Introduction to Aerospace Engineering
AE-201A

Course contents

- **Fixed wing vehicles**:
  - History of Aviation, introduction to fixed wing vehicles,
  - configuration and lay-out
  - propulsion, lift generation mechanism,
  - balance of forces and moments
  - control mechanisms

- **Space Vehicles**:
  - History
  - configuration and lay-out,
  - propulsion, lift generation mechanism,
  - balance of forces and moments
  - navigation.

- **Rotary wing vehicles**:
  - History of rotary wing vehicles
  - configuration and layout
  - Propulsion, lift generation mechanism
  - balance of forces and moments
  - control mechanisms

References

- ***Introduction to flight***
  - By John D Anderson (Jr)

- ***Fundamentals of Flight***
  - By Richard S. Shevell

- **The simple science of Flight: from insects to Jumbo Jets**
  - By Henk Tennekes
- **Meet Aerospace Vehicles**
  - By Victor Kirillov
- **Understanding Flight**
  - By David F. Anderson & Scott Eberhardt
- And web resources

Examinations

- **Examinations:**
  - One examination and two/three quizzes
  - (**65%** in Final exam +**35%** quizzes and attendance)
- **Grading policy**:
  - Relative

History of Aviation

Idea of flight

- From the dawn of civilization, birds are seen to fly

Source: Fundamentals of flight by R D Shevell

- Human, being most intelligent animals, must have caught with the idea of flying like birds

- In this regard, some mythological references may be put forward, for example in Ramayana (Pushpaka chariot), Greek mythology

Vedic Literatures

- Several descriptions of flying machines called vimanas are available in the Vedic literature of India

Source: web

Two categories are found:

(l) Man-made craft that resemble airplanes and fly with the help of birdlike wings

(2) Unstreamlined structures that fly in a mysterious manner and are generally not made by human beings.

Those in category (1) are described mainly in medieval, secular Sanskrit works dealing with architecture, military siege engines, and other mechanical contrivances.

Those in category (2) are described in ancient works such as the Rig Veda, the Mahabharata, the Ramayana, and the Puranas.

Resourses from http://www.ufoevidence.org/topics/vimanas.htm

Some books are also available

Books:

1. **Vimana Aircraft of Ancient India and Atlantis -**by D. H. Childress and Ivan T. Sanderson

2. **Vaimanika Shastra by Pandit Subbaraya Shastry**

   (English translation by Mr. G. R. Josyer was published in 1973)

One critical review of the book **Vaimanika Shastra** may also be found in link given below

http://cgpl.iisc.ernet.in/site/Portals/0/Publications/ReferedJournal/ACriticalStudyOfTheWorkVaimanikaShastra.pdf

Journey towards realizing the modern aircraft

- Many medieval people fashioned wings and met some serious accidents while leaping from towers or roofs.

- Finally strapping a pair of wings to arms had be to left out

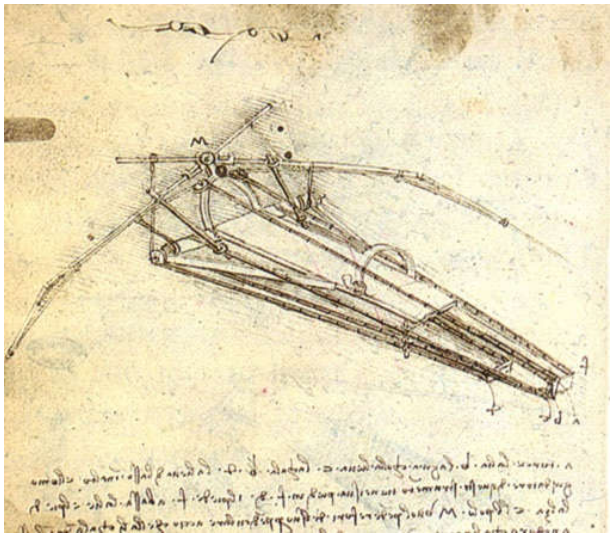
ORNITHOPTERS

❖ However, the idea of wings to be flapped up and down by various mechanical mechanisms, powered by some type of human arm, leg or body movement, gave birth a machine called *ORNITHOPTERS*

Leonardo da Vinci (1452 – 1519)

Source: web

- Historical search revealed that Leonardo da Vinci also got the idea of human flight
- He designed large number of Ornithopters towards the end of 15th century
- Literature revealed that he had penned down 35000 words and also made about 500 such sketches of Ornithopter



Sketch by Leonardo da Vinci, 1486-1490 Source: web

- But it is not found whether he built or tested any of his design

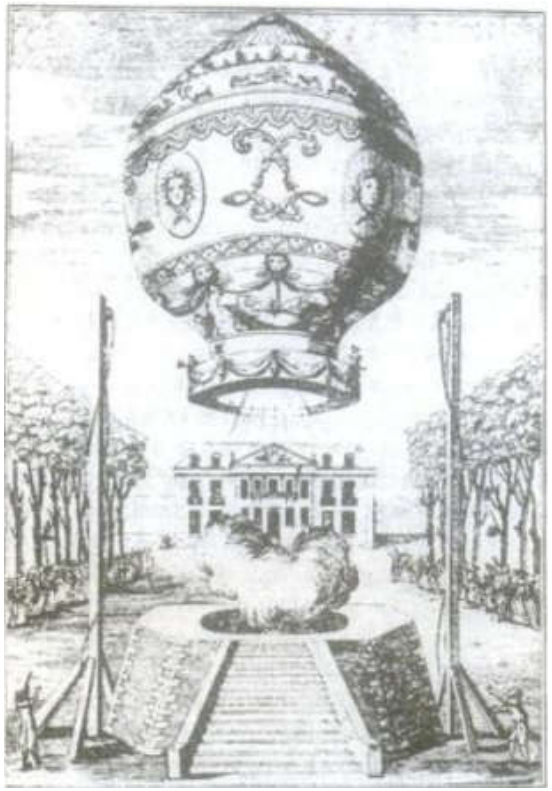
- The idea of human-powered flight had to be dropped finally

- In this sense, da Vinci's effort has not contributed much to the technological knowledge of modern aircraft

Flying by balloon

- Montgolfier brothers (**Joseph and Etienne**)
- They conceived the idea of hot air to lift a person from the surface of the earth
- They used a bag to trap hot air and shown that a balloon can be used for flying
- After public demonstration with sheep, rooster and duck as passenger, they designed a balloon for human passenger

The Montgolfier hot-air ballon



Source: Fundamentals of flight by R D Shevell

- Although the balloon rose into air and lasted for sometime, it finally fell into ground killing the human passenger, **Pilatre de Rozier** on Nov 21, 1783

- Leonardo da Vinci designed his ornithopter wings to flap simultaneously downward and backward for both lift and propulsion

Sir George Cayley (1773-1857)

(The true inventor of the Airplane)

