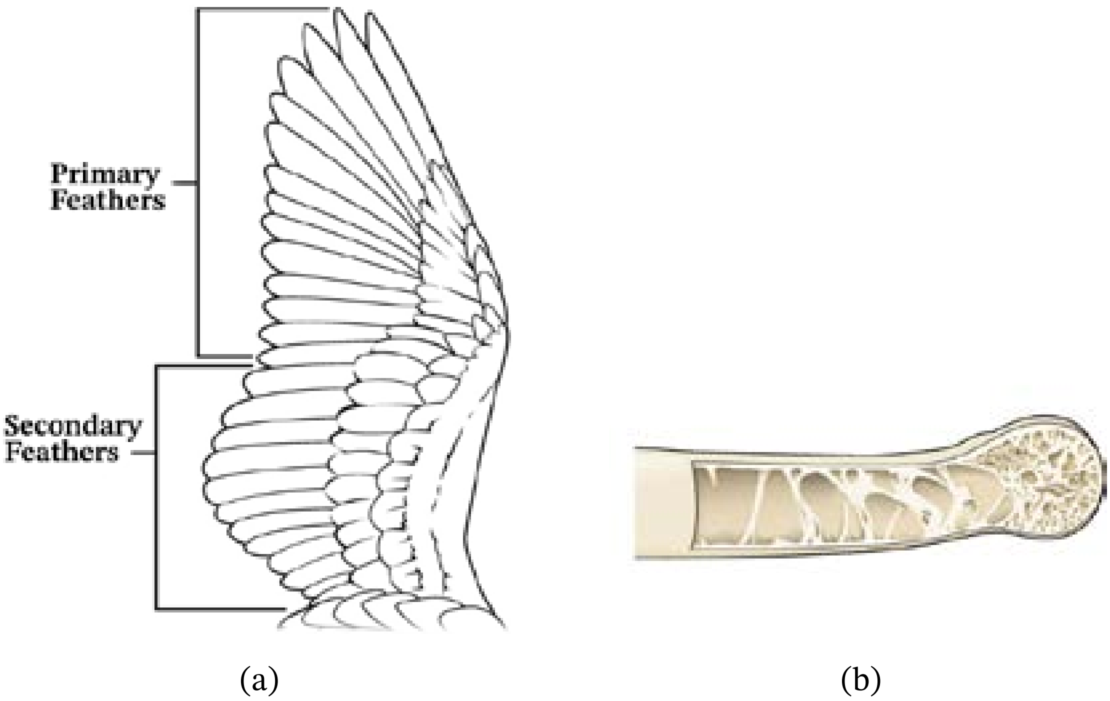

Fig 1.2 (a) bird feathers; (b) birds' hollow bones

Activity 1.1

1. Take a tour outside your classroom and observe different flying animals.
2. After your tour outside, make a list of animals you observed flying. What are the features of those animals that enable them to fly?

Name of animal observed flying	
Features that enable the animal to fly	
Name of animal observed flying	
Features that enable the animal to fly	

How do those features differ from animal to animal? Share your observation with your peer.

EARLY PIONEERS OF AVIATION

The Chinese in the 5th century invented the kite. It is the oldest heavier-than-air aircraft designed and was believed to ward off evil, deliver messages, and represent the gods. Currently, kites are used for pleasure and sports.

Fig 1.3 Ancient Chinese kite

HUMANS BEGINS TO DESIGN

Attempts made by humans to fly hinged on how birds fly using their wings. Some tried to imitate birds by putting wings and feathers on their backs. Leonardo da Vinci produced about 500 ornithopter sketches. Other people like Alphonse Pénaud, Abel Hureau de Villeneuve, and Victor Tatin also made ornithopters, but it took so much time before they realised they didn't possess the muscle power to sustain flight.

Fig 1.4 A sketch of an ornithopter

The Montgolfier brothers began to experiment with hot air balloons. In 1783, their balloon travelled 5 miles across Paris. Another approach to balloons was the use of lighter-than-air gases. In *1783,* French physicists *J. A. C. Charles and Nicolas-Louis Robert* flew a hydrogen-filled balloon for 2 hours and 5 minutes, covering 36 km. Most of the early flying machines were at the mercy of the wind. They lacked precise control.

Fig 1.5 Hot-air balloon

In 1799, *Sir George Cayley* introduced the concept of a flying machine. It was the first time a fixed wing was used for generating lift. It had a separate mechanism for propulsion. It had a combined horizontal and vertical tail surface for stability. Cayley generated information by conducting scientific experiments.

In 1804, he built a whirling-arm apparatus for testing airfoils. He built a model flier with a fixed wing and a horizontal and vertical tail that could be adjusted. This represented the first modern-configuration aeroplane in history. Cayley published his findings in his triple paper between 1809 and 1810.

In 1849, he built and tested a full-sized aeroplane which carried a 10-year-old boy down a hill.

Fig 1.6 Sir. George Cayley glider

Between 1857 and 1858, French naval officer *Du Temple* flew a monoplane with swept-forward wings powered by clockwork. It was the first successfully powered model aeroplane. In 1874, he achieved the first powered take-off by a piloted, full-sized aeroplane. *Mozhaiski* was the second to achieve powered take-off.

Neither Temple's nor Mozhaiski's aircraft experienced sustained flight.

