Introduction to Aerospace Engineering (R17A2101)

COURSE FILE

II B. Tech I Semester

(2018-2019)

Prepared By

Prof Vedantam Ravi

Department of Aeronautical Engineering

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

Affiliated to JNTU, Hyderabad, Approved by AICTE - Accredited by NBA & NAAC – 'A' Grade - ISO 9001:2015 Certified)

Maisammaguda, Dhulapally (Post Via. Kompally), Secunderabad – 500100, Telangana State, India.

MRCET VISION

- To become a model institution in the fields of Engineering, Technology and Management.
- To have a perfect synchronization of the ideologies of MRCET with challenging demands of International Pioneering Organizations.

MRCET MISSION

To establish a pedestal for the integral innovation, team spirit, originality and competence in the students, expose them to face the global challenges and become pioneers of Indian vision of modern society.

MRCET QUALITY POLICY.

- To pursue continual improvement of teaching learning process of Undergraduate and Post Graduate programs in Engineering & Management vigorously.
- To provide state of art infrastructure and expertise to impart the quality education.

PROGRAM OUTCOMES
(PO's)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design / development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multi disciplinary environments.
12. **Life- long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

DEPARTMENT OF AERONAUTICAL ENGINEERING

VISION

Department of Aeronautical Engineering aims to be indispensable source in Aeronautical Engineering which has a zeal to provide the value driven platform for the students to acquire knowledge and empower themselves to shoulder higher responsibility in building a strong nation.

MISSION

The primary mission of the department is to promote engineering education and research. To strive consistently to provide quality education, keeping in pace with time and technology. Department passions to integrate the intellectual, spiritual, ethical and social development of the students for shaping them into dynamic engineers.

QUALITY POLICY STATEMENT

Impart up-to-date knowledge to the students in Aeronautical area to make them quality engineers. Make the students experience the applications on quality equipment and tools. Provide systems, resources and training opportunities to achieve continuous improvement. Maintain global standards in education, training and services.

PROGRAM EDUCATIONAL OBJECTIVES – Aeronautical Engineering

1. **PEO1 (PROFESSIONALISM & CITIZENSHIP):** To create and sustain a community of learning in which students acquire knowledge and learn to apply it professionally with due consideration for ethical, ecological and economic issues.
2. **PEO2 (TECHNICAL ACCOMPLISHMENTS):** To provide knowledge based services to satisfy the needs of society and the industry by providing hands on experience in various technologies in core field.
3. **PEO3 (INVENTION, INNOVATION AND CREATIVITY):** To make the students to design, experiment, analyze, and interpret in the core field with the help of other multi disciplinary concepts wherever applicable.
4. **PEO4 (PROFESSIONAL DEVELOPMENT):** To educate the students to disseminate research findings with good soft skills and become a successful entrepreneur.
5. **PEO5 (HUMAN RESOURCE DEVELOPMENT):** To graduate the students in building national capabilities in technology, education and research

PROGRAM SPECIFIC OUTCOMES – Aeronautical Engineering

1. To mould students to become a professional with all necessary skills, personality and sound knowledge in basic and advance technological areas.
2. To promote understanding of concepts and develop ability in design manufacture and maintenance of aircraft, aerospace vehicles and associated equipment and develop application capability of the concepts sciences to engineering design and processes.
3. Understanding the current scenario in the field of aeronautics and acquire ability to apply knowledge of engineering, science and mathematics to design and conduct experiments in the field of Aeronautical Engineering.
4. To develop leadership skills in our students necessary to shape the social, intellectual, business and technical worlds.

SESSION PLANNER

R17A2101- INTRODUCTION TO AEROSPACE ENGINEERING

YEAR: II **SEMESTER: II**

S. N O	UNIT NO	TOPIC	NO OF CLAS SES HEL D
I	UNIT-1	**History of Flight- the Aerospace Environment**:	
1		Evolution of Flight, Usage of balloons, Dirigibles, Heavier than air aircraft	1
2		commercial air transport, introduction of jet aircraft, helicopters	2
3		Missiles, conquest of space, commercial use of space, exploring solar system and beyond.	1
4		Earth's atmosphere, standard atmosphere	2
5		The temperature extremes of space	2
6		Laws of gravitation, low earth orbit, microgravity, benefits of microgravity	2
7		The near-earth radiative environment. The magnetosphere. Environmental impact on spacecraft	2
8		Meteoroids and micrometeoroids, space debris. Planetary environments.	1 Total 13
	UNIT- II	**Aerodynamics and Performance**	
1		Airfoil-nomenclature and types;	2
2		Aerodynamic forces on wings and bodies. Generation of lift. Sources of drag.	2
3		Force and moment coefficients, Centre of Pressure. Control surfaces	4
4		Rotary wing aircraft concepts-forces while hovering; Propeller theory	2
5		Performance requirements of civil and military aircraft.	2 Total 12
III	UNIT III	**Propulsion-Aircraft, Rockets and Missiles**	
1		Thrust for flight; Reciprocating engines-two-stroke & four-stroke; the jet engine, rocket engines- description, types, principles of operation.	3

2		Types of missiles; similarities & differences with launch vehicles;	2
3		Control for missiles, airframe components of missiles	2
4		**Evolution of Space missions**: Space missions, mission objectives,	1
		Case studies. Human space flight missions- goals, historical background. The Soviet and US missions. The Mercury, Gemini, Apollo-Soyuz, Space Shuttle	2
		Types of orbits and maneuvers, International Space Station, extravehicular activity. Life support systems.	2
		History and evolution of ISRO; missions carried by ISRO	2 Total 14
IV		**Structures:** History of airplane construction; Loads on aircraft	**2**
2		Lift production/augmentation devices; Low speed/high speed aerfoils	3
3	**UNIT-IV**	Monocoque and semi-monocoque structures, Load bearing structural components	2
4		Use of composites in aircraft and aerospace vehicles	3 Total 10
V			
1		**Experimental Aerodynamics-** Requirement and importance of wind tunnel	2
2		Shock tubes; shock tunnel – types and principle of operation	2
3	**UNIT- V**	Measurement Techniques-Sensors and instrumentation-Pitot static tube	2
4		Cockpit layout of modern civil aircraft	3
5		Basic principles of Gyroscope, accelerometers	4
			Total 13
		TOTAL NO OF CLASSES HELD	**53**

II Year B. Tech, ANE-I Sem	**L**	**T/P/D**	**C**
	3	**1/-/-**	**3**

R17A2101 - INTRODUCTION TO AEROSPACE ENGINEERING

Objective:

1. Insight overview of various important areas in Aeronautical Engineering
2. Students will acquire the knowledge of the Evolution of Aerospace industry.
3. To provide an exposure of various forces and performance aspects important for flight.

UNIT - I

History of Flight - The Aerospace Environment

Evolution of flight, usage of balloons, dirigibles, Heavier than air aircraft, various advances in techniques for commercial transportation. Helicopters, missiles, Conquest of space and exploring solar system and beyond, Earth's atmosphere, standard atmosphere, the temperature extremes of space, laws of gravitation low earth orbit, microgravity, benefits of micro gravity. The near earth Radiative environment, magnetosphere, Environmental impact on spacecraft. Meteoroids, micrometeoroids, space debris and the planetary environments.

UNIT - II

Aerodynamics and Performance

Airfoil- nomenclature and types, Aerodynamic forces on a wings and bodies, Generation of lift, Sources of drag, Force and moment coefficients, centre of pressure. Rotary wing aircraft concepts – Forces while hovering, Propeller Theory.

Performance requirements of a civil and military aircrafts. Control surfaces,

UNIT - III

Propulsion- Aircrafts, Rockets and Missiles: Thrust for flight, Reciprocating engines-2 stroke/4 stroke; Jet engine and types, Rocket engines - Description, Principles of operation. Types of orbits and maneuvers, Types of Missiles, simililarities and differences with launch vehicle, controls for missiles, Airframe components of missiles

Evolution of Space Missions: Space missions, Mission objectives, Case studies, Human space flight missions - goals, historical background, The Soviet and US missions, The Mercury, Gemini, Apollo (manned flight to the moon), Skylab, Apollo-Soyuz, Space Shuttle, International Space Station, extravehicular activity, Life support systems. History and evolution of ISRO, Missions carried in ISRO.

UNIT – IV

Structures: History of airplane construction, Loads on aircraft, Lift production/augmentation devices, Low speed/ high speed airfoils, Monocoque and semi-monocoque structures, Load bearing structural components, use of composites in aircraft and aerospace vehicles.

UNIT - V

Experimental Aerodynamics: Requirement and importance of Wind tunnel, Shock Tubes, Shock Tunnel – types and principle of operation,

Measurement Techniques: Sensors and instrumentation- Pitot static tube, Cockpit layout of modern civil aircraft, Basic principles of Gyro, accelerometers.

TEXT BOOKS:

1. Anderson, J.D., Introduction to Flight, fifth edition, Tata McGraw-Hill, 2007, ISBN: 0-07-006082-4.
2. Kermode, Flight Without Formulae, fifth edition, Pearson Education, 2004, *ISBN*-10: 0273403605; *ISBN*-13: 978-0273403609

REFERENCES:

1. Bamard, R. H. and Philpot, D.R., Aircraft Flight, third edition, Pearson, 2004, ISBN: 81-297-0783-7.

Outcome:

1. Students acquire knowledge with Aerospace Engineering to take up study in detail through subsequent courses.
2. Students acquire fundamental concepts of all aspects of flight.
3. Students acquire the knowledge of the important design aspects of aerospace vehicles.

MALLA REDDY COLLEGE OF ENGINEERING AND TECHNOLOGY

(UGC AUTONOUMOUS – Govt. of INDIA)

II B.TECH I SEMESTER – AERONAUTICAL ENGINEERING

Introduction to Aerospace Engineering (R-17)

MODEL PAPER – I

MAXIMUM MARKS: 75

Year: II YR/ Sem I

MODEL PAPER I

PART A Marks : 25

ANSWER ALL THE QUESTIONS

1. (a) Explain lighter than air aircraft concept with a neat sketch

   (b) Explain Meteorites and micrometeoroids

   (c) Explain the control surfaces of an aircraft

   (d) Explain in brief about missile and launch vehicle

   (e) Explain about stalling speed and give the required equation

   (f) Enumerate the moment coefficient about CG and give equation for trimmed condition

   (g) Discuss the satellite missions

   (h) Discuss about EVA

   (i) Explain about design process

   (j) Discuss in brief about CAD

PART B 50Marks

ANSWER FIVE QUESTIONS

2. Explain the evolution of jet engines and aircrafts

or

3. Explain the structure of magnetosphere and effects of environmental impact on spacecraft design
4. Explain the various components, types and working principle of a helicopter

or

5. Explain with a neat sketch the working principle of a jet engine.
6. Consider an aircraft flying approximately at 1500 m altitude with
   case 1: A_a= 15m^2; c=1.6m; A=2.3m^2; l_t=1600kg.m^2; a_w=5rad^{-1}; $C_{M,ac}$=-0.07; ε=0.45; V=50 m/s; a_t= 4 rad^{-1} ;ρ=1kg/m3 . calculate is the neutral point of a/c.
   case2: let CG is placed halfway between ac and neutral point, x_a=0.21m and $x_{a/c}$=0.132. calculate the angle of attack of the tail and lift produced by tail.

   or

7. Derive the equation of motion for pull up and pull down maneuver.
8. Discuss about the Apollo mission with its phases in mission.

   or

9. Explain about power systems and thermal control in a satellite
10. Explain about drawing techniques available

   or

11. Discuss about orthographic and perspective projections and discuss their difference.

MODEL PAPER II

PART A

ANSWER ALL THE QUESTIONS 25 M

1. (a) Explain few points about exploring solar system

   (b) Explain about dirigibles

   (c) Explain the working principle of a turbojet engine

   (d) Explain about inlet and derive equation for inlet efficiency
   (e) Explain about gliding flight with required equation

(f) Discuss about dynamic stability with required graph
(g) Operational roles of propulsion system of satellite
(h) Discuss five points on skylab
(i) Discuss about orthographic projection
(j) Discuss in brief about CAM

PART B

ANSWER FIVE QUESTIONS 50M

2 Discuss few points on the history of aviation

or

3 Explain about planetary environments within the solar system

4 Derive the equation of buoyancy lift

or

5 Derive the equation of thrust of a jet engine.

6 Define the airplane geometry with a neat sketch and discuss about the two types of stability in detail.

or

7 Derive the equation for maximum lift-to-drag ratio.

8 Discuss about the Gemini mission

or

9 Derive the rocket thrust equation

10 Explain about CAE

or

11 Explain about- Conceptual, preliminary and detail design process.

MODEL PAPER III

PART A

ANSWER ALL THE QUESTIONS 25 M

1. Explain the success of first hot balloon 2M
2. Explain about van Allen belts 2M
3. Explain about compressor and its types, derive equation for CPR and work done 3M
4. Discuss the effect of CD and CL with α 2M
5. Discuss about static stability 2M
6. Discuss the thrust velocity curves and give equation for C_D 3M
7. Discuss 5 points on ADCS 3M
8. Discuss few points on shuttle-mir mission 2M
9. Discuss about orthographic projection 2M
10. Discuss in brief about CAM 3M

PART B

ANSWER FIVE QUESTIONS 5X10=50M

1. Explain few points on the advances took during jet engine development

   or

   Explain the types of heat transfer methods and derive expression for equilibrium $P_{emitted}$, $P_{absorbed}$ temperature of any body at a distance d from sun.
2. Explain the various types of drag with neat sketches

   or

   Explain with a neat sketch the components & working principle of ramjet engine.
3. Derive the endurance and range equation for a propeller and jet engine.

   or

   derive the equation for trimmed angle of attack.
4. Explain in detail about mercury mission.

   or

   Discuss about the elements of a satellite system.
5. Explain about drawing techniques available

   or

   Discuss about orthographic and perspective projections and discuss their difference.

MODEL PAPER IV

PART A

ANSWER ALL THE QUESTIONS 25 M

1. Explain few points regarding the first aircraft in the history by Wright brothers 2M
2. Explain in brief the layers of atmosphere 3M
3. Explain about induces drag and methods to reduce with neat sketch and give required equations 3M
4. Explain about nozzle and types with a neat sketch 2M
5. Discuss about range and endurance of an a/c 2M
6. Discuss the airplane axis system with a neat sketch 3M
7. Explain and give equation for power budget of a satellite 3M
8. Discuss about planetary EVA 2M
9. Explain about design process 2M
10. Discuss in brief about CAD 3M

PART B

ANSWER FIVE QUESTIONS 5X10=50M

1. Explain the attempts and success during space exploration

   or

   Explain the terms

   a. GCR b. Microgravity c. Solar activity d. Solar flares

2. Explain the terms

   a. Aspect ratio b. Airfoil nomenclature c. Symmetric airfoil d. Cambered

   or

   Derive equation governing propeller propulsion.

3. Derive the equation for longitudinal static stability

   or

   Discuss about accelerated flight and derive required equations.
4. Discuss about the spacesuit design, and discuss the difference between US and Russian.

   or

   with neat sketch explain the working of a ADCS
5. Explain about CAE

   or

   Explain about- Conceptual, preliminary and detail design process.

MODEL PAPER V

PART A

ANSWER ALL THE QUESTIONS 25 M

1. Discuss few points on the first man attempts to fly by Icarus and Deadalus
   2M
2. Discuss few points on GEO
   3M
3. Explain about overall efficiency and discuss all terms
   2M
4. Discuss about profile drag and give required equations
   3M
5. Explain the condition of steady flight with equations
   2M
6. Discuss and give equation for the resulting motion on an aircraft
   3M
7. Explain and give equation for $P_{emitted}$ and $P_{absorbed}$.
   2M
8. Discuss the functions of LSS
   3M
9. Discuss about isometric projections
   3M
10. Explain about personal design portfolio
    2M

PART B

ANSWER FIVE QUESTIONS 5X10=50M

1. Explain from the dawn how the improvements that took in aerospace industry from wright flyer to current black bird

   or

   Explain the different layers of atmosphere with a graph showing the temperature and pressure variation

2. Explain the different types of combustor and turbine, derive equations BPR, f, TPR, W_{turb}.

   OR

   a. Explain what is a pitot static tube, position in aircraft and the use.

   b. Using Bernoulli principles derive the equation for stagnation pressure, flow speed.