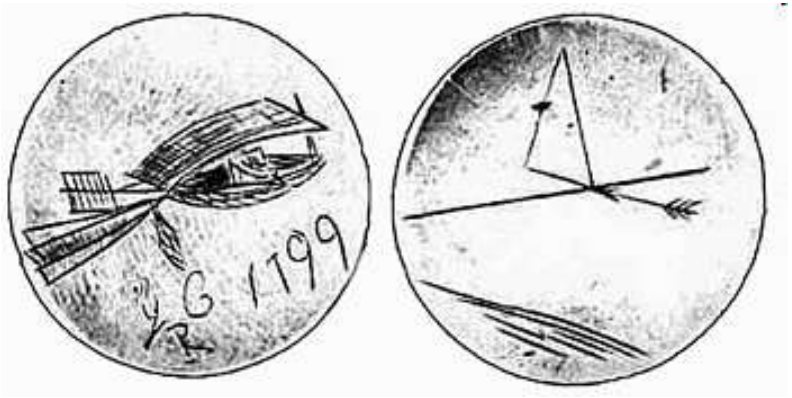
Source: web

- Cayley first conceptualized

  - a fixed wing for generating lift,
  - a separate mechanism for propulsion (paddles)
  - a combined horizontal and vertical tail for stability

  i.e. he separated the concept of lift from propulsion

- Cayley inscribed these ideas on a silver disk which is preserved in the Science Museum in London



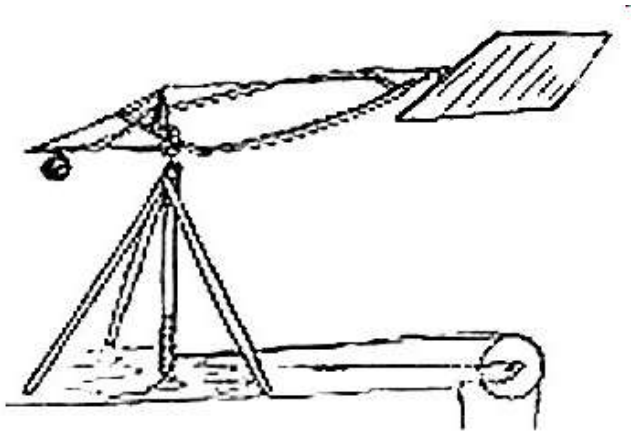
The silver disk on which Cayley engraved his concept for a fixed-wing aircraft in 1799

- Moreover, he built an apparatus called whirling arm for testing airfoil

- In modern aerospace engineering, Wind tunnel serves this purpose

- However, using this whirling arm, he used to measure aerodynamic forces and centre of pressure on lifting surfaces

Cayley's whirling arm apparatus



Source: web

- Cayley not only documented his idea on a disk, but also published these ideas in his momentous triple paper of 1809-1810

- It was published in *Nicholson's Journal of Natural Philosophy* entitled as "On Aerial Navigation"

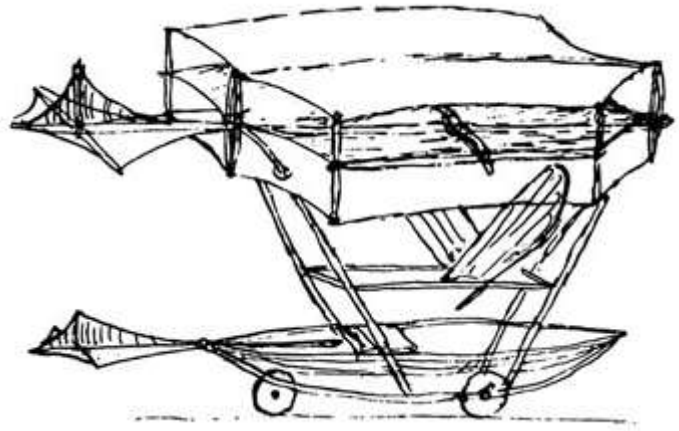
- Actually he published this after hearing reports that Jacob Degen had flown in a mechanical machine; but in reality he flew in a contraption that was lifted by balloon and Cayley did not know this fact.

- However, according to literatures, this publication was first treatise on theoretical and applied aerodynamics

- He also mentioned that an inclined surface to the direction of motion will generate lift and a curved (cambered) surface will do this more efficiently

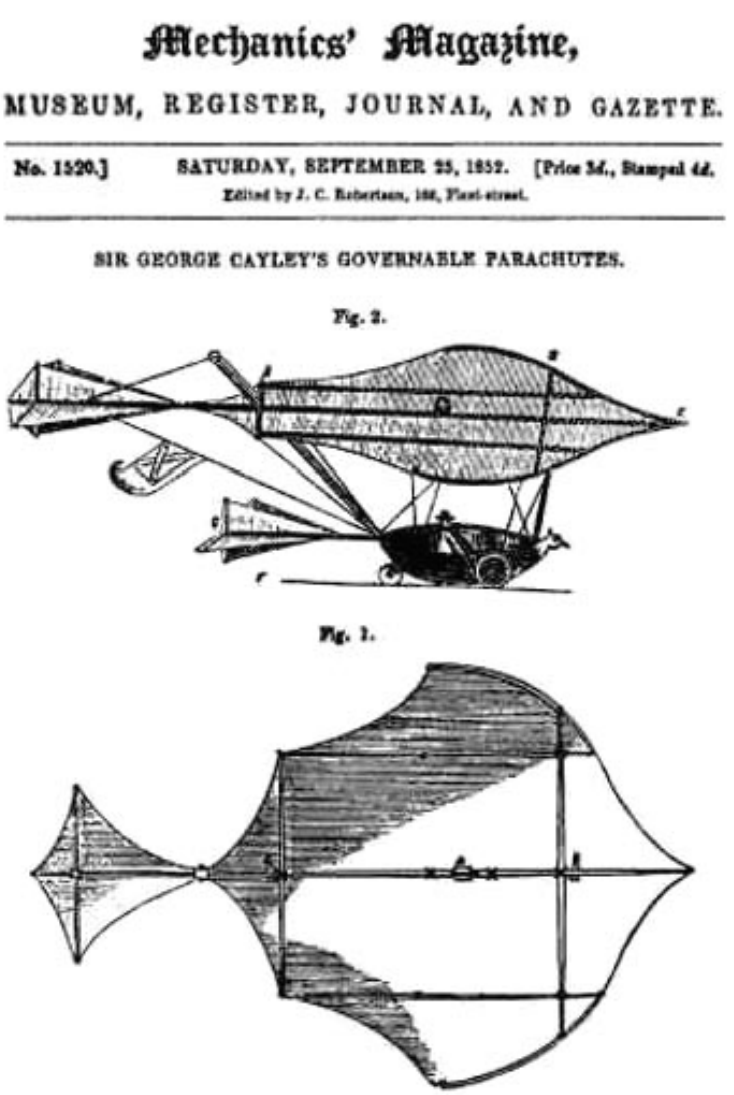
- He also designed a human carrying glider

George cayley's boy carrier



Source: Introduction to flight by J D Anderson

Cayley's Human carrying glider



Mechanics' Magazine,

MUSEUM, REGISTER, JOURNAL, AND GAZETTE.

No. 1520.] SATURDAY, SEPTEMBER 25, 1852. [Price 3d., Stamped 4d.

Edited by J. C. Robertson, 166, Fleet-street.

SIR GEORGE CAYLEY'S GOVERNABLE PARACHUTES.

Fig. 2.

Fig. 1.