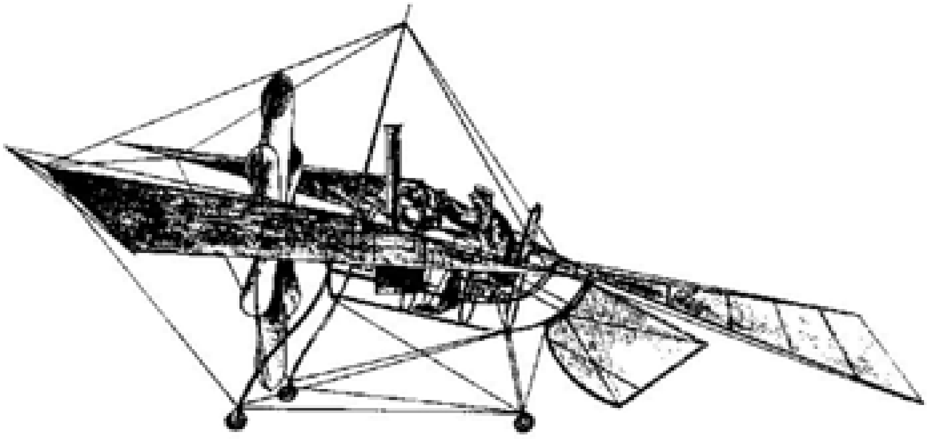

Fig 1.7 Felix du Temple's monoplane

French-born American civil engineer *Octave Chanute* published his book 'Progress in flying machines' in 1894. He summarised the progress in aviation to that date and suggested prospects for future powered flight. In 1896, he successfully designed and flew a biplane hang glider. In the same year, Samuel Langley's steam-powered models achieved flight. Between 1901 and 1903, he successfully tested scaled-down models of gasoline-powered aeroplanes. He built full-scale versions of his models and attempted two trials from houseboats; all of which ended unsuccessfully.

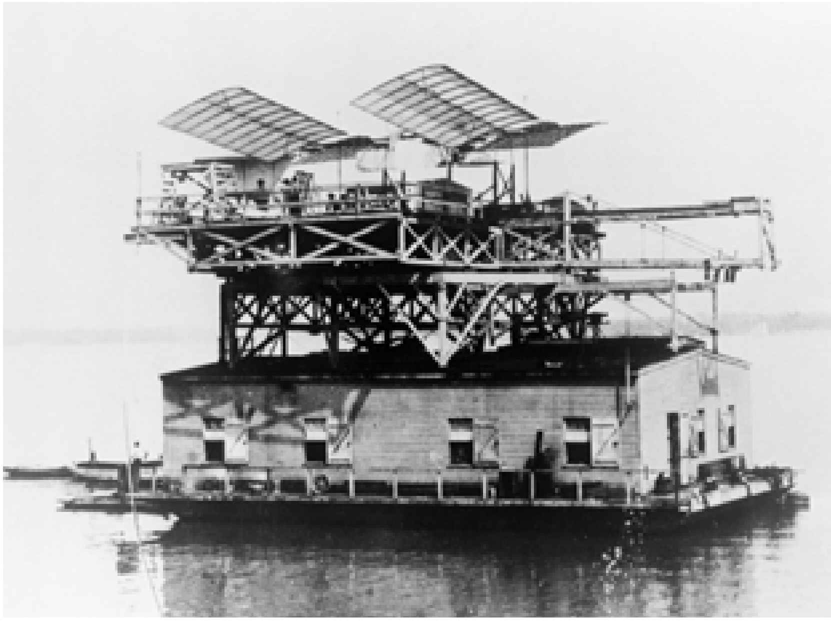

Figure 1.8 Samuel Langley's glider

Orville and Wilbur Wright set up a bicycle repair shop in 1892. They began to study the works of aviation pioneers like Lilienthal, Chanute, and Langley. In 1899, they built their first aircraft, a biplane kite with a wingspan of 5 ft. In late 1900, they flew a full-sized biplane glider at Kitty Hawk. Between 1901 and 1902, the Wright brothers conducted a series of aeronautical research using their own wind tunnel.

They tested over 200 different airfoil shapes, accurately measuring lift and drag. In 1903, they designed and built their own 12-horsepower gasoline engine, and in the summer of the same year, built their Wright Flyer I. On 17th December, 1903, taking turns at the controls, they achieved the first successful powered, controlled flight. The longest duration of their flights was 59 seconds.

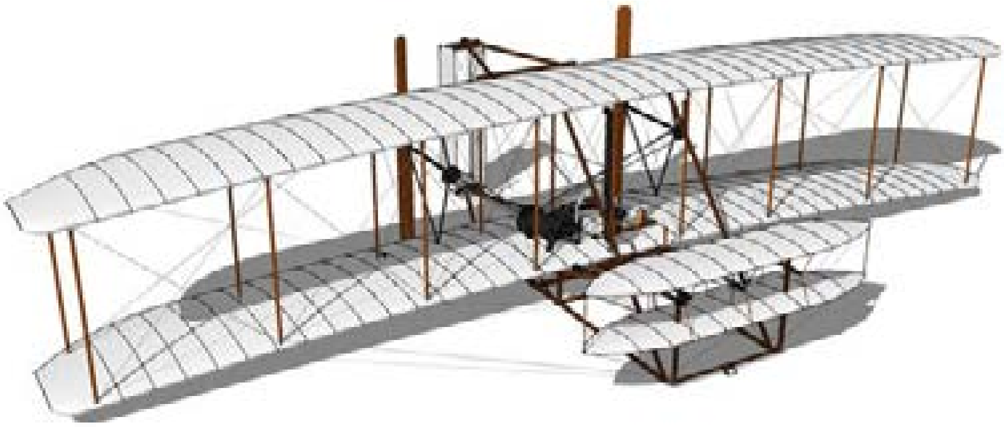

Figure 1.9 The Wright Flyer

Activity 1.2

1. Watch videos about the history of Aviation.
2. Summarise key milestones along the development of aviation.

Self-Assessment

- Develop a flowchart to illustrate the stages that led to the development of powered, controlled flight.
- What challenges did the pioneers of aviation face?