3. Discuss the V-n diagram with required equations

   or

   Define the airplane geometry with a neat sketch and discuss about the two types of stability in detail.
4. Explain about space shuttle mission and space shuttle with mir, their achievements and mission procedures

   or

   discuss the elements of satellite in detail
5. Explain about LTA design process and point on how LTA takes flight .

   or

   Explain about ornithopter design and CDR

UNIT I: History of Flight-The Aerospace Environment:

Evolution of Flight-Usage ofBalloons, dirigibles-Heavier than air aircraft:

Early Aviation period is from 1783 till 1915.

The development can be grouped as

- Balloons
- Derigibles
- Airships

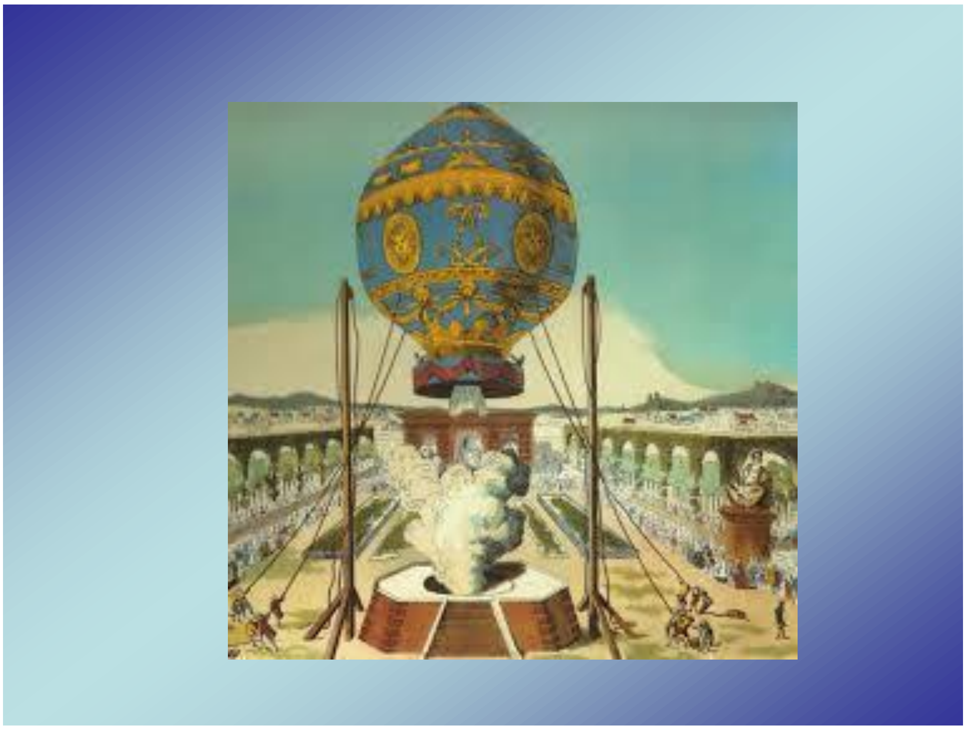
Flying Vehicles can be broadly classified as

- Lighter-than-air aircraft
- Heavier-than-aircraft

Manned Flight began in France in 1783. Joseph and Etienne Montgolfier invented the “hot air Balloon”

From the balloon, came dirigibles, the addition of power and controls and other developments.

Lighter-than-aircraft: Montgolfier brothers built the first hot air balloon in Apr 1783.

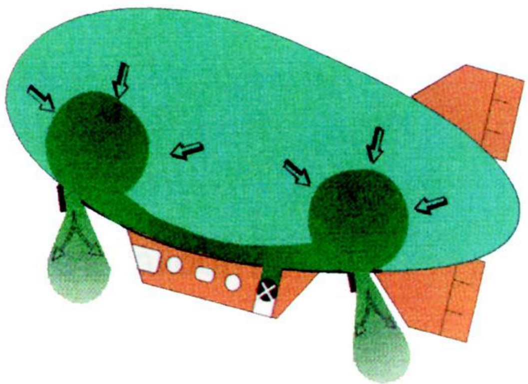


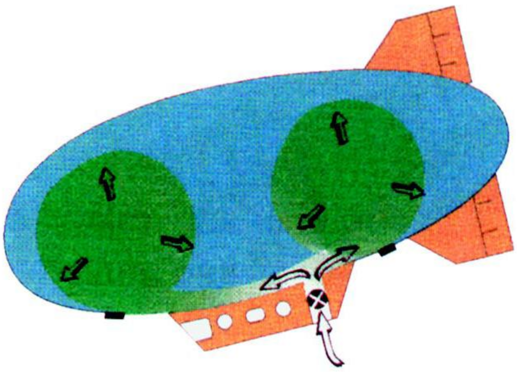
Hot air balloons were very popular till the 1900s; hydrogen was preferred as the filling gas, but, was considered unsafe, causing few explosions.

Balloons (airships) were used to carry cargo, passengers, observation platforms etc.

Controlling airships: Two inflatable air bags were kept inside the main balloon; these inflatable air bags, called “ballonets” are filled with helium. By varying the quantity of helium in the ballonets, the airship is controlled for maneuvering.

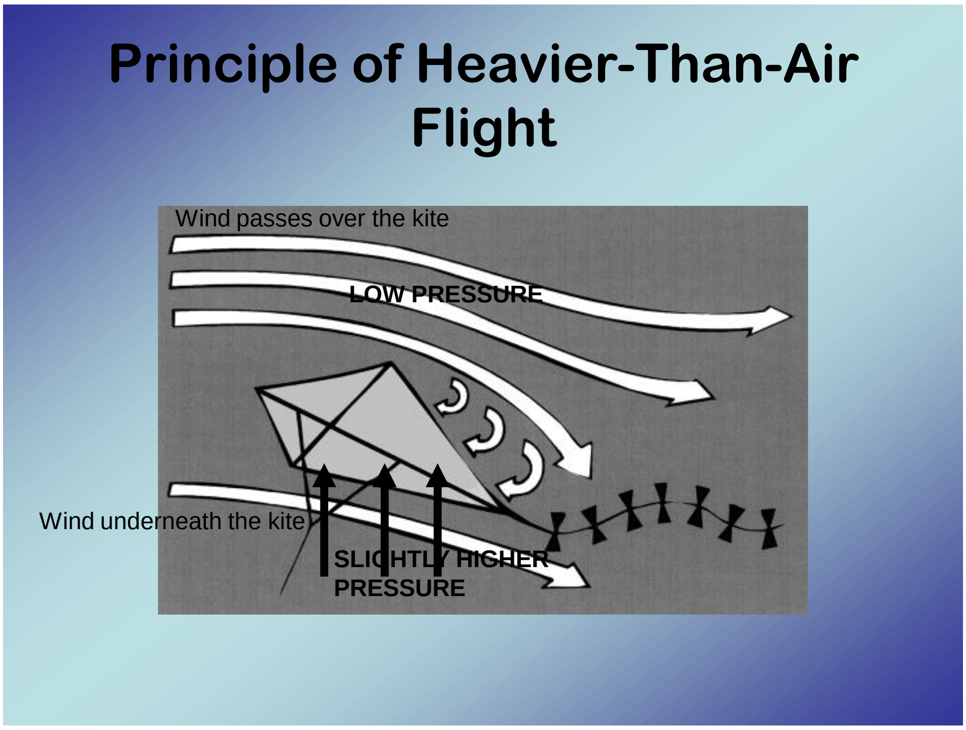
By releasing air into the ballonets or by pumping in more air into the ballonets, the helium inside ballonets is compressed or made to expand, thereby causing the airship to raise or descend.





Heavier-than-air-aircraft- Principle:

- Developed from the flight of a kite
- The shape of kite and its tail enable the kite fly at the correct angle in to the wind
- The weight of the kite is balanced by the force of the wind underneath (Lift)
- The wind passing over the top of the kite creates an area of low pressure
- The air underneath the kite is slightly higher in pressure, so it allows the kite to lift into the lower pressure



- In 1804, Dir George Caylay built a glider (kite without the string), with no controls
- In 1885, Gottlieb Daimler developed the first single cylinder (combustion engine) aircraft
- In 1903, Wright brothers flew their aircraft

Ornithopter Parachute Helicopter

Figure 1.- Designs of Leonardo da Vinci.

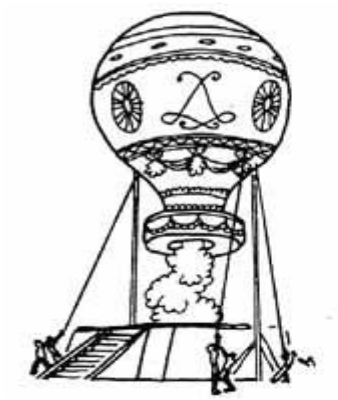


Figure 2.- Montgolfier balloon (1783). Figure 3.- Lilienthal glider (1896)

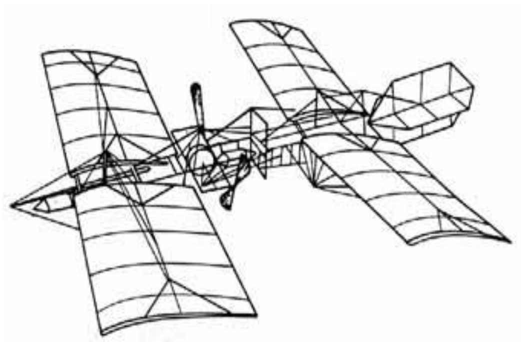


Figure 4.- Samuel Langley's "Aerodrome" (1903).

YF-16Modern (1974)

Commercial air transport, introduction of jet aircraft, helicopters:

1.1 Evolution of Flight Propulsion:

Classes of Aircraft:

- Lighter than air category-Airships; Free balloons; Captive balloons
- Heavier than air category-Power driven; non-power driven
  - Power driven category-Aeroplane; Rotorcraft; ornithopters
  - Aeroplanes-Landplanes; Seaplanes & Amphibians

History of flight Propulsion:

Earliest known propulsive device: Hero's Aeoipile in Year 250 B.C

The Aeolipile is a steam reaction turbine, invented by Egyptian inventor, Hero of Alexandria, in the year 250 BC. The Aeolipile is a steam reaction turbine.

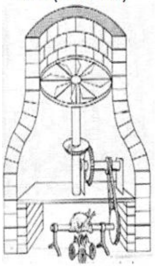
Hero mounted a sphere on top of a water kettle. A fire below the kettle turned the water into steam, and the gas traveled through the pipes to the sphere. Two L-shaped tubes on opposite sides of the sphere allowed the gas to escape. This produced a thrust to the sphere that caused it to rotate almost silently .

The aeolipile achieved spin speeds of at 1500 RPM.

Chinese used rockets with gunpowder, around AD 1000. They attached these rocket (bamboo) tubes to arrows and launched them with bows. Soon they discovered that these gunpowder tubes could launch themselves just by the power produced from the escaping gas. The true rocket was born.

Gunpowder changed the methods of war forever.

Da Vinci visualized flight vehicles as early as 1500 AD



In 1629 an Italian engineer, Giovanni Branca, was probably the first to invent an actual **impulse turbine**. This device, a stamping mill, was generated by a steam-powered turbine.

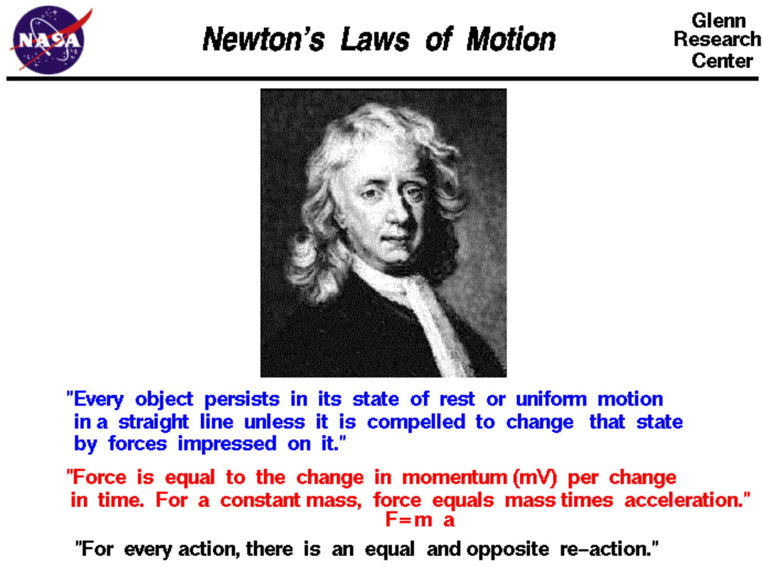
Newton's Steam Wagon 1687:

In 1687, Jacob Govesand, a Dutchman designed and built a carriage driven by steam power. Sir Isaac Newton was believed to have supplied the idea in an attempt to put his laws of motion to test.

The first Gas Turbine: In 1791 John Barber, an Englishman, was the first to patent a design that used the thermodynamic cycle of the modem gas turbine.

Wright Brothers first Airplane "Triumph": First Flight 1903 Dec

Concept of Jet Propulsion:



Newton's Laws of Motion

Newton's first law.

An object at rest will remain at rest unless acted on by an external force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by an external force.
This law is often called "the law of inertia" as it establishes the Newtonian frame of reference.

Newton's law I

This law states that if the vector sum of all the forces acting on an object is zero, then the velocity of the object is constant.
Consequently:

- An object that is at rest will stay at rest unless an unbalancing force acts upon it.
- An object that is in motion will not change its velocity (magnitude and/or direction) unless an unbalancing force acts upon it.

Newton's Laws of Motion

Newton's second law

Acceleration is produced when a force acts on a mass. The greater the mass (of the object) being accelerated the greater the amount of force needed to accelerate the object.

$$F = M A$$

From Newton's 2nd law of motion

The second law states that the net force on a body is equal to the time rate of change of its linear momentum $\mathbf{M_t}$ in a specified reference frame for the inertial motion under interest:

$$F = \frac{dM_t}{dt} = \frac{d(mV)}{dt} = m\frac{dv}{dt}$$

For a constant mass system

Any mass that is gained or lost by the system will cause a change in momentum that is not the result of an external force. A different equation is necessary for a variable-mass systems

Newton's Laws of Motion

Newton's third law

For every action there is an equal and opposite re-action.

While the Newton's 3rd law allows us to comprehend the mechanics of action of the propulsive force (Thrust) acting on a flying body, the production of thrust is actually facilitated by the Newton's 2nd law, active on the engine body. Hence it is not only the jet coming out at the exhaust that creates thrust, but the entire body of the engine participates in creation of thrust.

History of Internal Combustion (I.C) Engines:

The first 4 stroke engine was built by the Germans, August Otto and Evgen Langer in 1876. As a result, the 4 stroke engine cycle are always called Otto Cycle engines.

George Brayton of the USA, also built a gasoline engine in 1876. Gottieb Daimler has built most successful 4 stroke engine in 1885. The first 4 stroke engine was built by the Germans, August Otto and Evgen Langer in 1876. As a result, the 4 stroke engine cycle are always called Otto Cycle engines.

Same year, Karl Benz, has built a similar engine. These two engines were extensively used in automobiles.

Wright brothers used 4 stroke four cylinder IC Engine in 1903.

- **Air Breathing Engines**-Reciprocating& Jet Propulsion Engines.