Source: Introduction to flight by J D Anderson

Otto Lilienthal (1848-1896): The Glider man

- He designed a glider in 1889, and another in 1890 and unfortunately both were not successful

- However, he made a successful one in 1891. He flew it from a natural hill, and later on he built an artificial hill to fly his glider

Lilienthal monoplane hang glider

Source: web

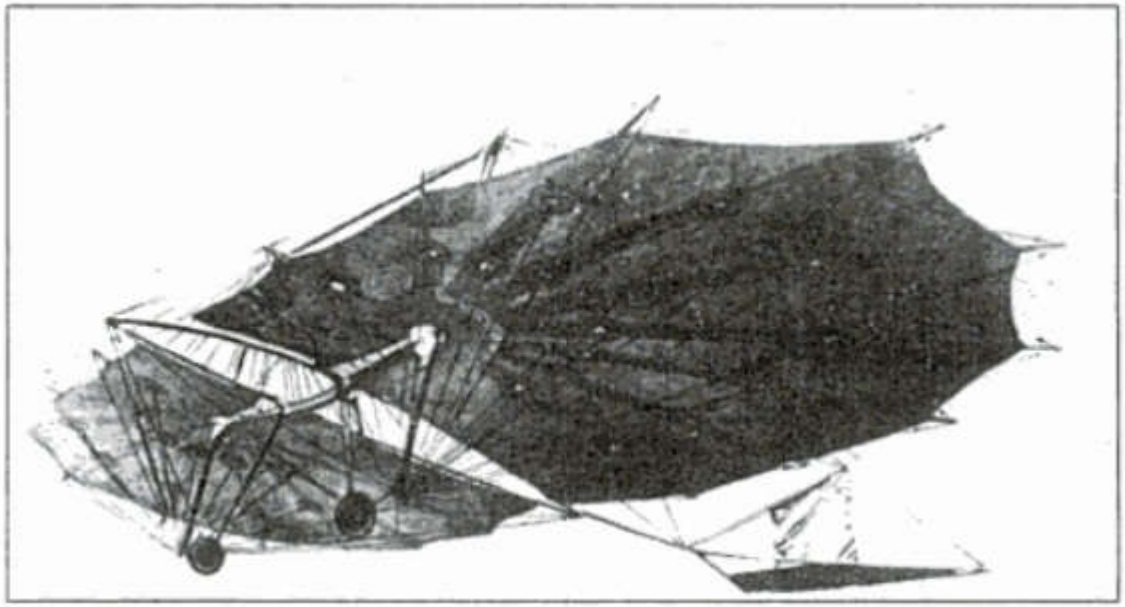
- He made over 2000 successful flights

- He believed that one need to get up in the air and fly around in gliders to obtain the feel of an air plane before an engine was used for powered flight

- Whatever aerodynamic data he obtained were published in papers which were circulated through out the world

Percy Pilcher (1867-1899)

- He extended the glider tradition after meeting Lilienthal in Berlin
- His most famous machine was *Hawk;* He also thought to power his Hawk by an engine.
- Unfortunately he died while demonstrating his glider



Pilcher's hang glider Source: Introduction to flight by J D Anderson

Octave Chanute (1832-1910)

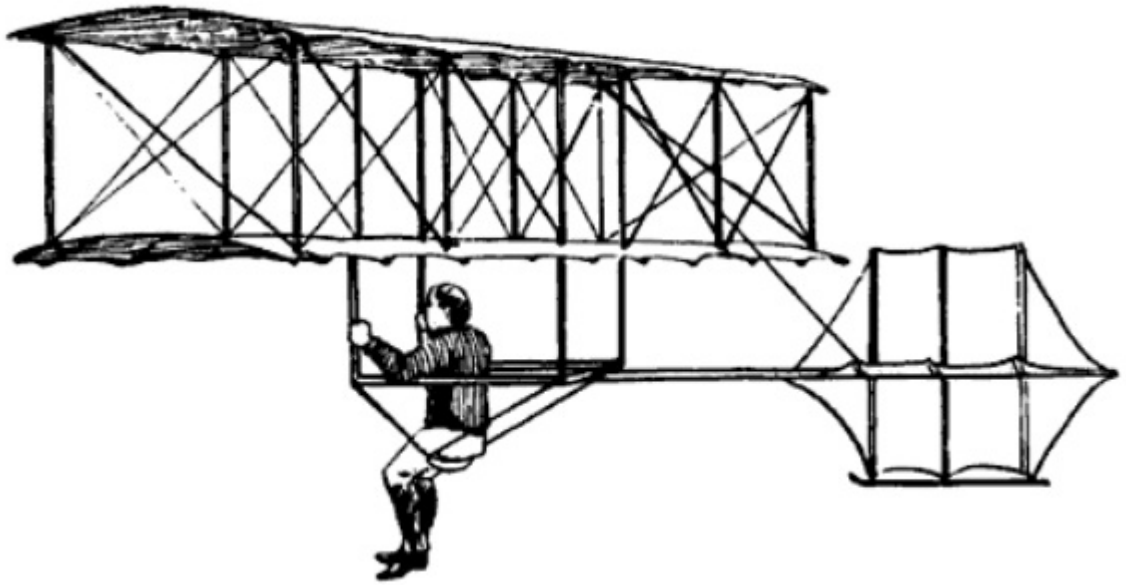
- Although, he was a civil engineer, he found interest in mechanical flight in about 1875.

- He complied every piece of aeronautical information he found, and managed to publish a book, entitled **Progress in Flying Machine**.

- This book contained all the previous important works

- **Wright brothers** thoroughly read this book, and eventually made friendship with Chanute, which lasted till the death of Chanute in 1910

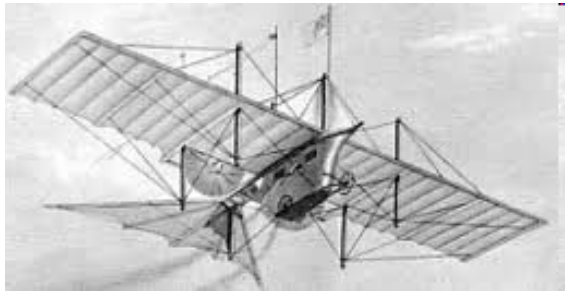
- Chanute succeeded in making a bi-plane glider which influenced Wright brothers for their success later on



Chanute's glider Source: Introduction to flight by J D Anderson

William Samuel Henson (1812-1888)

- William Samuel Henson was contemporary of George Cayley
- Henson published a design for a fixed wing airplane powered by steam engine driving two propellers; aerial steam carriage
- In reality this steam carriage was never built but encouraged the subsequent workers

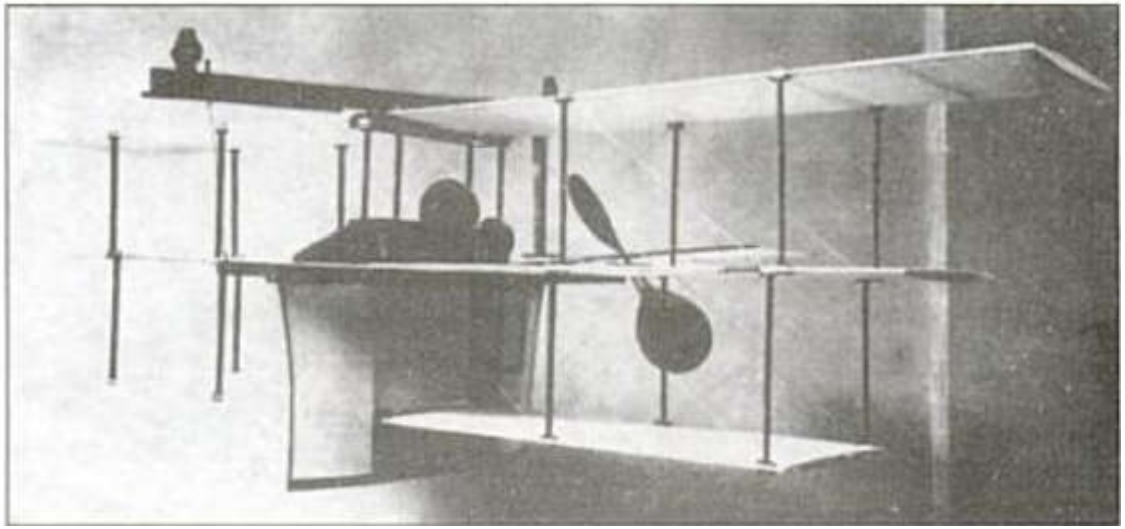


Source: web

John Stringfellow (1799 –1883)

- He built several small steam engines and attempted to power some monoplanes off the ground. He was close but unsuccessful.