Activity 1.3

Brainstorm, with peers, on human attempts to fly like birds using lighter-than-air balloons and kites.

Discussion points for brainstorming session

1. **Early experiments and inventors**
   - Explore the contributions of early inventors and visionaries, such as Leonardo da Vinci and the Montgolfier brothers, to the concept of human flight.
   - Discuss early experiments with hot air balloons and other aerial devices.

2. **Scientific principles of flight**
   - Discuss the fundamental principles of flight, including lift, drag, thrust, and weight.
   - Discuss how these principles apply to both lighter-than-air balloons and kite flying.

3. **Historical milestones**
   - Highlight key historical milestones in the development of human flight using balloons and kites; such as the first balloon flight and significant kite-flying achievements.
   - Discuss the impact of these milestones on the advancement of aviation technology.

4. **Challenges faced by early aviators**
   - Identify the challenges faced by early aviators, including control, stability, and navigation.
   - Discuss the risks and dangers associated with early flight attempts.

5. **Technological innovations**
   - Explore technological innovations and advancements that have contributed to the development of lighter-than-air balloons and kites.
   - Discuss improvements in materials, design, and construction techniques.

6. **Application and use**
   - Explore the various applications and uses of balloons and kites in scientific research, exploration, recreation, and military operations.
   - Discuss how balloons and kites have been used throughout history and in modern times.

7. **Modern developments and innovations**
   - Discuss modern developments and innovations in balloon and kite technology, including unmanned aerial vehicles (UAVs) and high-altitude balloons.
   - Explore how these advancements have expanded the possibilities of human flight and exploration.

8. **Cultural and historical significance**
    - Explore the cultural and historical significance of human flight using balloons and kites in different societies and civilisations.
    - Discuss how these achievements have inspired art, literature, and popular culture.

9. **Environmental impact and sustainability**
    - Consider the environmental impact of balloons and kites, including issues related to waste, pollution, and wildlife disturbance.
    - Discuss sustainable practices and alternative technologies for aerial exploration and recreation.

10. **Future possibilities and challenges**
    - Brainstorm future possibilities and challenges in the field of flight, considering emerging technologies and innovations.
    - Discuss potential applications in areas such as transportation, surveillance, and environmental monitoring.

TYPES OF AEROSPACE VEHICLES AND THEIR PARTS

How Do Aeroplanes Fly?

Airplanes fly by generating an upward force as they move through the air. Similar to birds, they have wings that create an aerodynamic lift to counteract gravity. The wings are designed with a curved upper surface and a flatter lower surface. When the plane speeds up, the air pressure above the wing decreases while the air pressure below increases. This pressure difference lifts the wings and the airplane into the sky. The diagram below shows how this works:

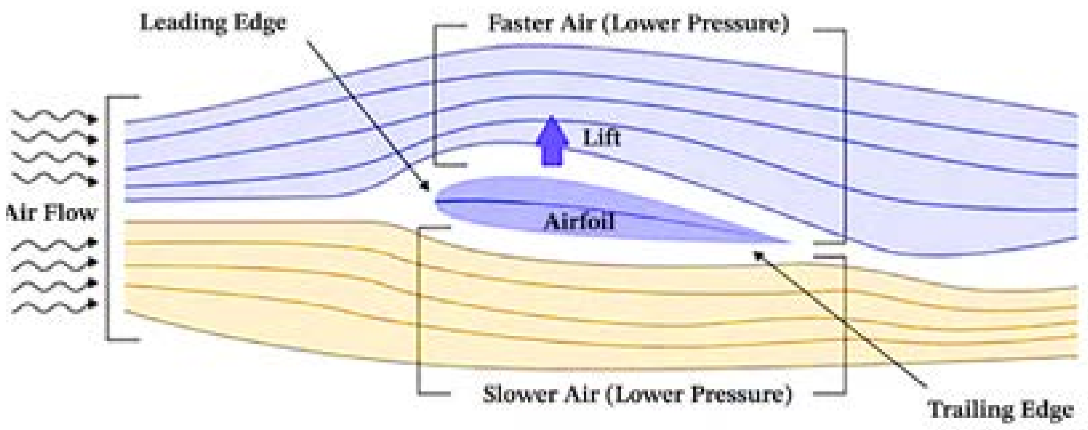

Figure 1.10 Image of an airfoil

Forces of Flight

As an aircraft moves through the air, it encounters four main forces that affect its movement.

- *Drag*: This is the resistance of the air against the body of the aircraft as it moves forward. It is preferable to reduce the drag on an aircraft to the minimum. This is because the higher the drag, the more power required to propel the aircraft forward. One prominent way to achieve drag reduction is by streamlining the airframe.
- *Thrust*: This is the forward push of the aircraft through the air by its engines.
- *Lift*: This is the upward force produced by the wings. On a fixed-wing aircraft, the lift is generated by the wings. On a rotary-wing, it is generated by the blades on the spinning rotors.
- *Weight*: This is the downward force produced by the total weight of the aircraft. This is due to gravity pulling on the aircraft's mass. Every single component on the aircraft contributes to the total weight.