1.2.1: Types of Aerospace Propulsion:

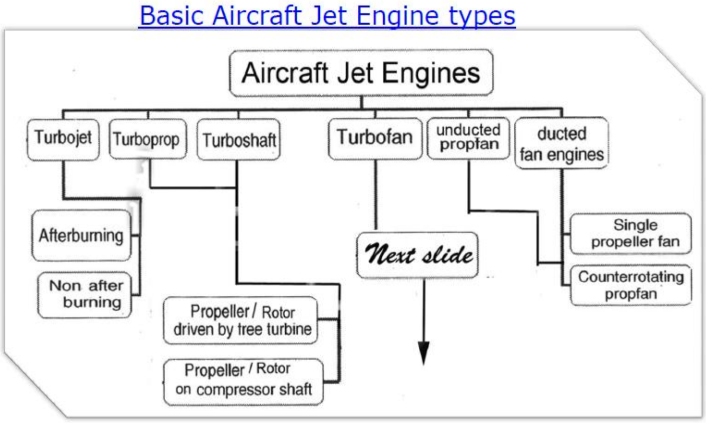
Air Breathing Systems

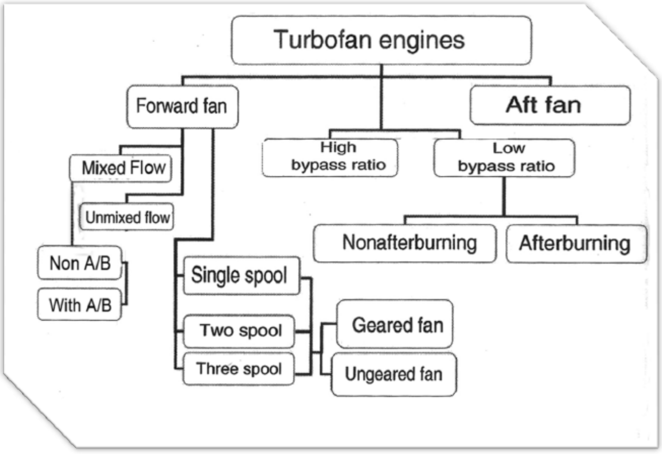
- Reciprocating Engines
- Gas Turbine Engines
- Ram Jets, Pulse Jets & Scram Jets

Non Air Breathing Systems

- Rockets

Basic Aircraft Jet Engine types





Missiles, conquest of space, commercial use of space, exploring solar system and beyond

In military parlance, missiles are powered / guided munitions are broadly categorised as follows:

- A powered, guided munition that travels through the air or space is known as a military **missile** (or *guided missile*.)
- A powered, *un*guided munition is known as a **rocket**.

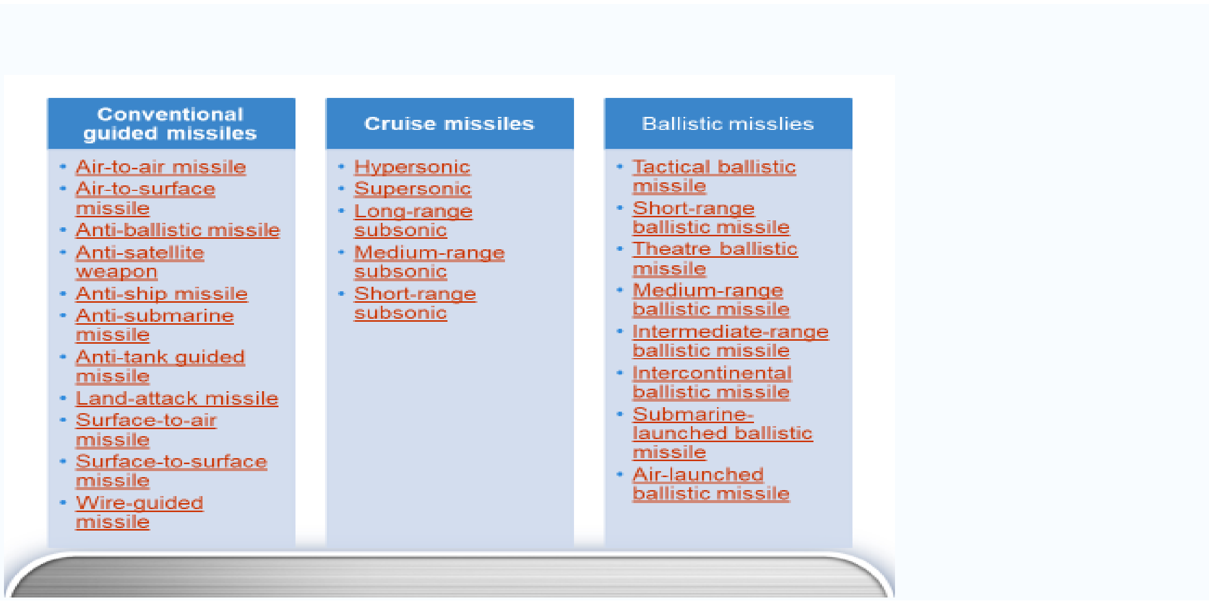
TECHNOLOGY :

Guided missiles have a number of different system components:

- Targeting and/or guidance
- Flight system
- Engine
- Warhead

Guidance systems

- Missiles may be targeted in a number of ways. The most common method is to use some form of radiation, such as infrared, lasers or radio waves, to guide the missile onto its target. This radiation may emanate from the target ,it may be provided by the missile itself (such as a radar) or it may be provided by a friendly third party. The picture may be used either by a human operator who steers the missile onto its target, or by a computer doing much the same job.



SPACE TRANSPORT

Space transport is the use of spacecraft to transport people or cargo through outer space. In human spaceflight, the people transported are the crew who operate the spacecraft, and occasionally passengers. Some cargo carrying spacecraft, like the Progress, have no crew or passengers during their flight and operate either by telerobotic control or are fully autonomous.

Currently, spacecraft most commonly use rocket technology for propulsion. Rocket engines expel propellant to provide forward thrust. Different ranges and types of rockets and other spacecraft have been used (or proposed) for different environments and goals, including:

- expendable launch system
- single stage to orbit
- orbital maneuvering system
- interplanetary travel
- interstellar travel
- intergalactic travel

SPACE FLIGHT:

A **spaceflight** is the sustained movement of a spacecraft into and through outer space. Spaceflights primarily use rocket technology for propulsion. A spaceflight begins with a launch, which provides the initial thrust to overcome the force of gravity and propel the spacecraft from the surface of the Earth. Once in space, the motion of a spacecraft -- both when unpropelled and when under propulsion -- is determined by astrodynamics.

Spaceflight is a necessary component of space exploration. It is also necessary for commercial uses of space, such as space tourism and the launching of telecommunications satellites. Non-commercial uses of spaceflight include space observatories, reconnaissance satellites and other earth observation satellites.

History of space flight

Spaceflight became an engineering possibility with the work of Robert H. Goddard's publication in 1919 of his paper 'A Method of Reaching Extreme Altitudes'; where his application of the de Laval nozzle to liquid fuel rockets gave sufficient power that interplanetary travel became possible. This paper was highly influential on Hermann Oberth and Wernher Von Braun, later key players in spaceflight.

The first rocket to reach space was a prototype of the GermanV-2, on a test flight in 1942. In 1957 the Soviet Union launched Sputnik 1, which became the first artificial satellite to orbit the Earth. The first human spaceflight was Vostok 1 on April 12, 1961, aboard which Soviet cosmonautYuri Gagarin made one orbit around the Earth.

Rockets remain the only currently practical means of reaching space. Other technologies such as scramjets still fall far short of orbital speed, although show some potential.

Reaching space

The most commonly used definition of outer space is everything beyond the Kármán line, which is 100 kilometers (62.1 mi) above the Earth's surface. (The United States sometimes uses a 50 miles (80.5 km) definition.)

Sub-orbital spaceflight

On a sub-orbital spaceflight the spacecraft reaches space, but does not achieve orbit. Instead, its trajectory brings it back to the surface of the Earth. Suborbital flights can last many hours. Pioneer 1 was NASA's first space probe, intended to reach the Moon. A partial failure caused it to instead follow a suborbital trajectory to an altitude of 113,854 kilometers (70,747.5 mi) before reentering the Earth's atmosphere 43 hours after launch.

On May 17, 2004, Civilian Space exploration Team launched the Go-Fast Rocket on a suborbital flight, the first amateur space flight. On June 21, 2004, Spaceship One was used for the first privately-fundedhuman spaceflight.

Orbital spaceflight

A minimal orbital spaceflight requires very much higher velocities than a minimal sub-orbital flight, and so it is technologically much more challenging to achieve. To achieve orbital spaceflight, the tangential velocity around the Earth is just as important as height. In order to perform a stable and lasting flight in space, the velocity of the launched craft should be such that a closed orbit is possible.

Launch pads and Spaceports, takeoff

A launch pad is a fixed structure designed to dispatch airborne vehicles.It generally consists of a launch tower and flame trench. It surrounded by equipment used to erect, fuel, and maintain launch vehicles.

A spaceport, by way of contrast, is designed to facilitate winged launch vehicles and uses a long runway.

Both spaceport and launch pads are situated well away from human habitation for noise and safety reasons. Rockets run though a countdown sequence prior to Rocket launch. A launch is often restricted to certain launch windows. These windows depend upon the position of celestial bodies and orbits relative to the launch site. The biggest influence is often the rotation of the Earth itself. Once launched, orbits are normally located within relatively constant flat planes at a fixed angle to the axis of the Earth, and the Earth rotates within this orbit.

Spacecraft propulsion

Spacecraft today predominantly use rockets for propulsion, but other propulsion techniques such as ion drives are becoming more common, particularly for unmanned vehicles, and this can significantly reduce the vehicle's mass and increase its delta-v.

Outer space

Outer space, sometimes simply called *space*, refers to the relatively empty regions of the universe outside the atmospheres of celestial bodies. *Outer* space is used to distinguish it from airspace (and terrestrial locations). Contrary to popular understanding, outer space is not completely empty (i.e. a perfect vacuum) but contains a low density of particles, predominantly hydrogen plasma, as well as electromagnetic radiation.

Earth's boundary

There is no clear boundary between the Earth's atmosphere and space as the density of the atmosphere gradually decreases as the altitude increases. Nevertheless, the Federation Aeronautique Internationale has established the Kármán line at an altitude of 100 km(62 miles) as a working definition for the boundary between atmosphere and space. This is used because, as Karman calculated, above an altitude of roughly 100 km, a vehicle would have to travel faster than orbital velocity in order to derive sufficient aerodynamic lift from the atmosphere to support itself. The United States designates people who travel above an altitude of 80 km (50 statute miles) as astronauts. During re-entry, roughly 120 km (75 miles) marks the boundary where atmospheric drag becomes noticeable, depending on the ballistic coefficient of the vehicle.

Solar System

Outer space within the solar system is called interplanetary space, which passes over into interstellar space at the heliopause. The vacuum of outer space is not really empty; it is sparsely filled with several dozen types of organic molecules discovered to date by microwave spectroscopy. According to the Big bang theory, 2.7 K blackbody radiation was left over from the 'big bang' and the origin of the universe, and cosmic rays, which include ionized atomic nuclei and various subatomic particles. There is also gas, plasma and dust, and small meteors and material left over from previous manned and unmanned launches that are a potential hazard to spacecraft. Some of this debris re-enters the atmosphere periodically.

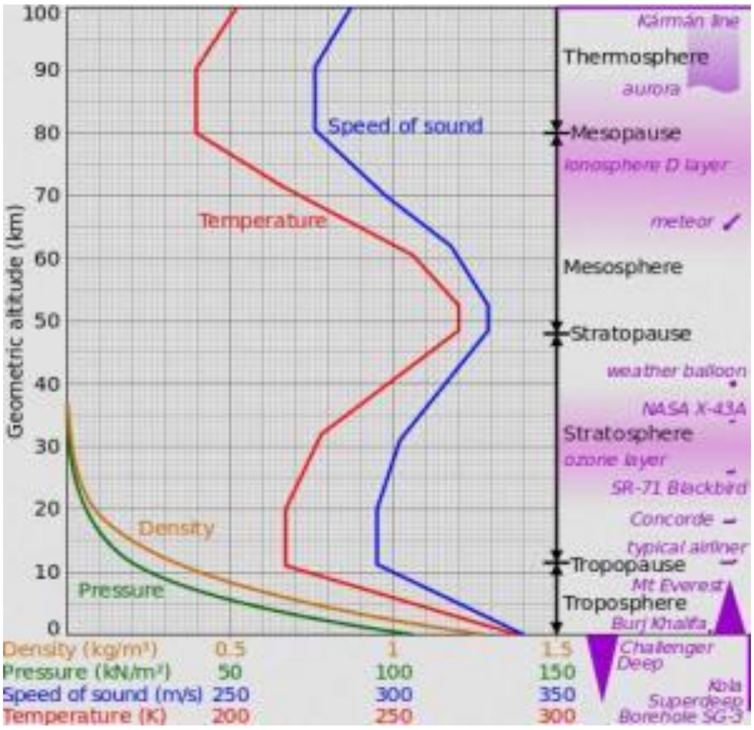
The absence of air makes outer space (and the surface of the Moon) ideal locations for astronomy at all wavelengths of the electromagnetic spectrum, as evidenced by the spectacular pictures sent back by the Hubble Space Telescope, allowing light from about 13.7 billion years ago - almost to the time of the Big Bang - to be observed. Pictures and other data from unmanned space vehicles have provided invaluable information about the planets, asteroids and comets in our solar system.

Satellites

There are many artificial satellitesorbiting the Earth, including geosynchronouscommunication satellites 35,786 km (22,241 miles) above mean sea level at the Equator. There is also increasing reliance, for both military and civilian uses, on satellites which enable the Global Positioning System (GPS). A common misconception is that people in orbit are outside Earth's gravity because they are obviously "floating". They are floating because they are in "free fall": the force of gravity and their linear velocity is creating an inward centripetal force which is stopping them from flying out into space. Earth's gravity reaches out far past the Van Allen belt and keeps the Moon in orbit at an average distance of 384,403 km (238,857 miles). The gravity of all celestial bodies drops off toward zero with the inverse square of the distance.

Earth's atmosphere, standard atmosphere

Variation of Pressure, temperature and density with altitude:



As the altitude increases, the pressure and density decreases so does the thrust. However, as altitude increases, temperature decreases, the thrust increases. The pressure and density decreases faster than the temperature, so the net effect on thrust is to reduce up to an altitude of 11000 (troposphere).

After 11000 mt, the temperature stops falling, but pressure continues to drop with altitude. Consequently, above 11000 mt, thrust will drop off more rapidly.

This makes 11000 mt as optimum altitude for long range cruise.

Laws of gravitation, low earth orbit, microgravity, benefits of microgravity

Gravity Effects (*Weightlessness and Microgravity)*

Gravity is one of the four **forces of nature**, along with the electromagnetic force and the strong and weak nuclear forces. It is an invisible force that is all-pervading. According to Newton's law :

$$F = G \times \frac{m_1 \times m_2}{r^2}$$

To get a better understanding of gravity and weightlessness, we must now focus our attention on what happens when you let an object fall freely. When an object is in**continuous free-fall** and there are no external forces acting on it, then the object can be described as being **weightless**. In this case, all gravity effects disappear and only the internal forces inside the object remain. Free-fall can be implemented in ground-based facilities called **drop towers**, in special aircraft which fly **parabolic flights**, as well as in **sounding rockets**. With these kinds of techniques we can achieve near-weightless conditions, more precisely known as **microgravity**.. For longer durations of microgravity we must devise more sophisticated free-fall methods. Coming back to the Newton's equation above, one can see that the further an object is transported from the Earth, the less it will be attracted. The equation to calculate the attractive force (F) of an object as a function of its altitude is as follows:

$$F = M \times g \times \frac{R^2}{(R+H)^2}$$

- From this equation, it can be seen that at an altitude of 400 km above the Earth's surface a stationary object would still have about 89% of its terrestrial weight. An adult male with mass 80 kg (or weight 785 Netwons) would appear to weigh about 71 kg (actually 699 Netwons), which is far from being weightless ! The trick to achieving weightlessness is to propel an object using a rocket engine with an initial velocity parallel to Earth's surface, while simultaneously allowing the object to fall freely. In this way, the object will be in continous free-fall but will never hit the Earth. In practice, it is almost impossible to attain absolute weightlessness because a number of secondary effects disturb the gravity environment of an orbiting spacecraft. Although these secondary effects are generally very small indeed they cannot be neglected completely. These effects include the **tidal acceleration** on the spacecraft as a result of different parts of a spacecraft having slightly different circular orbits, **residual aerodynamic drag** from high-altitude gases and the **solar radiation pressure** on the surface of the spacecraft, as photons collide with it.
- Weightlessness or 0g and microgravity or 10^{-6} gcomplicates many fluid and gas dynamic processes, includingthermal convection, compared with ground experience. The situation isparticularly exacerbated when one is designing for human presence.
- Gravity dictates the size and shape of a spacecraft's orbit. Launch vehicles must first overcome gravity to fling spacecraft into space. Once a spacecraft is in orbit, gravity determines the amount of propellant its engines must use to move between orbits or link up with other spacecraft.
- It is common to assume that orbital flight provides a weightless environmentfor a spacecraft and its contents. To some level of approximation this is true, but as with most absolute statements, it is inexact. A variety of effectsresult in acceleration levels (i.e., "weight" per unit mass) between 10^3g and 10^{11}g , where 1g is the acceleration due to gravity at the Earth's surface**.**
- Measurements of gravity aboard the **International Space Station** have shown that *g* is approximately 1 millionth of that on Earth, which is where the term microgravity comes from (scientifically speaking micro means one millionth or 10^{-6}). This is why astronauts are able to float around so effortlessly

Microgravity:

The term **micro-g environment** is more or less a synonym of *weightlessness* and *zero-G*, but indicates that g-forces are not quite zero, just very small.