Stringfellow's model triplane

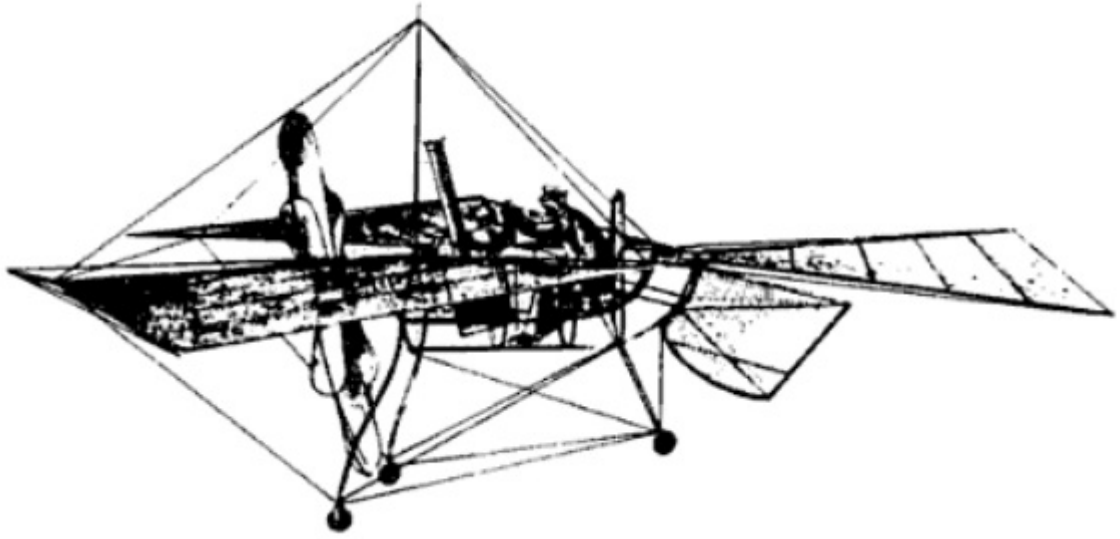


Source: Introduction to flight by J D Anderson

Felix Du Temple

- The French naval officer and engineer, Felix Du Temple flew a powered airplane.

- However, his powered airplane actually hopped off the ground in 1857-1858.

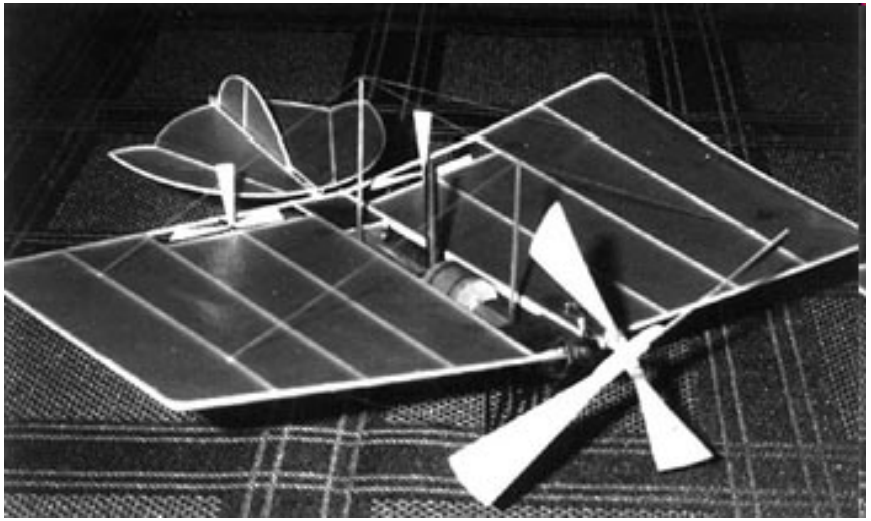


First airplane to make powered but assisted takeoff

Source: Introduction to flight by J D Anderson

Alexander F. Mozhaiski (Russian)

- In 1884, Alexander F. Mozhaiski designed an airplane which was powered by steam engine



Source: web

Model of Mozhaisky monoplane of 1884 by Tim Hayward-Brown

Samuel Pierpont Langley (1834-1906)

- He was a pre-Wright aeronautical engineer in USA
- He was not having any formal education beyond high school; but his interest took him to be a mathematics professor
- He built nearly 100 different types of rubber-band-powered model airplanes
- However, his effort in making a piloted powered airplane went in vein, although he attempted twice

Criteria for powered flight

- However, all these powered airplane discussed did not follow the criteria for powered flight

- C. H. Gibbs-Smith in his book states the following criteria to judge a successful powered flight

In order to quantify for having made a simple powered and sustained flight, a conventional airplane should have sustained itself freely in a horizontal or rising flight path –without loss of airspeed –beyond a point where it could be influenced by any momentum built up before it left the ground: otherwise its performance can only be rated as a power leap. Moreover, it must be shown that the machine can be kept in satisfactory equilibrium.

Finally Wright Brothers succeeded in making a powered flight

Wilbur Wright (1867-1912)

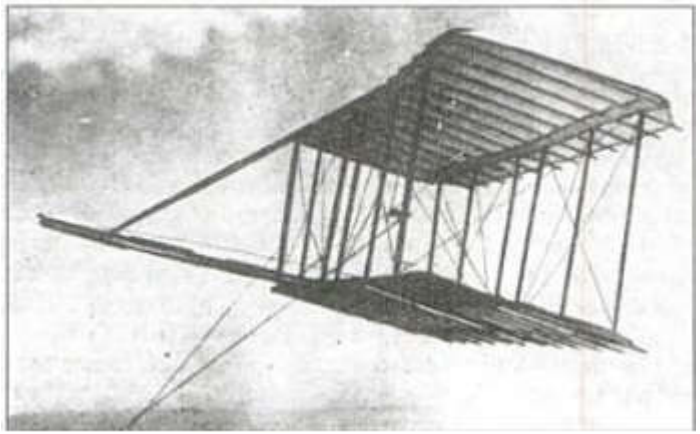
Orville Wright (1871-1948)

Source: world wide web

- They were the inventors of the first practical airplane

- They had a bicycle sales and repair shop in Dayton
- Their interest made them possible to come up with an airplane
- Their first aircraft was a biplane kite with a wing span of 1.5m; this was designed to test wing twist or wing warping to control airplane rolling motion
- They went on testing this idea in a biplane glider 1 with wing span 5 m at Kitty Hawk, North Carolina in 1900