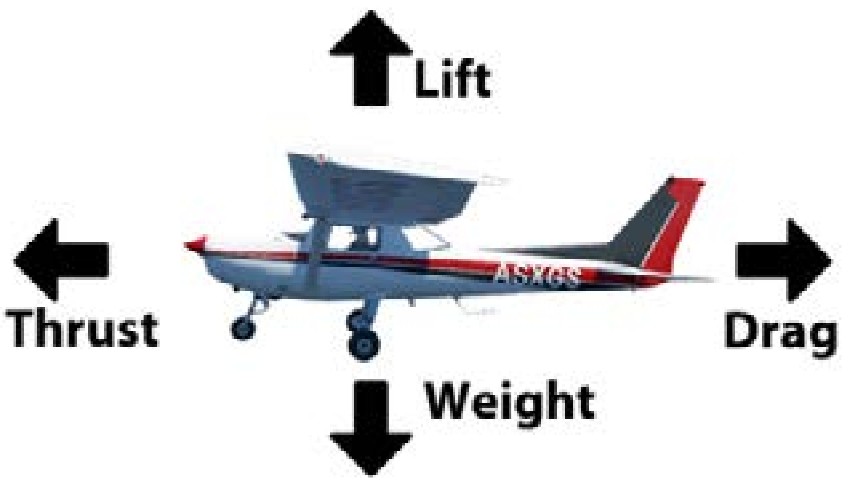

Fig 1.11 Forces of Flight

AEROSPACE VEHICLES

Aerospace vehicles can be broadly grouped into these three:

1. Fixed wing aircraft
2. Rotary wing aircraft
3. Spacecraft

Fixed wing aircraft

In this type of airplane, the wings are firmly attached to the body and don't move in relation to the rest of the plane. These planes, called fixed-wing aircrafts, are often used as passenger planes and for carrying cargo because they can hold a lot of weight. Figures 1.12 and 1.13 show a large commercial plane and a small two-seater plane, both of which are examples of fixed-wing aircraft. Fixed-wing planes have many parts that work together to help them fly. Figure 1.14 below shows a fixed-wing plane and labels some of its key parts.

Fig 1.12 A passenger airliner

Figure 1.13 A twin-seater light aircraft

"The main components of a fixed-wing aircraft include the following

Figure 1.14 Parts of a fixed-wing aircraft

1. **Fuselage**: This is the main body of the aircraft. It provides a surface on which the wings, tail, and landing gear are attached. It houses the payload (crew, passengers, and cargo).
2. **Wing**: The wing is responsible for generating the lift force to keep the aircraft airborne. A vertical cross-sectional view of the wing reveals a shape called an airfoil. The wing can generate lift due to the airfoil's shape. As the wing moves through the air, the air pressure on top of the wing decreases while the one on the bottom increases. This creates a pressure difference which results in a net upward force called *lift*. In many fixed wing aircrafts, the wings provide a convenient space to store fuel.

   Wings come in different shapes and forms depending on the performance requirement of the aircraft. For instance, swept wings are often favoured in high-speed aircraft design due to their reduced drag. The images below illustrate various wing configurations based on their planform and position.

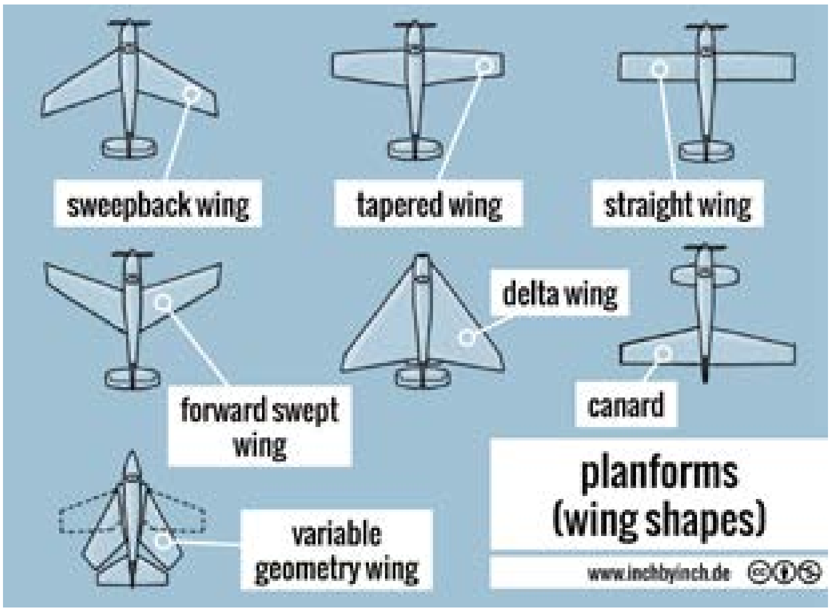

Figure 1.15 Various wing platform shapes

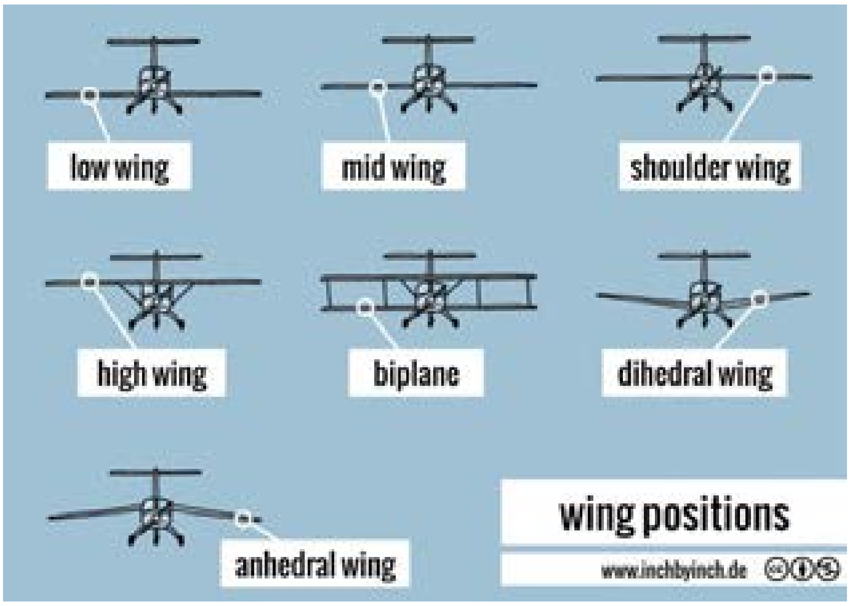

Figure 1.16 Wing positions

3. **Ailerons***:* These are movable control surfaces attached near the trailing edge of the wings, typically located towards the wingtips. The movable part, called the elevator, is used to pitch the aircraft up or down as shown in **Figure 1.20**.