Absence of Gravity:

1. A stationary micro-g environment would require travelling far enough into deep space so as to reduce the effect of gravity by attenuation to almost zero.
2. For example, to reduce the gravity of the Earth by a factor of one million one needs to be at a distance of 6 million km from the Earth,
3. But to reduce the gravity of the Sun to this amount one has to be at a distance of even 3700 million km.
4. To reduce the gravity to one thousandth of that on Earth one needs to be at a distance of 200,000 km.

The near-earth radiative environment. The magnetosphere. Environmental impact on spacecraft:

Space environment is a branch of astronautics, aerospace engineering and astronomy that seeks to understand and address conditions existing in space that would impact both the operation of spacecraft and also affect our planet's atmosphere and geomagnetic field.

Problems for spacecraft can include radiation, space debris, upper atmospheric drag, and the solar wind. Effects on Earth of space environmental conditions can include ionospheric storms, temporary decreases in ozone densities, disruption to radio communication, to GPS signals and submarine positioning. Some scientists also theorize links between sunspot activity and ice ages.

Solutions explored by scientists and engineers in the area of space environment study include, but are not limited to, spacecraft shielding, various collision detection systems, and atmospheric models to predict drag effects encountered in lower orbits and during re entry.

The field often overlaps with the disciplines of astrophysics, atmospheric science, space physics, and geophysics, albeit with a stronger emphasis on application.

The United States government maintains a Space Environment Center at Boulder, Colorado. The Space Environment Center (SEC) is part of the National Oceanic and Atmospheric Administration (NOAA). SEC is one of the National Weather Service's (NWS) National Centers for Environmental Prediction (NCEP).

SPACE WEATHER

Space weather is the concept of changing environmental conditions in outer space. It is distinct from the concept of weather within an atmosphere, and generally deals with the interactions of ambient radiation and matter within interplanetary and occasionally interstellar space. From the definition of the National Academy of Science: "Space weather describes the conditions in space that affect Earth and its technological systems. Our space weather is a consequence of the behavior of the sun, the nature of Earth's magnetic field, and our location in the solar system."

Within our own solar system, space weather is greatly influenced by the speed and density of the solar wind and the interplanetary magnetic field (IMF) carried by the solar wind plasma. A variety of physical phenomena are associated with space weather, including geomagnetic storms and substorms, energization of the Van Allen radiation belts, ionospheric disturbances and scintillation, aurora and geomagnetically induced currents at Earth's surface. Coronal Mass Ejections and their associated shock waves are also important drivers of space weather as they can compress the magnetosphere and trigger geomagnetic storms. Solar Energetic Particles, acclerated by Coronal Mass Ejections or solar flares are also an important driver of space weather as they can damage electronics onboard spacecraft and threaten the life of astronauts.

Space weather exerts a profound influence in several areas related to space exploration and development. Changing geomagnetic conditions can induce changes in atmospheric density causing the rapid degradation of spacecraft altitude in Low Earth orbit. Geomagnetic storms due to increased solar activity can potentially blind sensors aboard spacecraft, or interfere with on-board electronics. An understanding of space environmental conditions is also important in designing shielding and life support systems for manned spacecraft. There is also some concern that geomagnetic storms may also expose conventional aircraft flying at high latitudes to increased amounts of radiation.

Meteoroids and micrometeoroids, space debris. Planetary environments:

Meteoroids:

1. A meteoroid is a sand- to boulder-sized particle of debris in the Solar System.
2. The visible path of a meteoroid that enters Earth's (or another body's) atmosphere is called a *meteor*, or colloquially a *shooting star* or *falling star*.
3. If a meteoroid reaches the ground and survives impact, then it is called a *meteorite*.
4. Many meteors appearing seconds or minutes apart are called a meteor shower

Micrometeoroids:

1. A **micrometeoroid** is a tiny meteoroid; a small particle of rock in space, usually weighing less than a gram.
2. A **micrometeor** or **micrometeorite** is such a particle that enters the Earth's atmosphere or falls to Earth.

Effect of environment on Spacecraft:

- Micrometeoroids pose a significant threat to space exploration.
- Their velocities relative to a spacecraft in orbit can be on the order of kilometers per second, and resistance to micrometeoroid impact is a significant design challenge for spacecraft and space suit designers
- While the tiny sizes of most micrometeoroids limits the damage incurred, the high velocity impacts will constantly degrade the outer casing of spacecraft in a manner analogous to sandblasting.
- Long term exposure can threaten the functionality of spacecraft systems.

UNIT II: Aerodynamics and Performance:

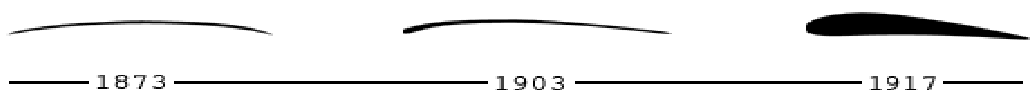
Aerodynamics and Performance
Airfoil-nomenclature and types;
Aerodynamic forces on wings anEvolution of aerfd bodies. Generation of lift. Sources of drag.
Force and moment coefficients, Centre of Pressure. Control surfaces
Rotary wing aircraft concepts-forces while hovering; Propeller theory
Performance requirements of civil and military aircraft.

Aerfoil – Nomenclature and types:

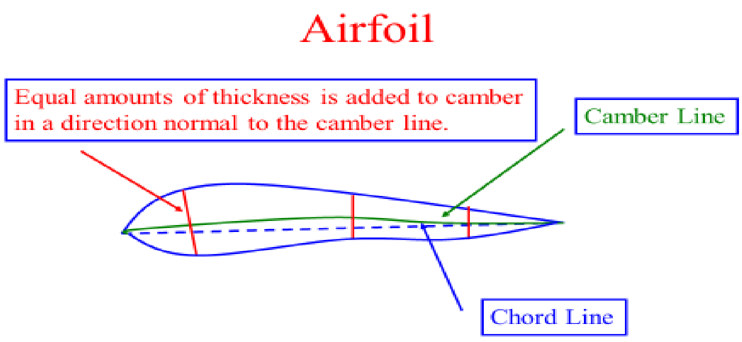
Use of aerfoil:

- Wings
- Propellers and Turbofans
- Helicopter Rotors
- Blade profiles of Compressors and Turbines
- Hydrofoils (wing-like devices which can lift up a boat above waterline)
- Wind Turbines

Evolution of aerfoil profile:



Early Designs - Designers mistakenly believed that these
airfoils with sharp leading edges will have low drag.
In practice, they stalled quickly, and generated considerable drag

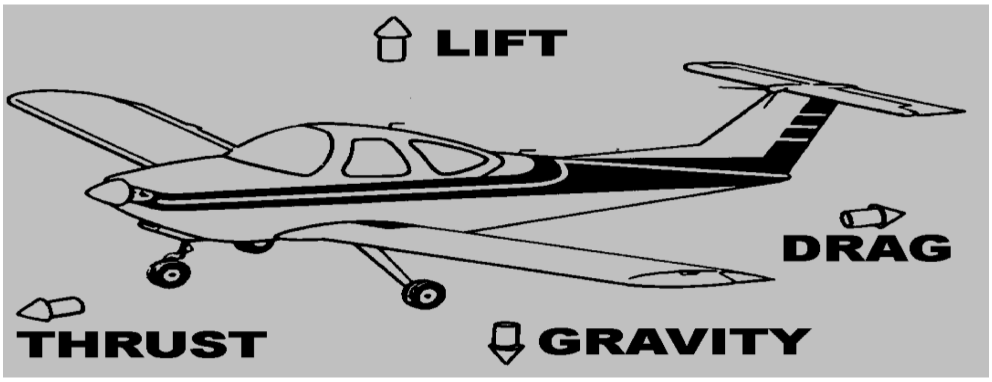


Aerodynamic forces on wings; Generation of lift; Sources of drag:

Aerfoil is defined by the following characteristics:

- Chord Line
- Camber line drawn with respect to the chord line.
- Thickness Distribution which is added to the camber line, normal to the camber line.
- Symmetric airfoils have no camber.

Aerodynamic Forces:



Lift (force)

Lift is the sum of all the fluid dynamic forces on a body perpendicular to the direction of the external flow approaching that body.

Sometimes the term **dynamic lift** or **dynamic lifting force** is used for the perpendicular force resulting from motion of the body in the fluid, as in an aerodyne, in contrast to the static lifting force resulting from buoyancy, as in an aerostat.

Lift is commonly associated with the wing of a aircraft. However there are many other examples of lift such as propellers on both aircraft and boats, rotors on helicopters, sails and keels on sailboats, hydrofoils, wings on auto racing cars, and wind turbines. While the common meaning of the term "lift" suggests an upward action, the lift force is not necessarily directed up with respect to gravity.

Physical explanation

There are several ways to explain lift which are equivalent — they are different expressions of the same underlying physical principles:

Reaction due to deflection

Lift is created as the fluid flow is deflected by an airfoil or other body. The force created by this acceleration of the fluid creates an equal and opposite force according to

Newton's third law of motion. Air deflected downward by an aircraft wing, or helicopter rotor, generating lift is known as downwash.

It is important to note that the acceleration of air flowing over an aircraft wing does not just involve the air molecules "bouncing off" the lower surface. Rather, air molecules closely follow both the top and bottom surfaces, and the airflow is deflected downward when the wing is producing lift. The acceleration of the air during the creation of lift can also been described as a "turning" of the airflow.

Many shapes, such as a flat plate set at an angle to the flow, will produce lift. This can be demonstrated simply by holding a sheet of paper at an angle in front of you as you move forward. However, lift generation by most shapes will be very inefficient and create a great deal of drag. One of the primary goals of airfoil design is to devise a shape that produces the most lift while producing the least Form drag.

Circulation

Another way to calculate lift is to determine the mathematical quantity called circulation; (this concept is sometimes applied approximately to wings of large aspect ratio as "lifting-line theory"). Again, it is mathematically equivalent to the two explanations above. It is often used by practising aerodynamicists as a convenient quantity, but is not often useful for a layperson's understanding. (That said, the vortex system set up round a wing is both real and observable, and is one of the reasons that a light aircraft cannot take off immediately after a jumbo jet.)

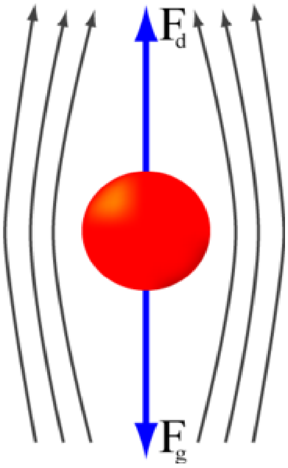
The circulation is the line integral of the velocity of the air, in a closed loop around the boundary of an airfoil. It can be understood as the total amount of "spinning" (or vorticity) of air around the airfoil. When the circulation is known, the section lift can be calculated using the following equation:

$$l = \rho V \times \Gamma$$

Where ρ is the air density, *V* is the free-stream airspeed, and Γ is the circulation. This is sometimes known as the **Kutta - Joukowski Theorem.**

A similar equation applies to the sideways force generated around a spinning object, the Magnus effect, though here the necessary circulation is induced by the mechanical rotation, rather than aerfoil action.

Sources of Drag:



An object falling through a gas or liquid experiences a force in direction opposite to its motion. Terminal velocity is achieved when the drag force is equal to force of gravity pulling it down.

In fluid dynamics, **drag** is the force that resists the movement of a solid object through a fluid (a liquid or gas). Drag is made up of friction forces, which act in a direction parallel to the object's surface (primarily along its sides, as friction forces at the front and back cancel themselves out), plus pressure forces, which act in a direction perpendicular to the object's surface. For a solid object moving through a fluid or gas, the drag is the sum of all the aerodynamic or hydrodynamicforces in the direction of the external fluid flow. (Forces perpendicular to this direction are considered lift). It therefore acts to oppose the motion of the object, and in a powered vehicle it is overcome by thrust.

In astrodynamics, depending on the situation, **atmospheric drag** can be regarded as inefficiency requiring expense of additional energy during launch of the space object or as a bonus simplifying return from orbit.

Types of drag:

Types of drag are generally divided into three categories: parasitic drag, lift-induced drag and wave drag.

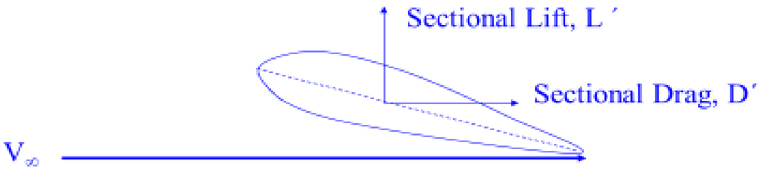
- Parasitic drag includes form drag, skin friction and interference drag.
- Lift-induced drag is only relevant when wings or a lifting body are present, and is therefore usually discussed only in the aviation perspective of drag.
- Wave drag occurs when a solid object is moving through a fluid at or near the speed of sound in that fluid.

The overall drag of an object is characterized by a dimensionless number called the drag coefficient, and is calculated using the drag equation. Assuming a constant drag coefficient, drag will vary as the square of velocity. Thus, the resultant power needed to overcome this drag will vary as the cube of velocity.

Wind resistance is a layman's term used to describe drag. Its use is often vague, and is usually used in a relative sense (e.g. A badmintonshuttlecock has more *wind resistance* than a squash ball).

Force and moment coefficients, Centre of Pressure. Control surfaces:

Lift and Drag Forces acting on a Wing Section

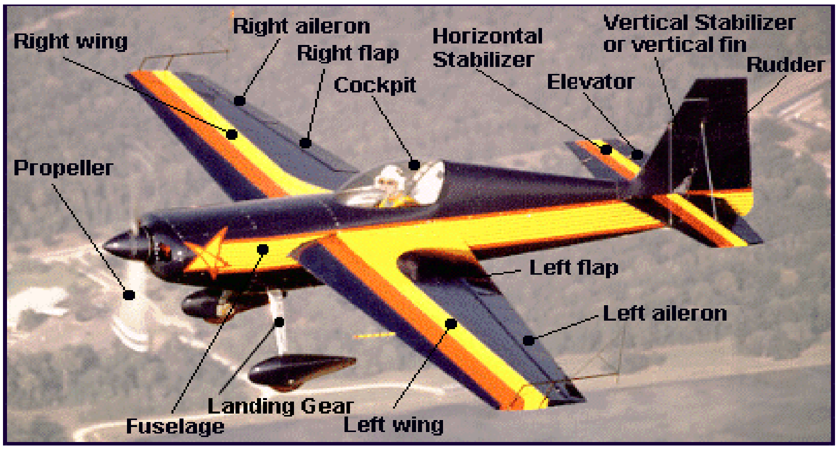


The component of aerodynamic forces normal to the freestream, per unit length of span (e.g. per foot of wing span), is called the sectional lift force, and is given the symbol L ′.

The component of aerodynamic forces along the freestream, per unit length of span (e.g. per foot of wing span), is called the sectional drag force, and is given the symbol D ′.