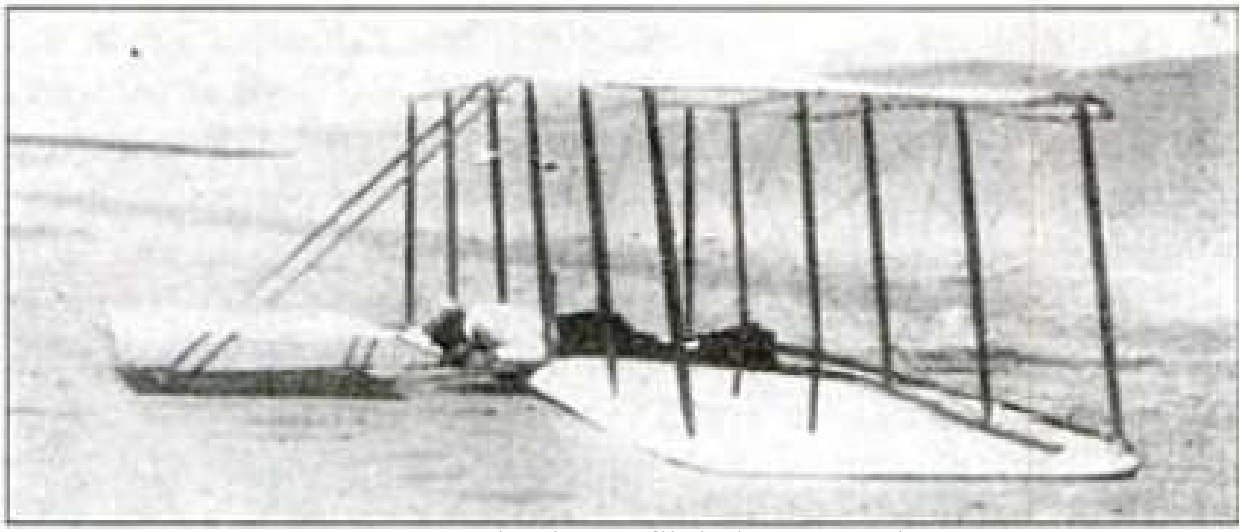
Wright brother's Glider 1 at Kitty Hawk, 1900



Source: Introduction to flight by J D Anderson

- Some amount of success led them to make one more glider with larger wing span of 7 m and with an elevator at the front part of the wing

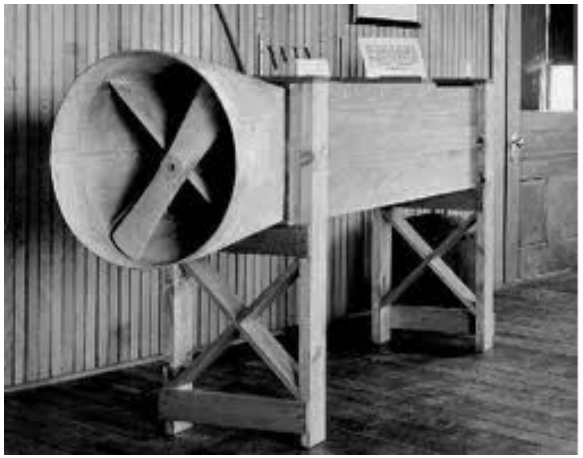
Wright brother's Glider 2 at Kill Devil Hills, 1901



Source: Introduction to flight by J D Anderson

- Forward elevator was put to protect them from fatal nosedive that killed Lilienthal

- They were not much satisfied with their flight test results
- They were using earlier aerodynamic data to test their machine performances
- They thought that data may be erroneous and they went to make their own wind tunnel to test airfoils

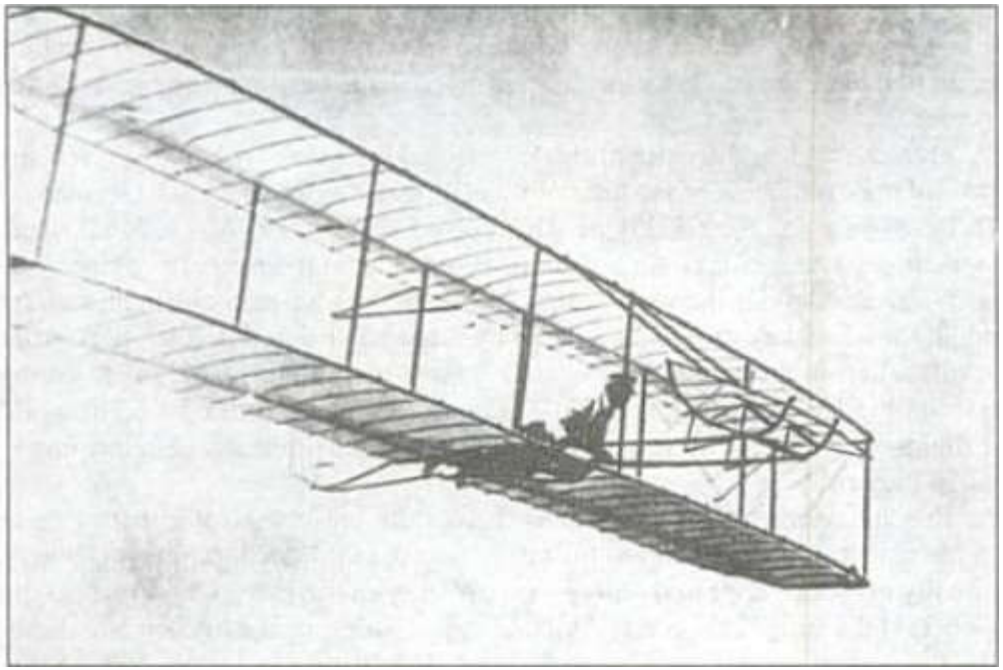


Source: web

- Using their own force balance, they could accurately measure lift and drag force

- Finally they came up with third glider with a vertical rudder behind the wing

Wright brother's Glider 3 in 1902



Source: Introduction to flight by J D Anderson

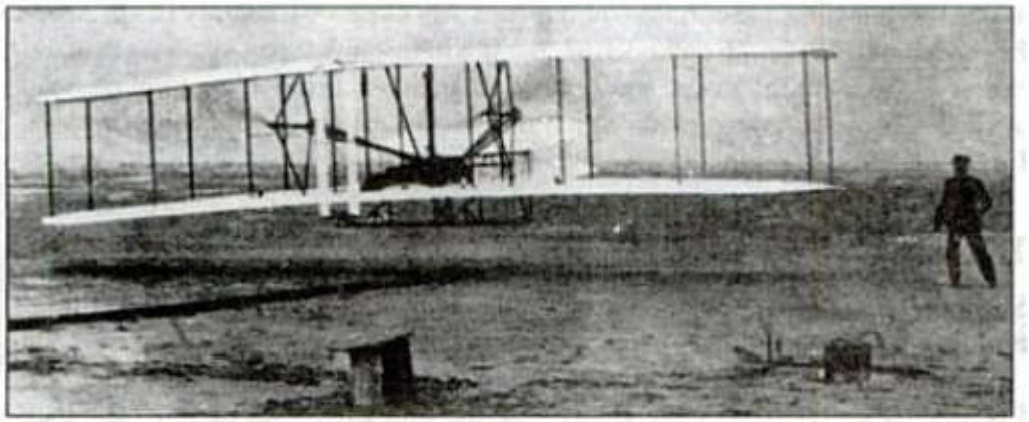
❖ These modifications finally led them to make a successful glider

Finally successful powered flight

- With their success in glider flight, powered flight is their next target
- But they found no commercial suitable engine
- They finally built their own 12 hp gasoline-fueled engine with 91 kg weight, and the suitable propeller, as well
- With these accomplishments, they came up with their **Wright Flyer I**, which closely resemble their glider 3 but with a wing span of 12 m