4. **Flaps***:* They are also found at the trailing edge of the wings. They generate more lift at lower speeds. They also help reduce the speed of the aircraft. They are mostly used during takeoff and landing. They can also be used mid-flight to enable the aircraft fly at low speeds.

5. **Tail/Empennage***:* The tail comprises the vertical tail and horizontal tail.
   Vertical tail: There is a fixed part and a movable part on the vertical tail. The fixed part, which does not move relative to the airframe, is called the vertical stabiliser. The vertical stabiliser provides directional stability to the aircraft. The movable part is called the rudder. The rudder is used to turn the aircraft's nose left or right about the vertical axis, as shown in **Figure 1.20**.

   Horizontal tail: The horizontal tail consists of both a fixed part and a movable part. The fixed part, known as the horizontal stabilizer, provides stability along the aircraft's lateral axis. The movable part, called the elevator, is used to pitch the aircraft up or down, as shown in **Figure 1.20**.

   There are various tail configurations, and the choice of configuration typically depends on the aircraft's intended purpose. The image below illustrates some common tail configurations.

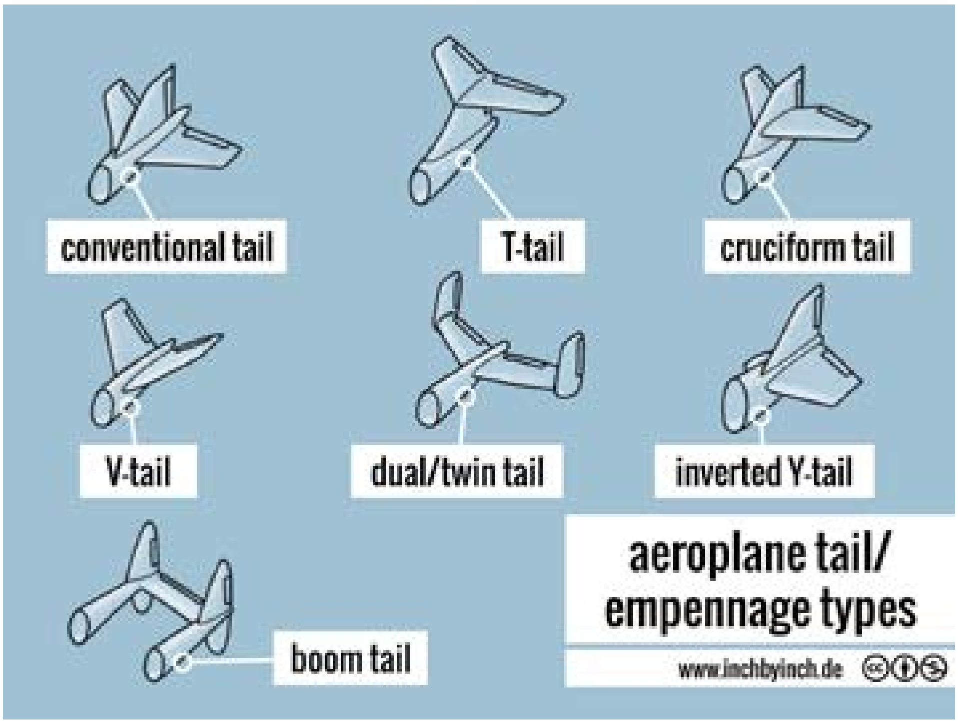

Figure 1.17 An image showing some common aircraft tail configurations

6. **Landing gear:** The landing gear supports the aircraft on the ground during taxiing, take-off, and landing. Depending on the environment in which the aircraft is used, it could be made of wheels, skis, or floats.

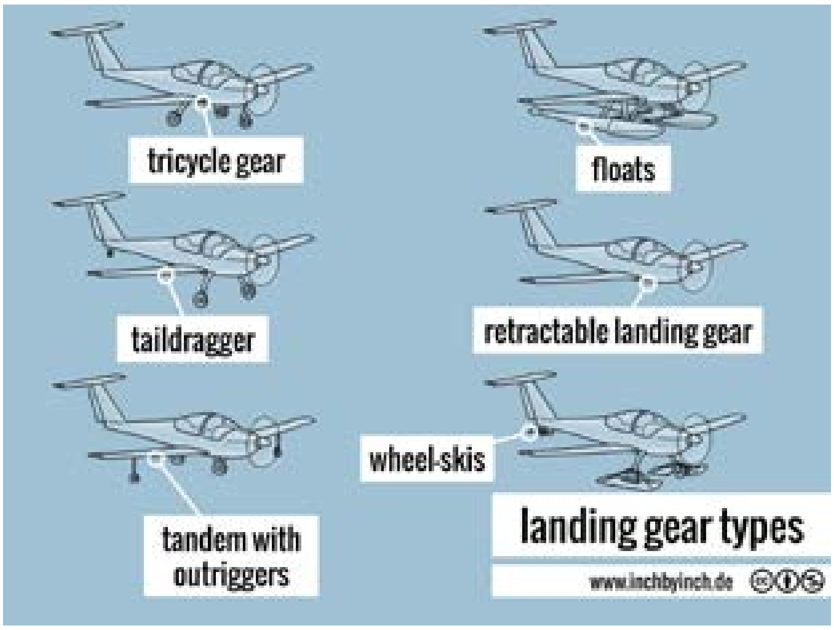

Figure 1.18: Type and arrangement of landing gears

7. **Engine:** This provides the power to move the aircraft through the air. It may be an internal combustion engine that drives a propeller to push backward a jet of air at high speed.

