Aerospace Engineering

X-15 flew at hypersonic speeds and contributed research to the manned flight programs.

All-weather attack aircraft with variable-swept wing Tornado; Max speed is Mach 1.3.

Air-launched suborbital spaceplane SpaceShip Two carried beneath White Night Two.

Cessna 172 civilian aircraft; Cruise speed: approximately 120 knots.

Boeing 747 commercial aircraft; Cruise speed: Mach 0.85 (570 mph).

Space Shuttle: retired low Earth orbit spacecraft; Velocity required to reach low Earth orbit: 17,500 mph (7.8 km/s).
## Flow Regimes

<table>
<thead>
<tr>
<th>Regime</th>
<th>Mach ($M_\infty$)</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsonic</td>
<td>$&lt; 0.8$</td>
<td>Subsonic flow over slender bodies; Freestream values close to $M = 1$ can cause supersonic regions of flow over an expanding aerodynamic body</td>
</tr>
<tr>
<td>Transonic</td>
<td>0.8-1.2</td>
<td>“pockets of supersonic flow over both the top and bottom surfaces of the airfoil, terminated by weak shock waves;” For values above Mach 1 a bow shock forms, behind which the flow becomes subsonic, and subsequently low supersonic; Weak shock waves are usually generated at the trailing edge in a “fishtail” pattern</td>
</tr>
<tr>
<td>Supersonic</td>
<td>$&gt; 1.0$ everywhere</td>
<td>Characterized by the presence of shockwaves “across which the flow properties and streamlines change discontinuously.”</td>
</tr>
<tr>
<td>Hypersonic</td>
<td>$&gt; 5.0$</td>
<td>“When $M_\infty$ becomes large enough such that viscous interaction and/or chemically reacting effects begin to dominate the flow, the flow field is called hypersonic.”</td>
</tr>
</tbody>
</table>
Flow Regimes - continued
History of Flight

Leonardo Da Vinci (1452 – 1519)

-The original Renaissance Man: painter, inventor, writer
-Sketched several ‘Aerospace’ vehicle concepts
History of Flight

Otto von Lilienthal (1848 – 1896)

- Collected Aerodynamic Data
- Emphasized that curvature of a bird wing is key to flight
- Made >2000 glider flights between 1891 and 1896
- Died in a glider accident in 1896
History of Flight

Wilbur Wright (1867 – 1912)
Orville Wright (1871 – 1948)

Wilbur was born in Indiana and Orville was born in Ohio; They grew up in Dayton, Ohio
Designed the Wright Flyer in their bicycle shop; Wind tunnel: Collected data on thousands of glider fights
December 17, 1903 at 10:35AM: First manned flight by Orville– Kitty Hawk, North Carolina; 12 sec, 120 ft.
Wright Flyer: 12 hp motor; warping wing (ailerons); 2 airscrews; rudder; elevator in front to protect from a fatal nose dive; launching rail
History of Flight

Bell X-1

- First supersonic flight 14 October 1947 by Capt. Charles Yeager
- Designed for conventional takeoff
- Launched by B-29 or B-50 bomber
- At 20,000ft

Length 31.00 ft (9.45 m)
Wingspan 28.00 ft (8.53 m)
Height 10.85 ft (3.31 m)
Wing Area 130.0 ft² (12.01 m²)
Max Takeoff 13,400 lb (6,080 kg)
Video Clip 1: Early Flight Attempts

http://www.youtube.com/watch?v=iMhdksPFhCM
https://www.youtube.com/watch?v=xAtG3UAIS-4
http://www.youtube.com/watch?v=CVFEDccid_A&feature=related
Video Clip 2b: Blue Angels

http://www.smithsonianchannel.com/sc/web/series/1003002/mighty-planes/3398548/blue-angels
http://www.blueangels.navy.mil/
A Few Concepts

Ref: http://commons.wikimedia.org/wiki/File:Yaw_Axis_Corrected.svg
Angle of Incidence: The angle between the aircraft longitudinal axis and the airfoil chord line. The AOI ($\alpha_i$) is usually fixed at $6^\circ$ in most civilian aircraft, and is used to maintain a level fuselage while cruising.

Angle of Attack: Usually, the angle between the airfoil chord line and the oncoming free stream flow.
Dihedral wing configuration is inherently more stable during conditions of uncompensated lift, which produce a sideslip (nose direction opposed to the roll direction); Dipped wing is yawed into oncoming airflow producing a greater angle of attack for the more forward wing; Larger aircraft usually employ a dihedral configuration since the center of gravity is above the wing, which creates less roll stability.

Anhedral wing configuration is the opposite wherein the wing tips are below the root.
Aerospace Engineering = Aero + Space

**Aero:**
- Inside the atmosphere
  - Airplanes
  - Helicopters
  - Sail planes
  - Gliders
  - Blimps
  - Ultra-lights
  - Parachutes

**Space:**
- Outside the atmosphere
  - Rockets
  - Space Shuttles
  - Space Center (ISS)
  - Satellites
  - Space Probes
Disciplines in Aerospace Engineering

- **Aerodynamics**
  - Motion of fluids, lift, drag
- **Propulsion**
  - Thrust generation, engines
- **Performance**
  - How fast, how long, how high, weight, payload
- **Acoustics**
  - Noise levels
- **Stability and Control**
  - Pilot inputs and aircraft responses
X-51A Subsystems Packaging

Engine Subsystems
(Packaged Wet in JP-7)
- Engine Fuel Pump
- Ethylene (Engine Start)
- Nitrogen (Fuel Pressurization)

Subsystems Bay
- GCU/MU/GPS
- FADEC
- Flight Test Instrumentation (FTI)

FTS, FTI and Control Systems
- Antennas
- Sensors
- Control Actuators

JP-7 Fuel
- Integral Tanks
- 271 lb

Fuel System
- Fuel Pump

Batteries
- Engine Systems
- Actuators
- Avionics and FTI
- Flight Termination System (Separate)

Source: http://www.techeblog.com/index.php/tech-gadget/futuristic-mach-6-x-51a-waverider-scramjet-will-take-you-from-london-to-ny-in-1-hour

Source: http://imageshack.us/photo/my-images/266/x51coolant3.jpg/sr=1

http://www.youtube.com/watch?v=E4gxmHiumDo
Figure 1.30 Typical flight velocities over the years.
Figure 1.31 Typical flight altitudes over the years.