Sectional Lift and Drag Coefficients

- The sectional lift coefficient C_l is defined as: $C_l = \frac{L'}{\frac{1}{2}\rho V_\infty^2 c}$
- Here c is the airfoil chord, i.e. distance between the leading edge and trailing edge, measured along the chordline.
- The sectional drag force coefficient C_d is likewise defined as: $C_d = \frac{D'}{\frac{1}{2}\rho V_\infty^2 c}$



Rotary Wing Aircraft Concepts – Propellor Theory:

HELICOPTERS

A helicopter main rotor or rotor system is a type of fan that is used to generate both the aerodynamic lift force that supports the weight of the helicopter, and thrust which counteracts aerodynamic drag in forward flight. Each main rotor is mounted on a vertical mast over the top of the helicopter, as opposed to a helicopter tail rotor, which is connected through a combination of drive shaft(s) and gearboxes along the tail boom. A helicopter's rotor is generally made up of two or more rotor blades. The blade pitch is typically controlled by a swash plate connected to the helicopter flight controls. Rotors are sometimes referred to as rotary wings, for they are the wings (as well as propellers) of a rotary-wing aircraft.

Design

The helicopter rotor is powered by the engine, through the transmission, to the rotating mast. The mast is a cylindrical metal shaft which extends upward from—and is driven by—the transmission. At the top of the mast is the attachment point for the rotor blades called the hub. The rotor blades are then attached to the hub. Main rotor systems are classified according to how the main rotor blades are attached and move relative to the main rotor hub. There are three basic classifications: rigid, semi-rigid, or fully articulated, although some modern rotor systems use an engineered combination of these classifications. The rotors are designed to operate in a narrow range of RPM.

Unlike the small diameter fans used in turbofan jet engines, the main rotor on a helicopter has a quite large diameter, permitting a large volume of air to be accelerated. This permits a lower downwash velocity for a given amount of thrust. As it is more efficient at low speeds to accelerate a large amount of air by a small degree than a small amount of air by a large degree, a low disc loading (thrust per disc area) greatly increases the aircraft's energy efficiency and this reduces the fuel use and permits reasonable range.

Parts and functions

- The simple rotor (Main Rotor), rotor head with mast
- Tail Rotor, Tail Boom
- Swash plate
- Cockpit, Fuselage, Cabin
- Landing skids

Main rotor

The main rotor serves to provide lift and propulsion to the helicopter. The main rotor blade performs the same function as an airplane's wings, providing **lift** as the blades rotate -- lift being one of the critical aerodynamic forces that keeps aircraft aloft. A pilot can affect lift by changing the rotor's revolutions per minute (rpm) or its **angle of attack**, which refers to the angle of the rotary wing in relation to the oncoming wind.

1. **Rotor mast** -- Also known as the rotor shaft, the mast connects the transmission to the rotor assembly. The mast rotates the upper swash plate and the blades.
2. **Stabilizer** -- The stabilizer bar sits above and across the main rotor blade. Its weight and rotation dampen unwanted vibrations in the main rotor, helping to stabilize the craft in all flight conditions. Arthur Young, the gent who designed the Bell 47 helicopter, is credited with inventing the stabilizer bar.
3. **Transmission** -- Just as it does in a motor vehicle, a helicopter's transmission transmits power from the engine to the main and tail rotors. The transmission's main gearbox steps down the speed of the main rotor so it doesn't rotate as rapidly as the engine shaft. A second gearbox does the same for the tail rotor, although the tail rotor, being much smaller, can rotate faster than the main rotor.

Fuselage

The fuselage holds the aircraft together and accommodates passengers and cargo, as appropriate.

Cockpit

The cockpit, at the front end of the fuselage, is the control and command centre, where the pilots sit and all the instrumentation is located.

Cabin

The cabin serves to accommodate passengers and cargo.

Landing skids

The skids serve to stand the helicopter while on the ground.

Tail boom

The tail boom holds the tail rotor for stabilizing the aircraft.

Tail rotor

The tail rotor prevents the helicopter from spinning as well as turns the aircraft.

Engine

The engine generates power for the aircraft. Early helicopters relied on reciprocating gasoline engines, but modern helicopters use gas turbine engines like those found in commercial airliners.

Swash plate

The pitch of main rotor blades can be varied cyclically throughout its rotation in order to control the direction of rotor thrust vector (the part of the rotor disc where the maximum thrust will be developed, front, rear, right side, etc.). Collective pitch is used to vary the magnitude of rotor thrust (increasing or decreasing thrust over the whole rotor disc at the same time). These blade pitch variations are controlled by tilting and/or raising or lowering the swash plate with the flight controls. The vast majority of helicopters maintain a constant rotor speed (RPM) during flight, leaving only the angle of attack of the blades as the sole means of adjusting thrust from the rotor.

The swash plate is two concentric disks or plates, one plate rotates with the mast, connected by idle links, while the other does not rotate. The rotating plate is also connected to the individual blades through pitch links and pitch horns. The non-rotating plate is connected to links which are manipulated by pilot controls, specifically, the collective and cyclic controls. The swash plate can shift vertically and tilt. Through shifting and tilting, the non-rotating plate controls the rotating plate, which in turn controls the individual blade pitch.
HELICOPTERS CAN BE USED FOR VARIOUS PURPOSE LIKE

Types

Helicopter arrangements

Rotor configurations

Most helicopters have a single, main rotor but require a separate rotor to overcome torque. This is accomplished through a variable pitch, anti-torque rotor or tail rotor. When viewed from above, the main rotors of helicopter designs from Germany, United Kingdom, The United States and Canada rotate counter-clockwise, all others rotate clockwise. This can make it difficult when discussing aerodynamic effects on the main rotor between different designs, since the effects may manifest on opposite sides of each aircraft.

Anti-torque: Torque effect on a helicopter

With a single main rotor helicopter, the creation of torque as the engine turns the rotor creates a torque effect that causes the body of the helicopter to turn in the opposite direction of the rotor. To eliminate this effect, some sort of antitorque control must be used, with a sufficient margin of power available to allow the helicopter to maintain its heading and provide yaw control. The three most common controls used today are the traditional tail rotor, Eurocopter's Fenestron (also called a fantail), and MD Helicopters' NOTAR.

Tail rotor

The tail rotor is a smaller rotor mounted so that it rotates vertically or near-vertically at the end of the tail of a traditional single-rotor helicopter. The tail rotor's position and distance from the center of gravity allow it to develop thrust in a direction opposite of the main rotor's rotation, to counter the torque effect created by the main rotor. Tail rotors are simpler than main rotors since they require only collective changes in pitch to vary thrust. The pitch of the tail rotor blades is adjustable by the pilot via the anti-torque pedals, which also provide directional control by allowing the pilot to rotate the helicopter around its vertical axis (thereby changing the direction the craft is pointed).

Ducted fan

Fenestron and FANTAIL are trademarks for a ducted fan mounted at the end of the tail boom of the helicopter and used in place of a tail rotor. Ducted fans have between eight and 18 blades arranged with irregular spacing, so that the noise is distributed over different frequencies. The housing is integral with the aircraft skin and allows a high rotational speed, therefore a ducted fan can have a smaller size than a conventional tail rotor.

NOTAR

NOTAR, an acronym for NO-TAil Rotor, is a helicopter anti-torque system that eliminates the use of the tail rotor on a helicopter. Although the concept took some time to refine, the NOTAR system is simple in theory and works to provide antitorque the same way a wing develops lift using the Coandă effect. A variable pitch fan is enclosed in the aft fuselage section immediately forward of the tail boom and driven by the main rotor transmission. This fan forces low pressure air through two slots on the right side of the tailboom, causing the downwash from the main rotor to hug the tailboom, producing lift, and thus a measure of antitorque proportional to the amount of airflow from the rotorwash. This is augmented by a direct jet thruster (which also provides directional yaw control) and vertical stabilizers.

Tip jets

Another single main rotor configuration without a tail rotor is the tip jet rotor, where the main rotor is not driven by the mast, but from nozzles on the rotor blade tips; which are either pressurized from a fuselage-mounted gas turbine or have their own turbojet, ramjet or rocket thrusters. Although this method is simple and eliminates torque, the prototypes that have been built are less fuel efficient than conventional helicopters and produced more noise. The Percival P.74 was underpowered and was not able to achieve flight, while the Hiller YH-32 Hornet had good lifting capability but performed poorly otherwise.

Dual rotors (counter-rotating)

Counter-rotating rotors are rotorcraft configurations with a pair or more of large horizontal rotors turning in opposite directions to counteract the effects of torque on the aircraft without relying on an anti-torque tail rotor. This allows the power normally required to drive the tail rotor to be applied to the main rotors, increasing the aircraft's lifting capacity. Primarily, there are three common configurations that use the counter-rotating effect to benefit the rotorcraft.

A. Tandem

Tandem rotors are two horizontal main rotor assemblies mounted one behind the other. Tandem rotors achieve pitch attitude changes to accelerate and decelerate the helicopter through a process called differential collective pitch. To pitch forward and accelerate, the rear rotor increases collective pitch, raising the tail and the front rotor decreases collective pitch, simultaneously dipping the nose. To pitch upward while decelerating (or moving rearward), the front rotor increases collective pitch to raise the nose and the rear rotor decreases collective pitch to lower the tail. Yaw control is developed through opposing cyclic pitch in each rotor; to pivot right, the front rotor tilts right and the rear rotor tilts left, and to pivot left, the front rotor tilts left and the rear rotor tilts right.

B. Coaxial

Coaxial rotors are a pair of rotors mounted one above the other on the same shaft and turning in opposite directions. The advantage of the coaxial rotor is that, in forward flight, the lift provided by the advancing halves of each rotor compensates for the retreating half of the other, eliminating one of the key effects of dissymmetry of lift: retreating blade stall. However, other design considerations plague coaxial rotors. There is an increased mechanical complexity of the rotor system because it requires linkages and swashplates for two rotor systems.

C. Intermeshing

Intermeshing rotors on a helicopter are a set of two rotors turning in opposite directions, with each rotor mast mounted on the helicopter with a slight angle to the other so that the blades intermesh without colliding. This configuration is sometimes referred to as a synchropter. Intermeshing rotors have high stability and powerful lifting capability. The arrangement was successfully used in Nazi Germany for a small anti-submarine warfare helicopter, the Flettner Fl 282 Kolibri. During the Cold War, an American company, Kaman Aircraft, produced the HH-43 Huskie for the USAF firefighting and rescue missions. The latest Kaman model, the Kaman K-MAX, is a dedicated sky crane design.

Transverse

Transverse rotors are mounted on the end of wings or outriggers, perpendicular to the body of the aircraft. Similar to tandem rotors and intermeshing rotors, the transverse rotor also uses differential collective pitch. But like the intermeshing rotors, the transverse rotors use the concept for changes in the roll attitude of the rotorcraft. This configuration is found on two of the first viable helicopters, the Focke-Wulf Fw 61 and the Focke-Achgelis Fa 223, as well as the world's largest helicopter ever built, the Mil Mi-12. It is also the configuration found on tiltrotors, such the Bell-Boeing V-22 Osprey and the AgustaWestland AW609.

Quadrotor:

A quadrotor helicopter has four rotors in an "X" configuration designated as front-left, front-right, rear-left, and rear-right. Rotors to the left and right are in a transverse configuration while those in the front and to the rear are in a tandem configuration.

The main attraction of quadrotors is their mechanical simplicity—a quadrotor helicopter using electric motors and fixed-pitch rotors has only four moving parts.

Blade design

The blades of a helicopter are long, narrow airfoils with a high aspect ratio, a shape which minimises drag from tip vortices (see the wings of a glider for comparison). They generally contain a degree of washout to reduce the lift generated at the tips, where the airflow is fastest and vortex generation would be a significant problem. Rotor blades are made out of various materials, including aluminium, composite structure and steel or titanium with abrasion shields along the leading edge. Rotorcraft blades are traditionally passive, but research into active blade control trailing edge flaps is performed.

Limitations and hazards

Helicopters with teetering rotors, for example the two-blade system on the Bell, Robinson and others, must not be subjected to a low-g condition because such rotor systems do not control the fuselage attitude. This can result in the fuselage assuming an attitude controlled by momentum and tail rotor thrust that causes the tail boom to intersect the main rotor tip-path plane, or result in the blade roots contacting the main rotor drive shaft causing the blades to separate from the hub (mast bumping).

Performance requirements of Civil and Military aircraft:

Airframe:

The structural backbone of an aircraft that balances the internal and external loads acting upon the craft is called airframe. These loads consist of internal mass inertia forces (equipment, payload, stores, fuel, and so forth), flight forces (propulsion thrust, lift, drag, maneuver, wind gusts, and so forth), and ground forces (taxi, landing, and so forth).

The strength capability of the airframe must be predictable to ensure that these applied loads can be withstood with an adequate margin of safety throughout the life of the airplane.

In addition to strength, the airframe requires structural stiffness to prevent excessive deformation under load and to provide a satisfactory natural frequency of the structure (the number of times per second the structure will vibrate when a load is suddenly imposed or changed).

The aerodynamic loads on the airframe can oscillate in magnitude under some circumstances, and if these oscillations are near the same rate as the natural frequency of the structure, runaway deflections (called flutter) and failure can occur. Consequently, adequate structural stiffness is needed to provide a natural frequency far above the danger range.

The overall airframe structure is made up of a number of separate components, each of which performs discrete individual functions. The fuselage provides the accommodations of crew, passengers, cargo, fuel, and environmental control systems.

The empennage consists of the vertical and horizontal stabilizers, which are used, respectively, for turning and pitching flight control. The wing passing through the air provides lift to the aircraft. Its related control devices, leading-edge slats and trailing-edge flaps, are used to increase this lift at slow airspeeds, such as during landing and takeoff, to prevent stalling and loss of lift. The ailerons increase lift on one side of the wing and reduce lift on the other in order to roll the airplane about its fore-and-aft axis.

Performance requirements (range, payload, speed, altitude, landing and takeoff distance, and so forth) dictate that the airframe be designed and constructed so as to minimize its weight. All the airframe material must be arranged and sized so that it is utilized as near its capacity as possible, and so that the paths between applied loads and their reactions are as direct and as short as possible. The accomplishment of these goals, however, is compromised by constraints such as maintenance of the aerodynamic shape, the location of equipment, minimum sizes or thicknesses that are practical to manufacture, and structural stability, among others.

To maintain structural efficiency (minimum weight), the material that forms the aerodynamic envelope of the airplane is also utilized as a primary load-carrying member of the airframe. For example, the thin sheets that are commonly used for outer fuselage skins are very efficient in carrying in-plane loads like tension and shear when they are stabilized (prevented from moving or deflecting out of the way when loads are applied). This structural support is provided by circumferential frames and longitudinal primary members called longerons.

The compression loads are also carried in the longerons and the thin skins when they are additionally stabilized by multiple secondary longitudinal stiffeners that are normally located between the frames. Illustration *a* shows a typical fuselage primary load path structure indicating the frames and longerons. This skeleton will be covered by thin skins.

UNIT III: Propulsion-Aircraft, Rockets and Missiles/Evolution of Space Missions:

Propulsion-Aircraft, Rockets and Missiles
Thrust for flight; Reciprocating engines-two-stroke & four-stroke; the jet engine, rocket engines-description, types, principles of operation.
Types of missiles; similarities & differences with launch vehicles;
Control for missiles, airframe components of missiles
Evolution of Space missions: Space missions, mission objectives,
Case studies. Human space flight missions- goals, historical background. The Soviet and US missions. The Mercury, Gemini, Apollo-Soyuz, Space Shuttle
Types of orbits and maneuvers, International Space Station, extravehicular activity. Life support systems.
History and evolution of ISRO; missions carried by ISRO

Thrust for Flight- Reciprocating Engines; Jet Engines:

Types of Aerospace Propulsion:

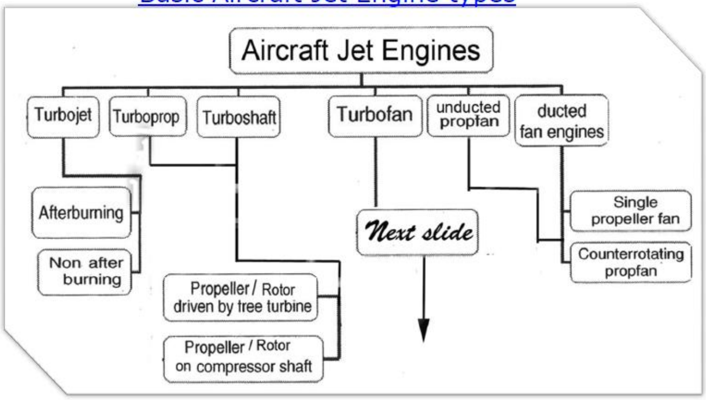
Air Breathing Systems: Broadly grouped as - Reciprocating& Jet Propulsion Engines.