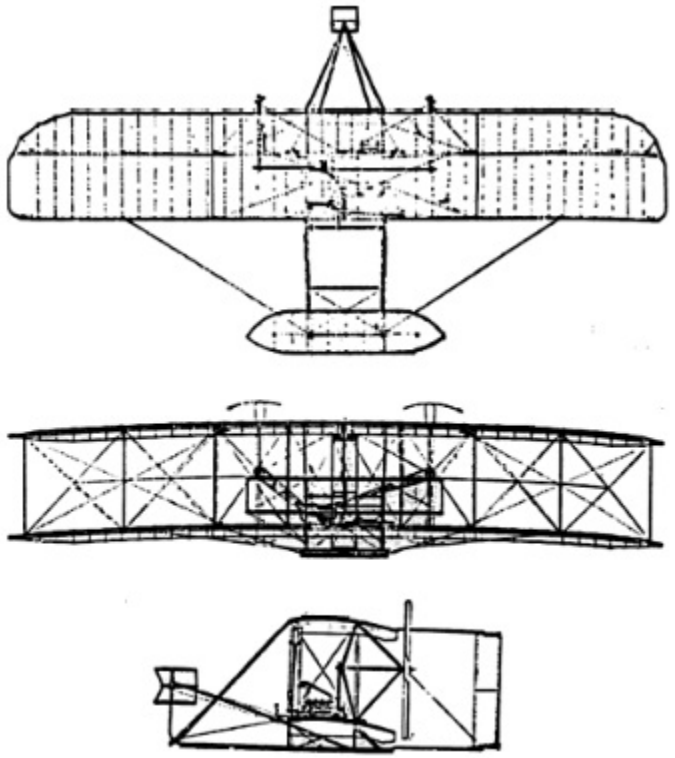
Wright Flyer I

First heavier than air flight in history: Wright Flyer I



Source: Introduction to flight by J D Anderson

All three views of Wright Flyer I



- Finally the Wright Flyer I was flown on 17 Dec, 1903
- And a branch of aeronautical engineering was born

Source: Introduction to flight by J D Anderson

Table 1.2 Selected specifications of the 1903 Wright *Flyer I*.

Item	Specification
Primary function	First heavier-than-air flying machine
Manufacturer	Orville and Wilbur Wright, Dayton, Ohio
First flight	17 December 1903
Crew	One pilot
Powerplant	In-line, 4-cylinder, water-cooled piston engine
Engine power	12 hp (8.9 kW) at 1020 rpm
Fuel capacity	0.2 gal (0.65 l) of gasoline
Propellers	Two 2-bladed, 8 ft (2.4 m) diameter
Empty weight	605 lb (274 kg)
Gross weight	750 lb (341 kg)
Length	21 ft 1 in (6.43 m)
Height	9 ft 4 in (2.8 m)
Wingspan	40 ft 4 in (12.3 m)
Wing area	510 ft^2 (47.4 m^2) (upper and lower wings)
Wing loading	1.47 lb/ft^2 (7.18 kg_f/m^2)
Maximum speed	30 mph (48.3 km/h)
Stall speed	22 mph (35 km/h)
Ceiling	30 ft (9.0 m)

Source: Into. Aero. Engg.
By Stephen Corda

- Subsequently, they went on making several flyers improving at every step
- For example, Wight flyer II, III
- Finally the world caught the idea of making different airplanes with the concept of faster and higher

- The monoplane in which Bleriot crossed the English channel

Source: fundamentals of flight by R S Shevell

- The French Spad, a leading World War I fighter

Source: fundamentals of flight by R S Shevell

After world war I

- End of war terminated the high level of military plane development
- Many company disappeared
- However, some companies started manufacturing commercial transport aircraft
- For example, in 1920 the British Handley page company built one 12 passenger airplane powered by twine-engine

Some of the transport aircrafts

- The Handley-Page W8b 12 passenger transport entered service in 1922

Source: fundamentals of flight by R S Shevell

- Similarly, other European nations also started making transport airplanes

- **Junkers F-13** was one of these aircrafts, which could carry four passengers; it was a monoplane powered by single engine

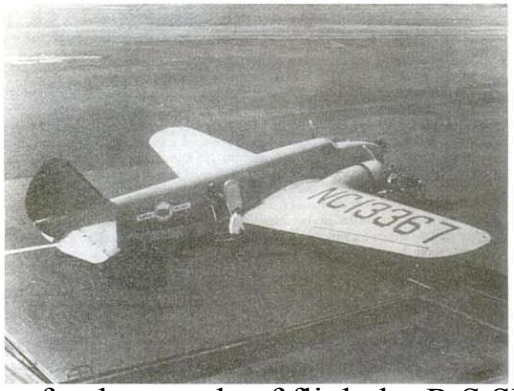
- Later model of this company was **Ju52** which could carry 17 passengers

Source: fundamentals of flight by R S Shevell

- In 1924, Antony Fokker ventured a series of aircrafts in Holland; FVIIb-3m was one of the models

- Boing came into market in 1928 with a model **80A**, which could carry 18 passengers; this plane was powered by three Pratt & Whitney Hornet 525 hp engines, and it was a biplane

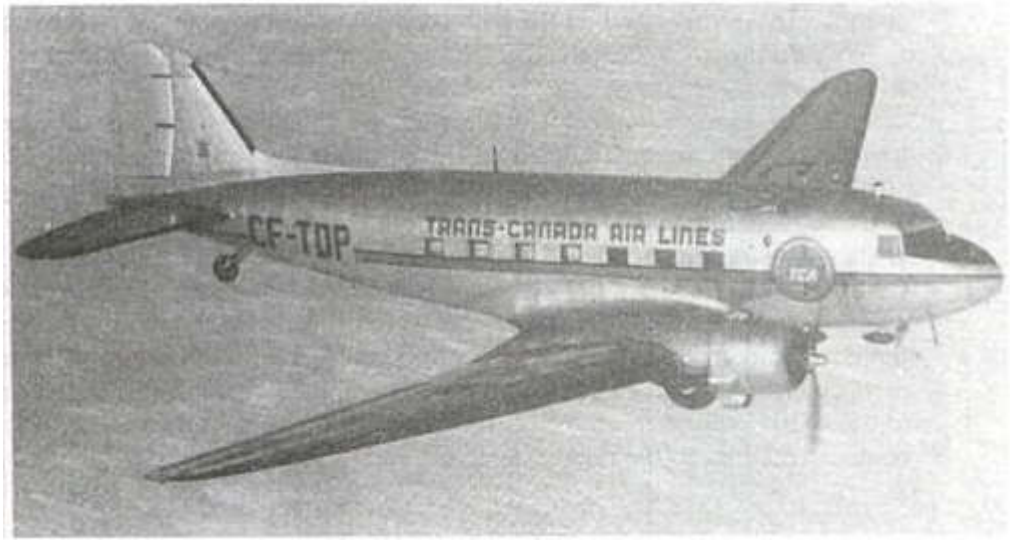
- In 1934, Boing introduced one more model, **Boing 247**; it was a 10-passengers airplane made of all metal and powered by twine engine with retractable landing gear; its speed was 155mph compared to previous aircrafts which could attain 125 mph around