Fig 1.19: Aircraft engine and propeller

Rotary Wing Aircraft

In this configuration, the rotors form the main lifting surface. They are 'wings' that rotate at high speed to generate lift for the aircraft. There are different types of rotary wing aircrafts. Quadcopter, octocopters, and helicopters are common examples of rotary wing aircrafts. Rotorcrafts share some features with fixed wing aircrafts. Quadcopters and octocopters fall under a category called multirotor. For example, the fuselage, power plant, and landing gear.

Fig 1.20 A Quadcopter

Fig 1.20b A Octocopter

Fig 1.21 A helicopter

Main rotor(s): The main rotors consist of two or more blades connected to a rotating shaft, powered by an engine that causes them to spin. This spinning action tends to make the airframe spin in the opposite direction. To counteract this, a tail rotor is used and without it, a single rotor helicopter would spin uncontrollably. Some rotary wing aircrafts use a coaxial rotor system or multiple rotors to correct the spin tendency of the airframe.

Tail rotor*:* The tail rotor, found in helicopters, is attached to a tail boom and functions to produce a counterforce that prevents the aircraft from spinning out of control. The rotor blades can also be adjusted to turn the aircraft. The tail boom houses the components that transmit power from the main engine to the tail rotor.

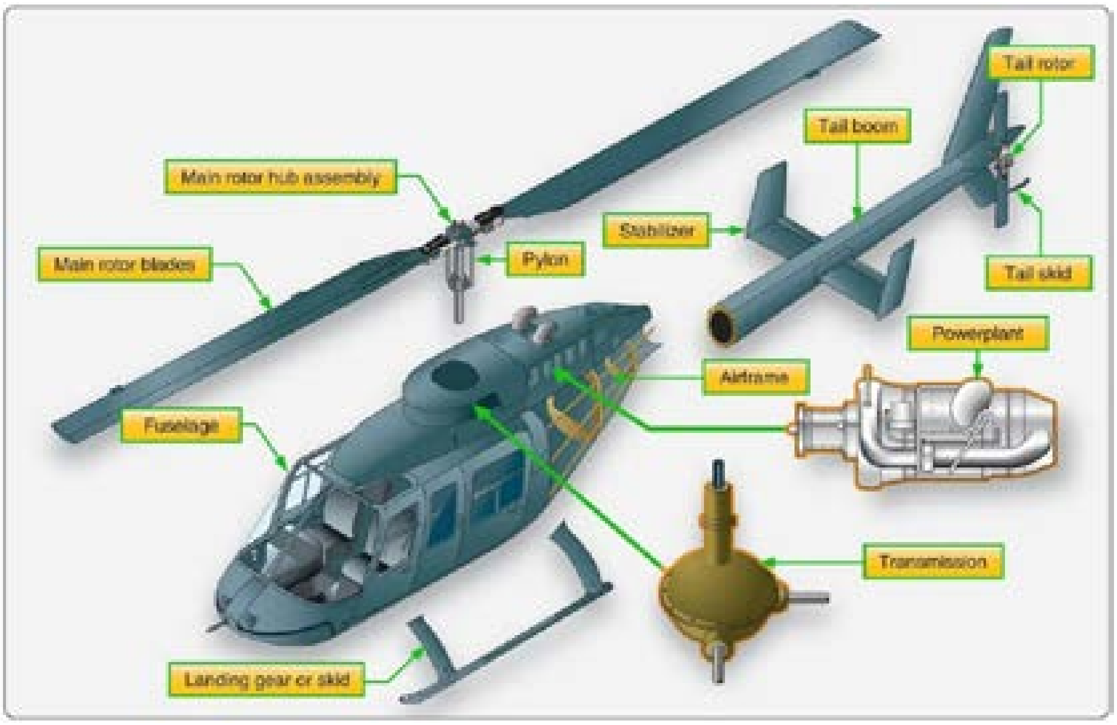

Figure 1.22 Parts of a helicopter

Figure 1.23 Tandem rotor helicopter

Differences between fixed wing and rotary wing aircraft

Fixed wing and rotary wing aircrafts have specific roles they play in air travel. These roles are determined by the capabilities of the aircraft. Each of these types of aircrafts has strengths and weaknesses. Let's explore some of them.

Fixed wing aircraft	
Advantages	**Disadvantages**
1. They can fly for a long period of time.	1. Require runways, catapults, or other facilities to take off and hence are limited in small spaces.
2. Highly efficient.	2. Cannot hover.
3. They can cover long distances.	3. Bulky
4. Can fly at high speeds.	4. Long setup time.
5. Can carry a heavier payload.	
6. More stable in strong winds.	

Rotary wing aircraft	
Advantages	**Disadvantages**
1. They have vertical take-off and landing (VTOL) capability.	1. They have short flight time.
2. They can hover.	2. They are not very fuel efficient.
3. Do not need a runway to take-off or land.	3. Shorter range.
	4. Generally, have lower speeds.

Spacecraft

These are vehicles designed to operate beyond Earth's atmosphere, such as launch vehicles, satellites, and deep space probes. Spacecrafts must carry oxidisers along with fuel since there is no air in space. The payload carried by a spacecraft varies depending on its mission. Common uses of spacecrafts include communications, Earth observation, meteorology, navigation, space exploration, planetary missions, and transporting humans and cargo.

A typical spacecraft may have the following elements:

- Instruments for conducting science experiments.
- Structures that hold all the equipment.
- Mechanisms that allow some parts to point independently of the main spacecraft.
- Telecommunications for sending and receiving data.
- Propulsion for correcting the spacecraft's flight path.