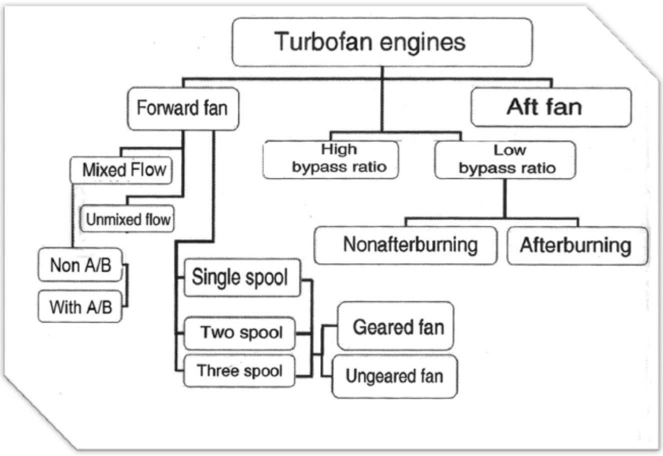
- Reciprocating Engines
- Gas Turbine Engines
- Ram Jets, Pulse Jets & Scram Jets

Non Air Breathing Systems

- Rockets

Basic Aircraft Jet Engine types





1.2.2. Working Principles, Advantages/Disadvantages & Applications:

1.2.2.1: Reciprocating Engines (I.C Engine): Working Principle: The four strokes of anInternal Combustion (I.C)engine are Intake, Compression, Power and Exhaust strokes.

During intake stroke, the piston moves downwards and the mixture of fuel and air (charge) is admitted in to the cylinder. At the completion of intake stroke, the inlet valve closes.

During the compression stroke, the piston moves up, compressing the charge. At the end of compression stroke, the electric spark ignites the charge.

On ignition, combustion of air fuel mixture releases thermal energy, exerting high force on the piston. This commences the power stroke.

During the power stroke, the piston is driven downwards.

Once the power stroke is completed, the exhaust valve opens. While the piston is moving up, the combustion gases are driven out of the cylinder through the exhaust valve. This creates a suction in the cylinder, that initiates the next cycle of operations.

The reciprocating movement of piston is transmitted to the crankshaft and converted into rotary motion. The crankshaft is connected to the propeller, which produces the forward thrust force for the aircraft.

The rotating output shaft of the I.C engine can be connected to a propeller, ducted fan, or helicopter rotor.

The propeller displaces a large mass of air rearwards, accelerating it in the process.

Reciprocating engines can produce up to 4000 KW power. Power to weight ratio (P/W) of up to 1.4 is produced.

The power produced by an I.C engine is given by

P = $\frac{KNV_c\rho_{air}fQ_f\eta_o}{60}$ where

K = constant; either 1.0 for 2 stroke engine or 0.5 for 4 stroke engine

N = rpm (around 5000-9000 rpm)

V_c = Volume of the cylinder

ρ_{air} = density of air

f = fuel air ratio (usually 13 to 15 ie one part fuel to 15 parts of air to burn the fuel completely)

Q_f = Calorific value of fuel (kerosene- 42 MJ/kg)

η_o = overall efficiency (usually 0.25 to 0.35)

$KNV_c\rho_{air}$ is the mass flow rate ingested in to the engine

- Multiplying mass flow rate with f gives the amount of fuel
- Multiplying with Q_f gives the heat energy released

To increase the power of the I.C engine, we need to

- Increase N –increases P
- As altitude increases ρ decreases, and P reduces. To offset this, turbo superchargers are used.

Advantages of Reciprocating Engines:

- Reciprocating engines provide excellent fuel economy and good take-off characteristics within their range of operations

- Highly suitable for small aircraft flying up to 500 km/hr and operating at low altitudes
- Components of reciprocating engines are subjected less thermal stresses than gas turbine-propeller combination
- Aircraft fitted with reciprocating engines need short runways
- Mainly used for business travel, farming & agriculture, air-taxi/ambulance, pilot training and unmanned aerial vehicles

Disadvantages of Reciprocating Engines:

- Reciprocating engines suffer drop in power at altitudes
- Difficulty in cooling and lubrication
- Low Power/Weight ratios compared to gas turbine engines
- Need high octane fuels to improve power output
- Increase in power output require larger number of cylinders, thereby increasing the frontal area and weight
- Use of reciprocating engines is limited to low speeds and altitudes
- Development reached a saturation stage as far as maximum power is concerned
- Maintenance requirement of piston-prop engines is more than turbojet aircraft
- Exhaust gases have less impurities in turbojet engines

1.2.2.2: Aircraft gas turbine Engines

All modern aircraft are fitted with gas turbine engines. Gas turbine engines can be classified into the following:-

(a) Turbojet engines

(b) Turbofan engines

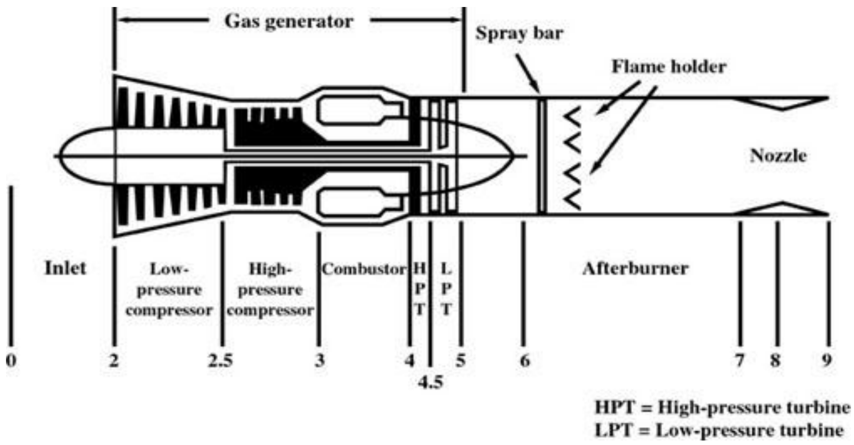
(c) Turbo-shaft engines

(d) Turboprop engines

Taken in the above order they provide propulsive jets of increasing mass flow and decreasing jet velocity. Therefore, in that order, it will be seen that the turbojet engines can be used for highest cruising speed whereas the turboprop engine will be useful for the lower cruising speed at low altitudes.

In practice the choice of power plant will depend on the required cruising speed, desired range of the aircraft and maximum rate of climb.

Turbojet Engine: Schematic diagram of a turbojet engine with station numbering is given below:



Working Principle:

1. The thrust of a turbojet engine is developed by compressing the free stream air in the diffuser or inlet and compressor. The diffuser converts the kinetic energy of the entering air into pressure rise which is achieved by ram effect. Diffusion in the inlet occurs due the geometric shaping of the inlet.
2. The compressor is driven by the turbine. It rotates at high speed, adding energy to the airflow and at the same time squeezing (compressing) it into a smaller space. Compressing the air increases its pressure and temperature
3. Compressor types used in turbojets were typically axial or centrifugal.
4. Use of axial flow compressors enable high pressure ratios. Modern axial compressors are split into low pressure and high pressure spools, driven by corresponding two stage turbine. High compressor ratios of 15:1 or more can be achieved while improving stability of operation at off-design conditions.The high pressure air is then mixed with fuel and burnt in the combustion chamber under constant pressure condition.
5. The combustion gasses at high temperature and pressure are expanded in the turbine and the exhaust nozzle. The expansion of gasses in the turbine provides power to drive the compressor while the exhaust nozzle expands the gasses to atmospheric pressure, thereby producing propulsive force, thrust.
6. The net thrust delivered by the engine is the result of converting internal energy to kinetic energy.
7. The exhaust products downstream of the turbine still contain adequate amount of oxygen. Additional thrust augmentation can be achieved by providing an afterburner in the jet pipe in which additional amounts of fuel can be burnt.
8. Turbojet engines are most suitable for speeds above 800 km/hr and up to 3.0 mach number

Advantages of Turbojet:

1. Power to Weight ratio is about 4 times that of Piston-Prop combination
2. Simple, easy to maintain, requires lower lubricating oil consumption. Complete absence of liquid cooling reduces frontal area
3. Turbojets allow faster supersonic speeds up to 3.0 M
4. There is no limit to power output while piston engines reached their peak power, beyond which any increase will result in high complexity and greater weight/frontal area.
5. Speed of turbojet is not limited by the propeller.
6. Turbojets can attain higher speeds than turboprop aircraft

Disadvantages-Turbojet:

- Fuel economy at low operational speeds is very poor
- It has low take-off thrust and hence poor starting characteristics
- High operating temperatures and engine parts are subjected to thermal stresses

Application:Turbojet engine is highly suited for aircraft at speeds above 800 km/hr.

Advantages of Gas turbines over Reciprocating Engines:

- **Mechanical Efficiency**: Mechanical efficiency of gas turbine engines is higher than reciprocating engines. This is mainly due to high friction losses in reciprocating engines.
- **Balancing**: Due to absence of reciprocating mass in gas turbine engines, balancing can be near perfect. Torsional vibrations are absent because gas turbine is a flow machine.
- **Smooth & Vibration-free operation**: Turboprop engines have fewer moving parts than piston-prop engines, offering greater reliability and time-between-overhaul (TBO).
- **Power**: The higher power of a turbo-prop engine allows it to fly at higher speeds and altitudes.
- **Shape**: Gas turbine engines have streamlined shape suitable from aerodynamic point of view.
- **Fuel**: Aviation turbine fuel is much cheaper than the high octane fuels used by reciprocating engines.
- **Lower Cost**: For a given power, gas turbine engine has lower cost and can be built faster
- **Weight:** Gas turbine engineshave higher power-to-weight ratios. This means, for a given weight, gas turbine engines develop more power.
- **Lubrication:** Lubrication in gas turbine engines is much simpler than reciprocating engines. The requirement is chiefly to lubricate the main bearing, compressor shaft and bearing auxiliaries.
- **High operational speed:** Turbine canbe run at much higher speed than reciprocating engine. Turbine can also be made lighter than the reciprocating engine of similar

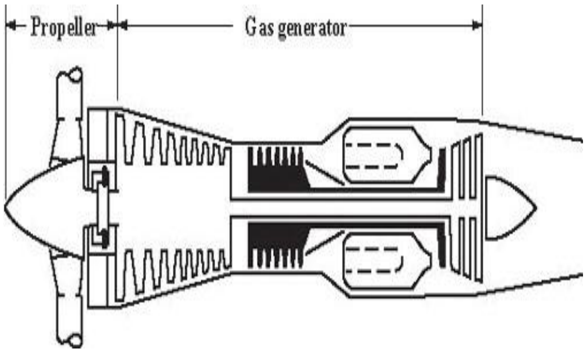
output. Therefore, for a given output, and higher speed, the torque can be lower. Gas turbine engines have better torque characteristics.

- **Silent Operation:** Since exhaust from gas turbine engines occurs under practically constant pressure conditions unlike the pulsating nature of the reciprocating engine exhaust, the usual vibrational noises will be absent in gas turbine engines.
- **Maintenance:** Relatively simpler in case of gas turbine engines.

Advantages of Reciprocating Engines over Gas turbine Engines:

- **Efficiency**: The overall efficiency of gas turbine engines is much less than the reciprocating engines.
- **Temperature Limitation**: The turbine blades in gas turbine engine are exposed to high temperature gasses continuously, and hence cannot exceed 1500 K.
- **Cooling**: We can achieve very good results by cooling the cylinder walls effectively. Cooling of turbine blades is complicated.
- **Ease of Starting**: It is more difficult to start a gas turbine than a a reciprocating engine.
- **Complexity**: Reciprocating engines are far less complex than their turbo-prop counter parts, from engineering considerations. This is primarily because of the high temperatures and forces unique to turbo-prop engine operation, which must be accommodated from materials and engine design.

1.2.2.3: Turboprop Engine: Schematic diagram is given below:



Working Principle: Turboprop engine is an intermediate between a pure jet engine and a propeller engine.

Turboprop engine provides high thrust per unit mass flow of fuel burnt by increasing mass flow of air. It offers better fuel economy. The propeller displaces a large mass of air rearwards, thereby increasing the net thrust.

The turbine extracts more power from the combustion gasses to drive the propeller. A small remaining energy is extracted by expansion in the jet nozzle.

The propeller and the compressor may be mounted on a single shaft or on separate shafts with a free turbine driving the propeller.

Advantages:

Turboprop engines have a higher thrust at take-off and better fuel economy.

The engine can operate economically over a wide range of speeds ranging from low speeds, where turbojet is uneconomical, to high speeds of about 800 km/hr where piston-prop engine cannot operate efficiently

It is easy to maintain and has lower vibration levels than piston-prop engine. The frontal area is much less than corresponding piston-prop engine.

Disadvantages:

The main disadvantage is that the propeller efficiency decreases greatly at high speeds due flow separation and shocks. The maximum speed is thus limited.

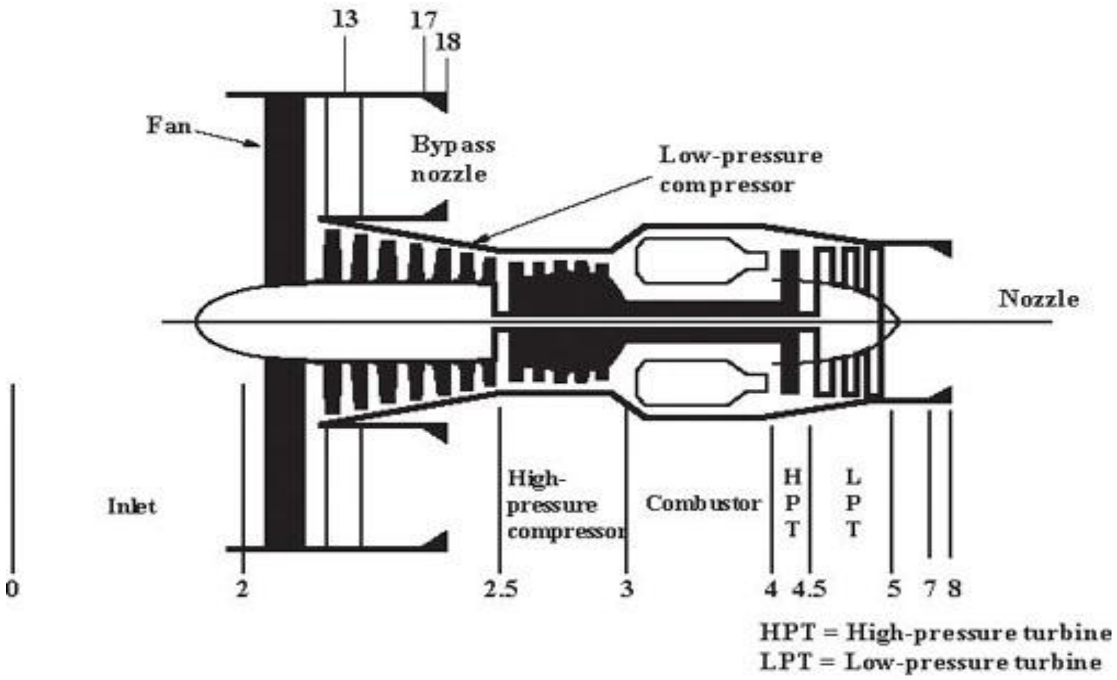
The turbine speeds need to be reduced through a suitable reduction gearing so that propeller runs at lower speeds, which adds to weight.

Applications:

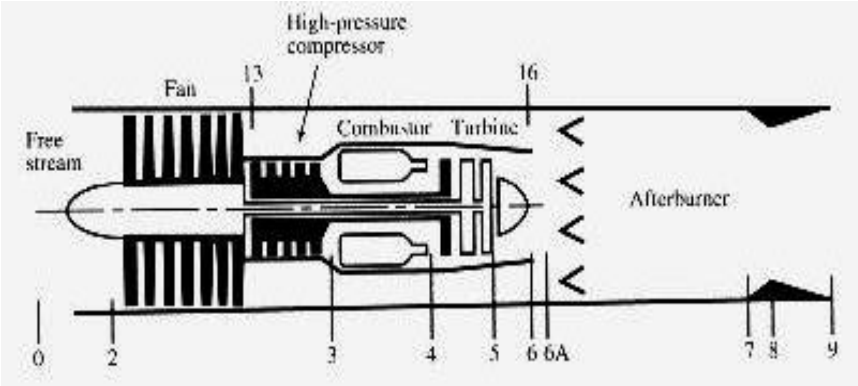
The turboprop engine is widely used in commercial and military aircraft due to its flexibility of operation and good fuel economy.