Source: fundamentals of flight by R S Shevell

- Douglas Aircraft Co. came with a model **DC-2**, speed of which was 170 mph

- Similarly**, DC-3** with speed 180 mph was also introduced; this aircraft lasted for long time;



Source: fundamentals of flight by R S Shevell

- Even larger model was **DC-4**, which was introduced in 1942; it could carry 44 passengers. **DC-4** which was powered by Pratt & Whitney engine of **1450 hp** could cruise at 230 mph

Source: fundamentals of flight by R S Shevell

- **Developments also took place for military aircrafts i.e. fighters and bombers;**

- In this regard, Boing **F4B-4, P26A**, Lockheed **P38** fighters and the Grumman **F3F, F4F** were notable

Earlier fighter aircrafts

Boing P26 in 1934

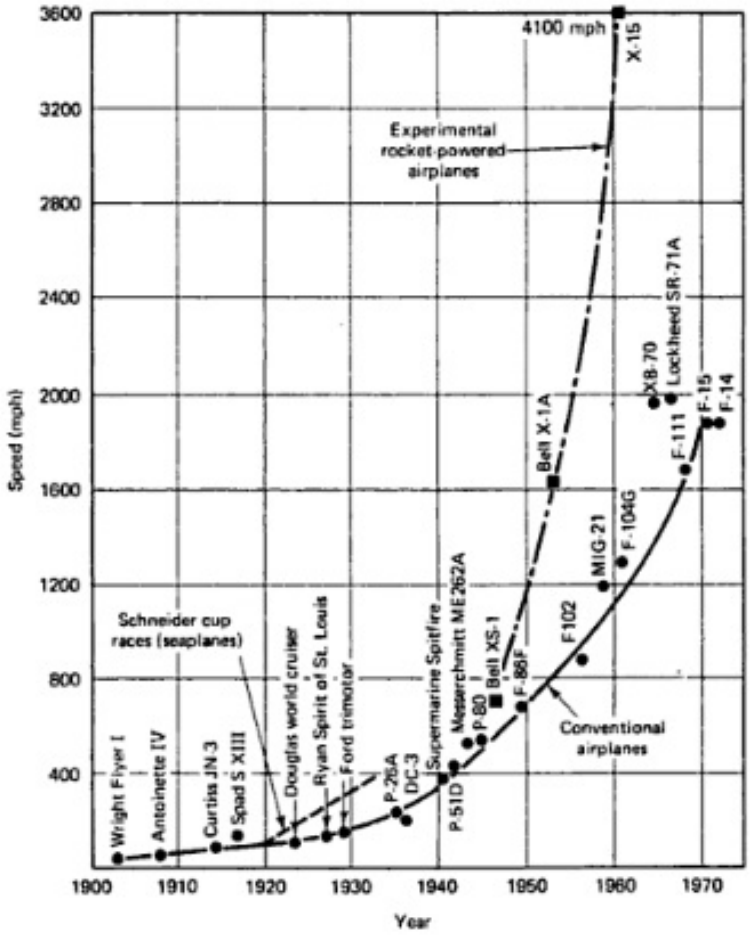
Lockheed P 38 in 1940

Source: fundamentals of flight by R S Shevell

- **After world war II, the developments which happened in the case of fighter and bombers were applied for passenger aircraft**

- Results were faster and bigger passenger aircrafts; for example **DC-8**, **Boing 707** and so on

- The following plot summarizes this



Source: fundamentals of flight by R S Shevell

History of modern aviation in India

- Indian aviation history started in the year 1912, as the route Karachi to Delhi was operationalized on this date
- During World War II, HAL Bangalore started assembling some aircrafts of US origin under the supervision of **Dr. Vishnu Madav Ghatage**
- HT-2 was first model plane which was maiden flown in 1951

Military aircraft in India

- HT-2

- The success of HT-2 resulted in tremendous confidence among aircraft designer in India

- Subsequently, HAL came with Hindustan Jet Trainer (HJT-16), Kiran subsonic jet trainer that first flew in 1964 and inducted in IAF in 1973

- KIRAN

Source:http://www.bharat-rakshak.com/IAF/Images/Current/Trainers/Kiran2/

- With advancement made in the field of aerospace engineering, an aircraft with state of the art features became essential

- The initiative ultimately resulted in making an Intermediate Jet Trainer (IJT), which was first flown on March 7, 2003

- The striking features of this trainer is good visibility; the rear cockpit is raised a bit for good visibility and look over for the instructor

- It also has large glass cockpits with large side opening canopy

- It was powered by a single highly reliable Larzac 04-20 engine, a twin spool tutbofan with 2 stage LP and 4 stage HP axial compressors

Intermediate Jet Trainer

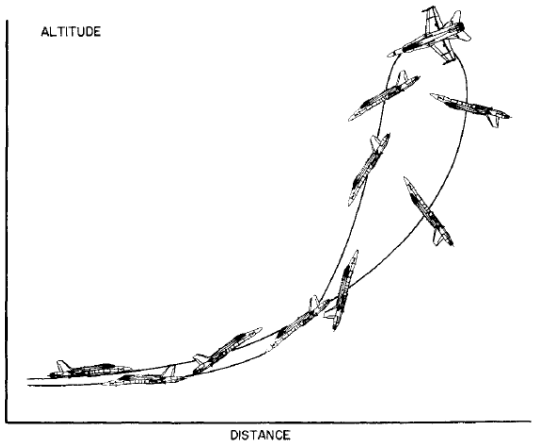
Source: web images

- This success was due to the experience gained during building India's first **Light Combat Aircraft (LCA)**

- The light combat program was initiated in 1983 to replace the old **MIG-21** aircraft

- **Aeronautical Development Agency (ADA)** was established to manage Light Combat Aircraft program with the following visions
  - Making of **fly-by-wire** (FBW)
  - Developing **Flight Control System** (FCS)
  - Multi-mode **pulse-doppler-radar**
  - Building after burning **turbofan engine**
- The tailless, compound-delta plan form is for smallness and lightweight

- It was designed to make alpha maneuvering



Source: http://arc.aiaa.org/doi/pdf/10.2514/3.21104

- With weight 9530 kg (take-off), its maximum speed is of Mach 1.8

- It is under production for IAF; it has been made 1000 test flights as on 22 January, 2009