- Guidance, navigation, and control systems.
- Thermal systems for maintaining proper temperatures.
- Electrical power, usually derived from solar panels.

Fig 1.24 A spacecraft

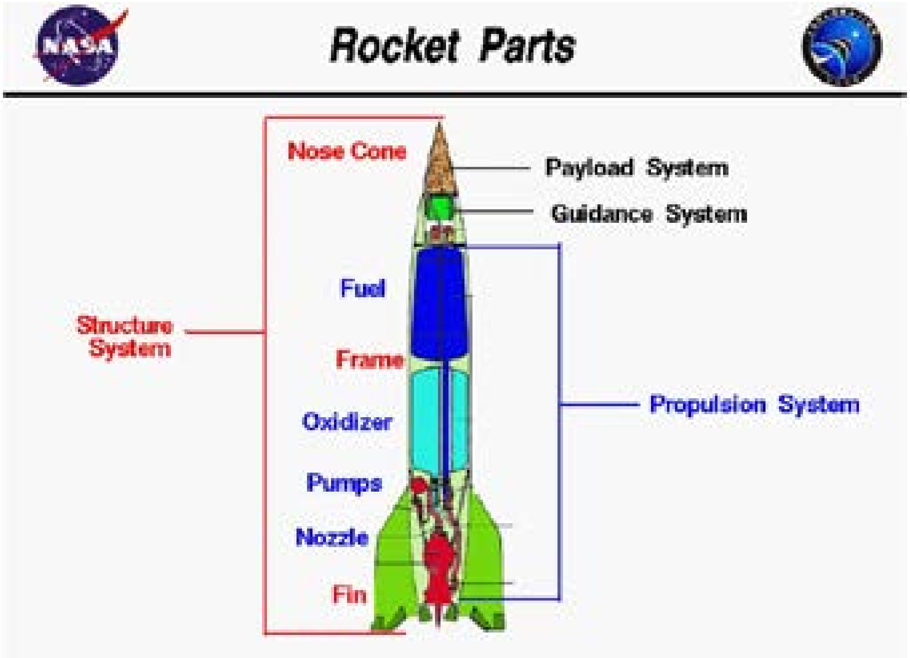

Figure 1.25 Parts of a rocket

How Does a Rocket Work?

Rockets operate based on Newton's third law of motion, which states that 'for every action, there is an equal and opposite reaction'. Rocket engines harness this principle by expelling high speed gases through their nozzles to generate thrust. This thrust creates a reaction force that propels the spacecraft upward. This principle can be likened to the experience of releasing the neck of an inflated balloon; as the air exits from the tip, the balloon moves in the opposite direction. Similarly, in rockets, the action is the expulsion of gases from the nozzles and the reaction is the propulsion of the rocket in the opposite direction.

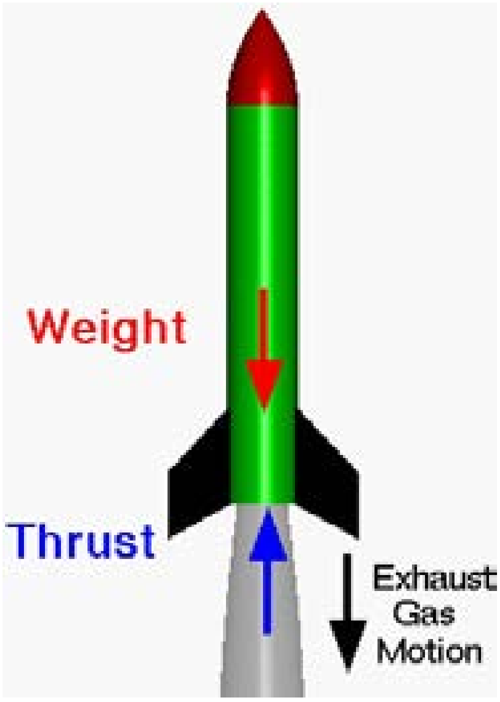

Fig 1.26 An image showing the action (exhaust gas motion) and reaction force (thrust) on a rocket

Activity 1.4

Class discussion

Discuss flight vehicle terminologies based on the following topics. Take note of important features or ideas to share with the class later.

Discussion points

1. **Requirement for flight: generation of lift**
   a. Discuss the principle of lift and how it enables flight.
   b. Explain the role of air foils, such as wings and rotor blades, in generating lift.
   c. Highlight the importance of aerodynamics in designing flight vehicles.
2. **Broad classes of aircraft: fixed wing and rotary wing**
   a. Define fixed wing and rotary wing aircraft and their respective characteristics.
   b. Discuss examples of each type of aircraft and their primary applications.
3. **Major parts of a helicopter and a fixed wing aircraft**
   a. Identify and discuss the major parts of a helicopter, including the main

rotor, tail rotor, fuselage, and landing gear.

b. Similarly, identify and discuss the major parts of a fixed wing aircraft, including the wings, fuselage, empennage, and landing gear.

4. Major differences between rotary and fixed wing aircraft

a. Compare rotary and fixed wing aircrafts, focusing on their design, flight characteristics, and operational capabilities.

b. Highlight the advantages and disadvantages of each type of aircraft for specific missions and tasks.

5. Types and components of space vehicles

a. Identify the different types of space vehicles.

b. Give the major components of space vehicles and their functions.

c. Outline the importance of space vehicles.

6. Summarise your findings below.

Activity 1.5

Design and fly a simple paper aeroplane or kite.

Materials needed:

a. Paper

b. Sticks

c. Paper clips

d. Pieces of cloth or plastic bags

Use lightweight locally available materials like paper or fabric for the kite's sail. Pieces of sticks can be used for the frame and a string as the flying line. Glue, strings or tape can be used for holding the frame together. The string should be light and strong enough to be able to withstand the tugging caused by the wind. Adding a tail is optional but recommended to provide stability to the drone. The tail can be made from a long piece of fabric of about a metre long. Markers or paint could be used to decorate the sail. The kite should be tested in an open field with plenty of space and light wind. Ensure there are no power lines or tall structures around the field where the kite will be flown.