Turbofan Engine

Schematic Diagram of Turbofan (with station numbering): High by-pass ratio (used for commercial aircraft)



Turbofan with afterburner & Mixed flow: Low by-pass ratio (used for military aircraft)



Turbofan engine is designed as a compromise betweenturbojet and turbopropengines. The turbofan engine consists of a fan larger in diameter than the compressor, driven by the turbine. The fan displaces/bypasses free stream air around the primary engine. Two streams of air flow through the engine, primary airstream pass through the compressor and is delivered to the combustion chamber at high pressure to mix with fuel, while the other stream bypasses the primary engine to be expanded in the nozzle as a cold stream. The **hot and cold streams may be expanded through separate nozzles or combined together through a single nozzle**. The ratio of mass of cold air to the hot air is the by-pass ratio.

Thus the turbofan accelerates a larger mass of air at lower velocity than turbojet for a higher propulsive efficiency. Turbofan engines can also employ afterburner for higher thrust.

Turbofan engines can be aft-fan or forward fan (position of the fan), mixed or unmixed(hot and cold air streams) and high and low bypass ratio configuration

Advantages:

Fan is not as large as the propeller, therefore higher aircraft speeds can be attained without facing flow separation problems.

Turbofan engines do not encounter vibration problems associated with propellers. The fan could be encased in a duct/cowling to provide better aerodynamic shape.

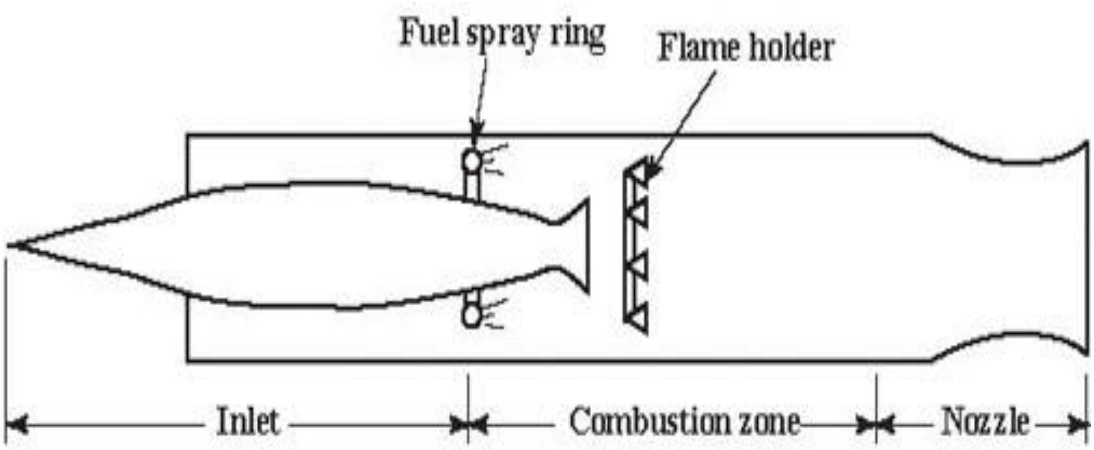
A **geared fan** connected to turbine reduces power consumed by the fan. It also produces low sound.

Turbofan is fuel efficient than turbojet, offers better propulsive efficiencies.

Lowers the sound levels of the exhaust gasses

Ramjet Engine

Schematic Diagram:



Operating Principle:

Ramjet Engine consists of supersonic diffuser, subsonic diffuser, combustion chamber and nozzle section

Air from atmosphere enters the supersonic diffuser at a very high speed. The air velocity gets reduced in the supersonic diffuser through normal and oblique shock waves.

Air velocity is furthur reduced in the subsonic diffuser.

The diffuser converts the kinetic energy of the entering air into static pressure and temperature rise which is achieved by ram effect. Diffusion in the inlet also occurs due the geometric shaping of the diffuser. The diffuser thus slows down the air enabling combustion.

Fuel is injected into the combustor through suitable injectors causing mixing of fuel with the air and the mixture is burnt

Combustion gases attain a temperature of around 1500-2000 k by continuous combustion of fuel air mixture

Fresh air supply continuously will not allow gasses towards the diffuser. Instead, gases are made to expand towards the tail pipe and nozzle, which expands the gases completely.

The gases leave the engine with a speed much higher than the air entering the engine.

The rate of increase of momentum of the working fluid produces thrust F in the direction of flight

Distinguishing Features:

Air enters the engine at supersonic speeds, must be slowed down to subsonic value, to prevent blow out of the flame in the combustor

Velocity must be low enough (approximately around 0.2-0.4 mach number) to allow mixing of fuel and stable combustion

Cycle pressure ratio depends on the diffusion pressure ratio. Very high pressure ratios of about 8 to 10 through ram compression is possible, therefore, a mechanical compressor is not required

Slowing down speeds from mach 3.0 to 0.3 will result in a pressure ratio of more than 30

As the ram pressure increases, a condition is reached where the nozzle gets choked. Thereafter, the nozzle operates at Mach 1 condition at throat

Advantages:

Ramjet is a simple machine and does not have any moving parts

Since turbine is not used, maximum temperature allowed is very high, around 2000 C, as compared to around 900 C in turbojets.

We can burn air/fuel ratios of 13:1which gives greater thrust

Specific fuel consumption is much better than other gas turbine engines, at high speeds and altitudes

Wide range of fuels can be used

It is very cheap to produce; adoptable for mass production

It is not possible to start a ramjet engine without an external launching device

The engine heavily relies on the diffuser and it is very difficult to design a diffuser which gives good pressure recovery over a wide range of speeds

Due to high air speed, the combustion chamber requires flame holders to stabilize the combustion

At very high temperatures of about 2000 C, dissociation of combustion products take place, reducing the efficiency of the plant

High fuel consumption at low speeds

Applications:

Highly suitable for propelling missiles.

Used in high speed military aircraft, in a combined cycle engine (Turbojet-Ramjet combination).

Development is in progress for a hypersonic aircraft system using turbojet-ram-scramjet combined cycle.

Subsonic ramjets are used as target weapons in conjunction with turbojet aircraft.

Pulsejet Engine:

Schematic Diagram:

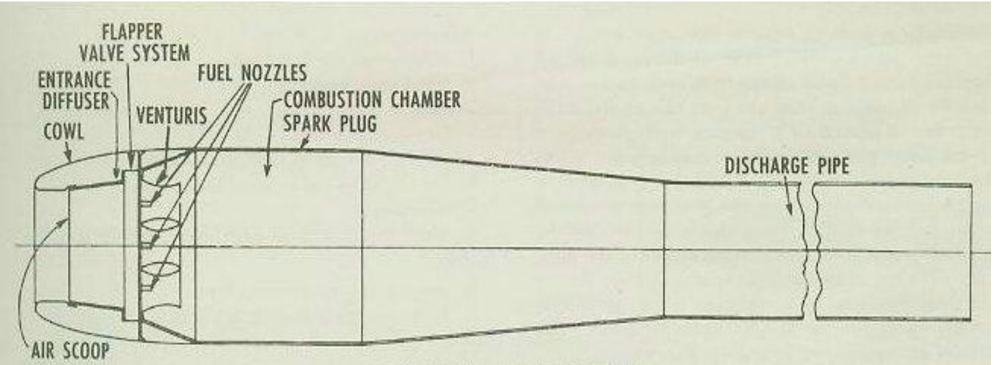


FIGURE 11D3.—A pulse-jet engine.

Basic Components are diffuser, Valve grid with spring loaded flapper valves, Combustion chamber with spark plug, tail pipe and discharge nozzle

Operation:

The diffuser converts the kinetic energy of the entering air into static pressure rise and slows down the air. Ram action also builds pressure in the diffuser.

The pressure differential opens the flapper valves which are spring loaded and the high pressure air enters the combustion chamber.

Fuel is injected and ignited by the spark plug

Combustion proceeds at constant volume with sudden explosion.

There is a sudden pressure rises in the combustion chamber which closes the flapper valves

The combustion gasses expand in the nozzle and escape to the atmosphere at high velocity

As combustion products leave the combustion chamber, a low pressure is created which causes the valves to open and a new charge of air enters the chamber

Distinguishing feature: Since the combustion chamber builds pressure, the engine can operate in static condition also. Proper design makes the duct to fire at a given pulse rate which can be as high as 500 cycles/sec

Advantages:

1. Simple to construct and hence cheap.
2. Can be mass produced in a short time.
3. Since it does not have any moving parts like compressor of turbine, it can be used in high temperatures.
4. Can be used for military applications.

Disadvantages:

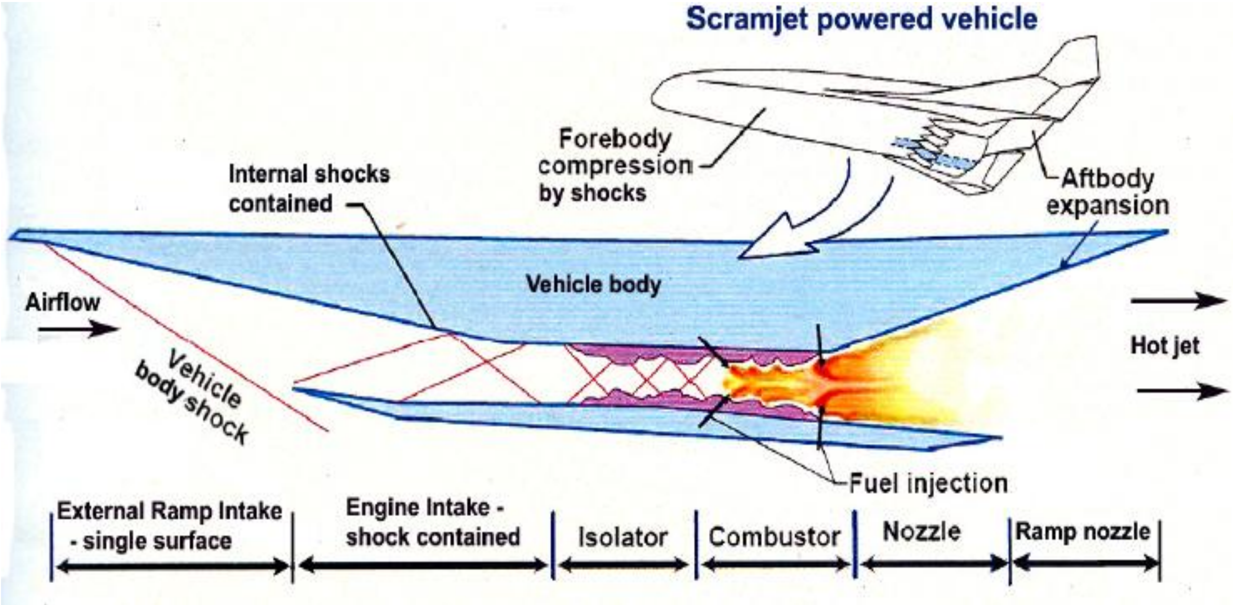
1. It is having limited flight speed only.
2. Limited flying altitude.
3. High vibration and noise due to the pulses of thrust produced

Scramjet Engine:

- Scramjet engine stands for supersonic combustion ramjet engine.
- The flow speed in the combustion chamber is supersonic
- Scramjet engine is characterized by high flow speeds ie low residence times in the engine.
- The engine needs larger combustion volumes; leading to integrated design of airframe and engine.
- In scramjet aircraft, the entire lower body of the aircraft is occupied by the engine. The front portion of the underside operates as external/internal diffuser, with rear portion providing expansion surface.

The scramjet consists of

- Diffuser (compression component) consisting of external ramp intake and engine intake
- Isolator
- Supersonic combustor
- Exhaust nozzle or aft body expansion component



Scramjet Engine- Construction:Scramjet engine is characterized by slow reaction times and high flow speeds ie low residence times in the engine. The engine needs larger combustion volumes; leading to integrated design of airframe and engine. In scramjet aircraft, the entire lower body of the aircraft is occupied by the engine. The front (fore) portion of the underside operates as external/internal diffuser, with rear (aft) portion providing expansion surface.

The scramjet consists of

- Diffuser (compression component) consisting of external ramp intake and engine intake
- Isolator
- Supersonic combustor
- Exhaust nozzle or aft body expansion component

Diffuser

- It consists of fore-body external intake and internal intake
- The fore-body provides the initial external compression and contributes to the drag and moments of the vehicle.
- The internal inlet compression provides the final compression of the propulsion cycle.

Since the flow upstream is supersonic, the geometry of the diffuser is entirely convergent.

Isolator: Isolator is constant area diffuser containing the internal shock structure, swallowed during supercritical operation of the inlet (or during operation after the inlet "started"). The isolatoris inserted before thecombustor to diffuse the flow further, through a shock train, producing desired flow speeds in the combustors. The function of the isolator is:

- The shock train provides a mechanism for the supersonic flow to adjust to a static back pressure higher than its inlet static pressure
- The isolator cross-sectional area may be constant or slightly divergent to accommodate boundary layer separation.
- When the combustion process begins to separate the boundary layer in the combustor, a pre-combustion shock train forms.
- The shock structure allows the required pressure rise, thus isolating the combustion process from the inlet compression process. Thus the isolator functions to prevent inlet surge or "unstart".

Combustor: Main features include:

- Avoidance of hot pockets near the walls implies that the fuel be injected from centrally located struts.
- The usual circular configuration for combustors can be sacrificed in favor of a rectangular configuration.
- Typical velocities in the combustion chamber are about 1 to 1.5 km/s and the Mach numbers will be 1.4 to 2.3 for a typical combustor entry Mach number of 2.5

Combustion limits: Two limits are very critical for the operation

- First, since when a supersonic flow is compressed, it slows down, the level of compression must be low enough (or the initial speed high enough) not to slow the gas below Mach 1. If the gas within a scramjet goes below Mach 1 the engine will "choke", transitioning to subsonic flow in the combustion chamber. Additionally, the sudden increase in pressure and temperature in the engine can lead to an acceleration of the combustion, leading to the combustion chamber exploding.

- Second, the heating of the gas by combustion causes the speed of sound in the gas to increase (through increase of $\sqrt{t}$and hence cause Mach number to decrease) even though the gas is still travelling at the same speed. Forcing the speed of air flow in the combustion chamber under Mach 1 in this way is called "**thermal choking**".
- A thermal throat results when the flow is slowed through tailored heat for causing dual-mode operation.
- There are engine designs where a ramjet transforms into a scramjet over the Mach 3-6 range, known as dual-mode scramjets.

Expansion System:

- The expansion system, consists of
  a. Internal nozzle

  b. Vehicle aft body
- It completes the propulsion flow path and controls the expansion of the high pressure and temperature gas mixture to produce net thrust.