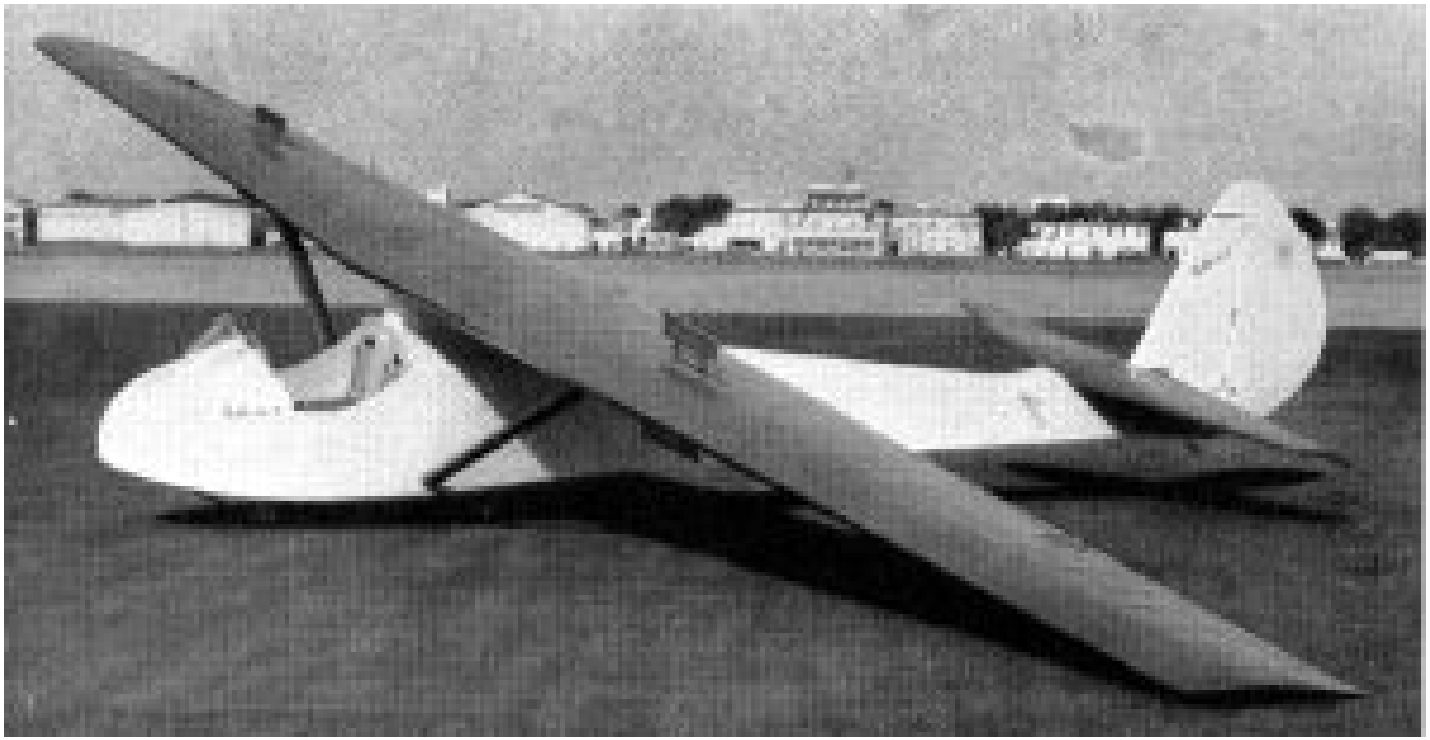
Tejas

Source: wiki

Civil Indian aircrafts

- Rohini-I
  - It is a two seat side-by-side training sailplane first flown in 1961
  - It was a high-wing monoplane of wooden construction and a top speed of 174 kmp
  - This machine, a side by side two seater was designed by Mr S Ramamithram
  - The initial flight demonstration took at Delhi flying club

A pictorial view of Rohini



http://www.probertencyclopaedia.com/cgi-bin/res.pl?keyword=Rohini-I&offset=0

- There are now several aviation sectors in India
- For example, **National Aerospace Laboratories (NAL)**, **Hindustan Aeronautical Laboratories (HAL)**
- Private sector, like **TAAL** also involved in making civil aircraft

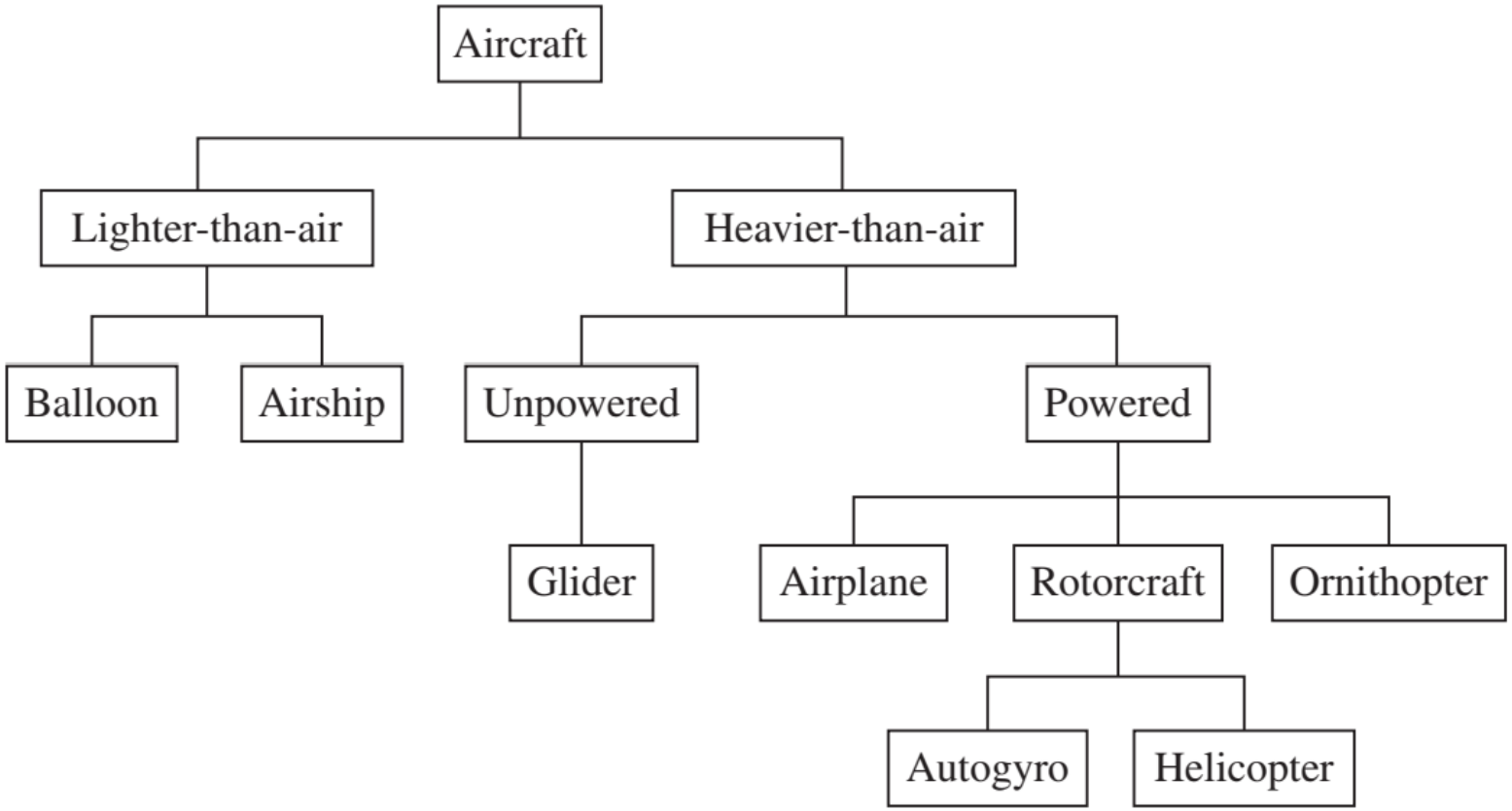
Hansa

- It is a **NAL** product for sports and hobby flying
- It is India's first all **composite aircraft**
- It has excellent visibility, pleasing control harmony with an reliable engine called Rotax 914F3
- The lightening protection and night flying capability adds on its exceptional features

Saras

- It is light transport aircraft designed by **NAL**
- Its maiden flight was in Bangalore on 29 May, 2004
- Empty weight of the aircraft was 4125 kg
- Its tail and wing includes composite structure
- It is powered by 850hp PT6A-66 Pratt & Whitney engine

Classification of Aircrafts



Source: Into. Aero. Engg.
By Stephen Corda