In the course of performing this activity, ensure the following safety precautions are adhered to:

1. Wear the necessary personal protective equipment (like safety goggles and nose mask).
2. Use the right tool for the appropriate task.
3. When using glue, be careful so as to not spill it around. Any spillage should be quickly wiped with a tissue. In the case where CA glue (Cyanoacrylate glue or "super glue") is being used, avoid direct contact with skin and eyes as this can cause irritation. Do not directly inhale CA glue as this may cause drowsiness. Also be mindful when using hot glue as it may cause burns when it comes into direct contact with the skin.
4. Adhere to standard safety practices.

   The links below provide a more visual description of how to build a kite using locally available materials:

   https://www.youtube.com/watch?v=h5k8M2k6GrM

   https://www.youtube.com/watch?v=lBukRxTt_uA

Self-Assessment

Why was your model effective or not? How can it be improved?

Self-Assessment

What happens when the volume of water in the water rocket is reduced or increased? Write your results below:

SKETCHES OF CURRENT AND FUTURE AEROSPACE VEHICLES

Your teacher will guide you through the following activity. You will need some materials. Contact your teacher or friends if you are not able to acquire them. Follow the instructions your teacher will give in class and seek help if you have any difficulty.

Materials needed:

- Pencil
- Pen
- Ruler
- Eraser
- Plain sheet
- Drawing book

In this session, you will make a sketch of aircrafts.

Current aircrafts

- A current fixed wing aircraft
- A current rotorcraft
- A current spacecraft

Possible future aircrafts

- A future fixed-wing aircraft
- A future rotorcraft
- A future spacecraft

Activity 1.6

Watch the following videos:

Parts of Aircrafts and their Functions https://www.youtube.com/watch?v=1kDazWUImGU	
Essential Aircraft Anatomy: Main Parts of an Airplane https://www.youtube.com/watch?v=EaaG94UMZTw	
Parts of a Helicopter and their functions https://www.youtube.com/watch?v=Jg9NLUJKmdM	

Parts of a space shuttle with functions https://www.youtube.com/watch?v=22kd14jrLxg	
Types of Aircraft https://youtu.be/7zOffU-W_4U	

Self-Assessment

Make a list of different aerospace vehicles.

Fixed wing Aircraft	Rotary wing aircraft	Spacecraft
E.g. Monoplane	Autogyro	Space shuttle

Write down and compare the features of the aerospace vehicles you have noted and share your findings with a friend.

Develop a PowerPoint presentation with your answers.

GLOSSARY

WORD	MEANING
Airfoil	The cross-section of a wing that gives it the most favourable conditions to generate lift
Wind tunnel	A large tube designed to test how an object reacts to moving air
Taxi	The movement of an aircraft on the ground with its own power
Co-axial rotor	Two main rotors mounted on one mast sharing the same axis of rotation but turning in opposite directions, one on top of the other
Tandem rotor helicopter	A helicopter that has two main rotors, one at the front of the fuselage and the other at the back, which counteract each other's torque
Aerodynamics:	the way air moves around objects, particularly when they are in motion

Review Questions

1. Note down one flying animal. If you are tasked to develop an aircraft, which part of the animal would you incorporate in your design to make it work better? Briefly explain your answer.
2. Using an appropriate table or chart, trace the notable milestones in aircraft design among the early pioneers of aviation.
3. Among the early pioneers of flight, whose invention seemed most revolutionary in aircraft development?
4. Identify the different parts of the following flight vehicles:
   i. Rotary wing
   ii. Fixed wing
   iii. Spacecraft
5. State two differences between an aircraft and a spacecraft.
6. You are appointed as the chief of police in a busy urban environment. Which aircraft type would you choose for aerial patrols, and why?
7. Make sketches of two possible future concepts of an aircraft or spacecraft.

Answers to Review Questions

1. Sample parts
   a) Wings
   b) Tail
   c) Body
   d) Hollow bones
2. Sample developments
   a. Ancient folklore
   b. Development of the kite
   c. Development of ornithopters
   d. Development of hot-air balloons
   e. Development of gliders
   f. Development of internal combustion engines
   g. Development of controls
   h. Success of the Wright Flyer
3. Sample inventors
   a) Leonardo Da Vinci – sketches of ornithopters
   b) Montgolfier Brothers – hot air balloons
   c) Nicolas-Louis Robert - hydrogen-filled balloon
   d) Sir George Cayley – separated lift structure from propulsion device
4. Sample parts
   i. **Rotary wing** – Rotors, Mast, Boom, Tail-Rotor, Landing Skids, Engine-Transmission, Cockpit, Fuselage.
   ii. **Fixed wing** - Wing, Landing Gear, Nose Gear, Vertical Stabiliser, Horizontal Stabiliser, Rudder, Elevator, Ailerons, Flaps.
   iii. **Spacecraft** – Body, Fins, Thrusters, Payload, Recovery Chute, Propellant, Oxidiser, Electronic Guidance System.
5. (a) An aircraft uses a surface through the atmosphere for lift whereas a spacecraft uses its engines for lift.

   (b) An aircraft is designed to work in the Earth's atmosphere whereas a spacecraft is designed for use outside the Earth's atmosphere.
6. A fixed wing aircraft has its main lifting surface permanently fixed to its body whilst a rotary wing aircraft has its lifting surface rotate constantly through the air to produce lift. (Choose your own solution and explain your decision)
7. Produce a sketch of possible future aircrafts or spacecrafts.

References and extended reading

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Videos

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