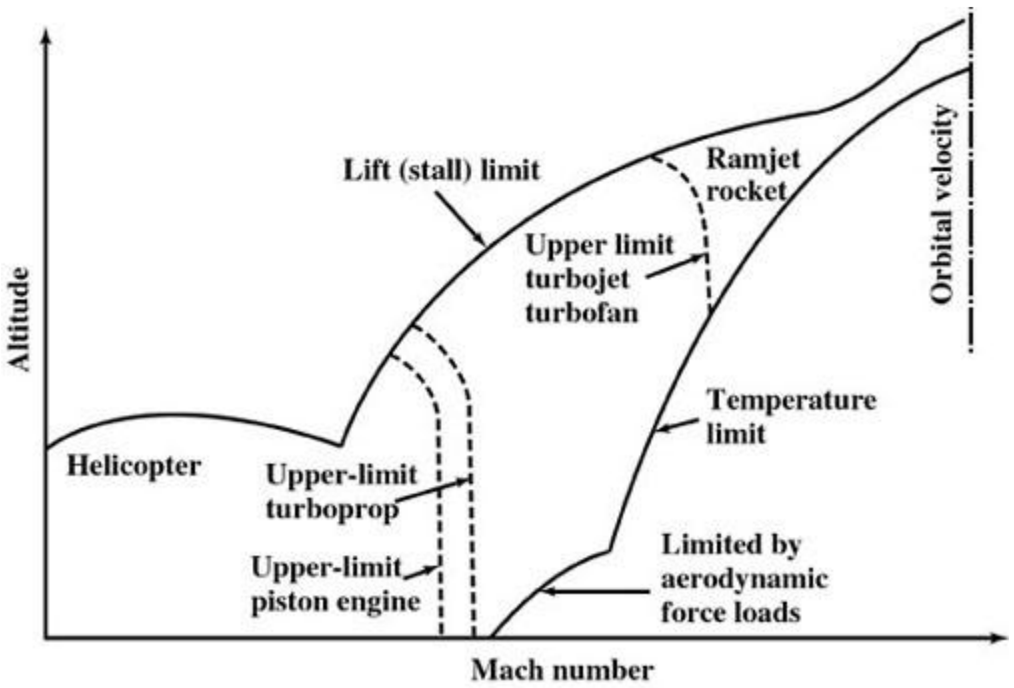
Applications of Scramjets:

- Weapons systems -hypersonic cruise missiles
- Aircraft systems - global strike / reconnaissance
- Space access systems that will take off and land horizontally like commercial Airplanes
- Using these Scramjet technologies, along with additional ground-and flight-test experiments, will pave the way for affordable and reusable air-breathing hypersonic propulsion systems such as missiles, long range aircraft and space-access vehicles

Advantages:

1. Need not carry oxygen on board
2. No rotating parts makes it easier to manufacture than a turbojet
3. Has a higher specific impulse (change in momentum per unit of propellant) than a rocket engine; could provide between 1000 and 4000 seconds, while a rocket only provides 450 seconds or less
4. Higher speed could mean cheaper access to outer space in the future

Flight Limits/Operating Envelope:



Types of missiles; similarities & differences with launch vehicles;
Control for missiles, airframe components of missiles
Evolution of Space missions: Space missions, mission objectives,
Case studies. Human space flight missions- goals, historical background. The Soviet and US missions. The Mercury, Gemini, Apollo-Soyuz, Space Shuttle
Types of orbits and maneuvers, International Space Station, extravehicular activity. Life support systems.
History and evolution of ISRO; missions carried by ISRO

Missiles:

In military parlance, missiles are powered / guided munitions are broadly categorised as follows:

- A powered, guided munition that travels through the air or space is known as a military **missile** (or *guided missile*.)
- A powered, *un*guided munition is known as a **rocket**.

TECHNOLOGY :

Guided missiles have a number of different system components:

- Targeting and/or guidance
- Flight system
- Engine
- Warhead

Basic categorization

Missiles are generally categorized by their launch platform and intended target. Other kinds of military missiles are Glide- Bombs , Torpedos etc.

Their basic types are

Conventional guided missiles	Cruise missiles	Ballistic misslies
Air-to-air missile	Hypersonic	Tactical ballistic missile
Air-to-surface missile	Supersonic	Short-range ballistic missile
Anti-ballistic missile	Long-range subsonic	Theatre ballistic missile
Anti-satellite weapon	Medium-range subsonic	Medium-range ballistic missile
Anti-ship missile	Short-range subsonic	Intermediate-range ballistic missile
Anti-submarine missile		Intercontinental ballistic missile
Anti-tank guided missile		Submarine-launched ballistic missile
Land-attack missile		Air-launched ballistic missile
Surface-to-air missile		
Surface-to-surface missile		
Wire-guided missile		

Space Launch Vehicle:

A **launch vehicle** is the rocket we see sitting on the launch pad during countdown.

In spaceflight a **launch vehicle** or **carrier rocket** is a rocket used to **carry a payload from the Earth's surface into outer space**. A **launch system** includes the launch vehicle, the launch pad and other infrastructure.

ROLE :

- It provides the **necessary velocity change** to get a spacecraft into space.
- At lift-off, the launch vehicle blasts almost straight up to gain altitude rapidly and get out of the dense atmosphere which slows it down due to drag. When it gets high enough, it slowly pitches over to gain horizontal velocity.

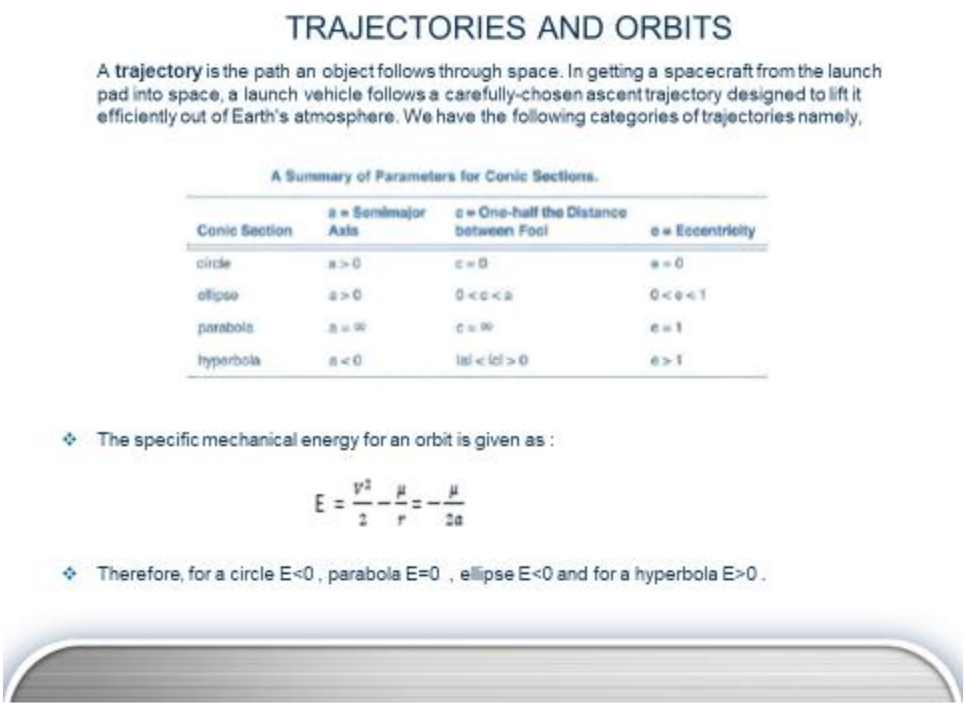
A launch vehicle consists of a series of smaller rockets that ignite, provide thrust, and then burn out in succession, each one handing off to the next one like runners in a relay race. These smaller rockets are **stages.** In most cases, a launch vehicle uses at least three stages to reach the mission orbit.

Types of Launch Vehicles:

Based on Usage

- Expendable launch vehicles are designed for one-time use. They usually separate from their payload, and may break up during atmospheric reentry.
- Reusable launch vehicles, on the other hand, are designed to be recovered intact and used again for subsequent launches.
- For orbital spaceflights, the Space Shuttle was the only launch vehicle with components which have been used for multiple flights.
- Non-rocket spacelaunch alternatives are at the planning stage.

Launch vehicles are often **characterized by the amount of mass** they can lift into orbit. Launch vehicles are also characterized by the number of stages they employ.Other frequently-reported characteristics of launch vehicles are the nation or space agency responsible for the launch, and the company or consortium that manufactures and launches the vehicle. For example, the European Space Agency is responsible for the Ariane V, and the United Launch Alliance manufactures and launches the Delta IV.



TRAJECTORIES AND ORBITS

A **trajectory** is the path an object follows through space. In getting a spacecraft from the launch pad into space, a launch vehicle follows a carefully-chosen ascent trajectory designed to lift it efficiently out of Earth's atmosphere. We have the following categories of trajectories namely,

A Summary of Parameters for Conic Sections.

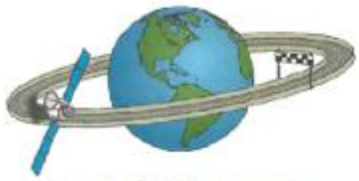
Conic Section	a = Semimajor Axis	c = One-half the Distance between Foci	e = Eccentricity
circle	$a > 0$	$c = 0$	$e = 0$
ellipse	$a > 0$	$0 < c < a$	$0 < e < 1$
parabola	$a = \infty$	$c = \infty$	$e = 1$
hyperbola	$a < 0$	$\lvert a \rvert < \lvert c \rvert > 0$	$e > 1$

- The specific mechanical energy for an orbit is given as :

$$E = \frac{v^2}{2} - \frac{\mu}{r} = -\frac{\mu}{2a}$$

- Therefore, for a circle E<0 , parabola E=0 , ellipse E<0 and for a hyperbola E>0 .

Once in space, the spacecraft resides in an **orbit.** An orbit is a fixed "racetrack" on which the spacecraft travels around a planet or other celestial body. When selecting an orbit for a particular satellite mission, we need to know where the spacecraft needs to point its instruments and antennas.



The Orbit. We can think of an orbit as a fixed racetrack in space that the spacecraft drives on. Depending on the mission, this racetrack's size, shape, and orientation will vary.

There are many ways to categorize the orbits either by using the time period or by using the inclination. And in order to classify them we **require six classical orbital elements** and they are namely :

The other types of orbits are :

- **A geostationary orbit** is a circular orbit with a period ofabout 24 hours and inclination of 0°. Geostationary orbits are particularlyuseful for communication satellites because a spacecraft in this orbitappears motionless to an Earth-based observer, such as a fixed ground station for a cable TV company.
- **Geosynchronous orbits** are inclined orbits with a period of about 24 hours.
- A **semi-synchronous orbit** has a period of 12 hours.

- **Sun-synchronous orbits** are retrograde, low-Earth orbits (LEO) typically inclined 95° to 105° and often used for remote-sensing missions because they pass over nearly every point on Earth's surface.
- A **Molniyaorbit** is a semi-synchronous, eccentric orbit used for some specific communication missions.

The Mercury, Gemini, Apollo-Soyuz, Space Shuttle

Mercury: Mercury, America's first human space flight program, introduced the nation to its first astronauts. There were six total flights with six astronauts flown. Total flight time for these missions was 53 hours, 55 minutes and 27 seconds

Project Mercury was the first human spaceflight program of the United States. It ran from 1959 through 1963 with two goals: putting a human in orbit around the Earth, and doing it before the Soviet Union, as part of the early space race. It succeeded in the first but not the second: in the first Mercury mission on 5 May 1961,[1] Alan Shepard became the first American in space; however the Soviet Union had put Yuri Gagarin into space one month earlier.[2] John Glenn became the first American (third overall, following Gagarin and Titov) to reach orbit on February 20, 1962, during the third manned Mercury flight.[3]

The program included 20 unmanned launches, followed by two suborbital and four orbital flights with astronaut pilots. Early planning and research were carried out by the National Advisory Committee for Aeronautics (NACA),[4] but the program was officially conducted by its successor organization, NASA. It also absorbed the USAF program Man In Space Soonest which had had the same objectives. Mercury laid the groundwork for Project Gemini and the follow-on Apollo moon-landing program.

The project name came from Mercury, a Roman god often seen as a symbol of speed. Mercury is also the name of the innermost planet of the Solar System, which moves faster than any other and hence conveys an image of speed, although Project Mercury had no other connection to the planet.

Gemini:

Project Gemini was the second human spaceflight program of NASA, the civilian space agency of the United States government. Project Gemini was conducted between projects Mercury and Apollo, with ten manned flights occurring in 1965 and 1966.

Its objective was to develop space travel techniques in support of Apollo, which had the goal of landing men on the Moon. Gemini achieved missions long enough for a trip to the Moon and back, perfected extra-vehicular activity (working outside a spacecraft), and orbital maneuvers necessary to achieve rendezvous and docking. All manned Gemini flights were launched from Cape Canaveral, Florida using the Titan II GLVlaunch vehicle.[1]

NASA selected McDonnell Aircraft, which had been the prime contractor for the Project Mercury capsule, to build the Gemini capsule in 1961 and the first capsule was delivered in 1963. The spacecraft was 19 feet long and 10 feet wide with a launch weight of 8,490 pounds. The Gemini capsule first flew with a crew on March 23, 1965.[5]

Gemini was the first manned spacecraft to include an onboard computer, the Gemini Guidance Computer,[6] to facilitate management and control of mission maneuvers. Unlike the Mercury, it used ejection seats, in-flight radar and an artificial horizon—devices similar to those used in the aviation industry.

Unlike Mercury, which could only rotate around the axes of pitch, yaw, and roll to change its orientation in space, the Gemini spacecraft was designed also to translate in all three perpendicular axes (forward/backward, left/right, up/down), and also to alter its orbital inclination and altitude. It used these capabilities to dock with the Agena target vehicle, which had its own rocket engine which could be used to perform larger altitude changes.

A major difference between the Gemini and Mercury spacecraft was that Mercury had all systems other than the reentry rockets situated within the capsule, most of which were accessed through the astronaut's hatchway. In contrast, Gemini housed power, propulsion, and life support systems in a detachable Equipment Module located behind the Reentry Module, which made it similar to the Apollo Command/Service Module design. Many components in the capsule itself were reachable through their own small access doors.

The original intention was for Gemini to land on solid ground instead of at sea, using a Rogallo wing rather than a parachute, with the crew seated upright controlling the forward motion of the craft. To facilitate this, the airfoil did not attach just to the nose of the craft, but to an additional attachment point for balance near the heat shield. This cord was covered by a strip of metal which ran between the twin hatches. This design was ultimately dropped, and parachutes were used to make a sea landing as in Project Mercury. The capsule was suspended at an angle closer to horizontal, so that a side of the heat shield contacted the water first. This eliminated the need for the landing bag cushion used in the Mercury capsule.

Early short-duration missions had their electrical power supplied by batteries; later endurance missions used the first fuel cells in manned spacecraft.

Apollo:

The **Apollo program** was a United States human spaceflight program carried out by the National Aeronautics and Space Administration (NASA), that landed the first humans on Earth's Moon in 1969 through 1972. Conceived during the Presidency of Dwight D. Eisenhower as a follow-on to Project Mercury which put the first Americans in space, Apollo began in earnest after PresidentJohn F. Kennedy proposed the national goal of "landing a man on the Moon and returning him safely to the Earth" by the end of the 1960s in a May 25, 1961 address to Congress.[1][2]

Kennedy's goal was accomplished with the Apollo 11 mission when astronauts Neil Armstrong and Buzz Aldrin landed their Lunar Module (LM) on the Moon on July 20, 1969 and walked on its surface while Michael Collins remained in lunar orbit in the command spacecraft, and all three landed safely on Earth on July 24. Five subsequent Apollo missions also landed astronauts on the Moon, the last in December 1972. In these six spaceflights, 12 men walked on the Moon.[3]

Apollo ran from 1961 to 1972, and was supported by the two-man Gemini program which ran concurrently with it from 1962 to 1966. Apollo used Saturn family rockets as launch vehicles. Apollo / Saturn vehicles were also used for an Apollo Applications program which consisted of three Skylab space station missions in 1973–74.

Apollo succeeded despite the major setback of a 1967 Apollo 1 cabin fire that killed the entire crew during a pre-launch test. Six manned landings on the Moon were achieved. A seventh landing mission, the 1970 Apollo 13 flight, failed in transit to the Moon when an oxygen tank explosion disabled the command spacecraft's propulsion and life support, forcing the crew to use the Lunar Module as a "lifeboat" for these functions to return to Earth safely.

Apollo set several major human spaceflight milestones. It stands alone in sending manned missions beyond low Earth orbit; Apollo 8 was the first manned spacecraft to orbit another celestial body, while the final Apollo 17 mission marked the sixth Moon landing and the ninth manned mission beyond low Earth orbit. The program spurred advances in many areas of technology incidental to rocketry and manned spaceflight, including avionics, telecommunications, and computers. Apollo also sparked interest in many fields of engineering and left many physical facilities and machines developed for the program as landmarks. Its command modules and other objects and artifacts are displayed throughout the world, notably in the Smithsonian's Air and Space Museums in Washington, DC, Kennedy Space Center Visitor Complex in Florida, Space Center Houston in Texas, the U.S. Space and

Rocket Center in Alabama, and the Kansas Cosmosphere and Space Center in Hutchinson, Kansas.