AE 451 Aeronautical Engineering Design I
The philosophy of airplane design

Prof. Dr. Serkan Özgen
Dept. Aerospace Engineering
October 2017
The philosophy of airplane design

• Airplane design is the intellectual engineering process of creating a flying machine to:
  • Certain specifications and requirements established by potential users (almost all commercial and military airplanes).
  • Pioneer innovative ideas and technology (almost all experimental aircraft).
• Design process requires intellectual activity and also good intuition and experience.
Military Aircraft (F-16, Lightweight Fighter Competition)
Civilian Aircraft (Airbus A-380)
Experimental aircraft (X-1 and X-15)
Phases of aircraft design

- Design process starts when an airplane first materializes in peoples’ minds, ends when the finished product rolls out of manufacturer’s door (when the last aircraft is withdrawn from use).

- Three distinct phases of design:
  - Conceptual design
  - Preliminary design
  - Detail design
Design process – YF-16 prototype

• Daytime fighter
• Weight: 12250 kg
• Engine power: 10885 kg
Design process – F-16C Block 50

• Multirole fighter
• Weight: 19200 kg
• Engine power: 13158 kg
Design process – even beyond; F-16C Block 50+ or Block 60

• Attack optimised fighter
• Weight: 20884 kg
• Engine power: 14755 kg
• Conformal fuel tanks, dorsal avionics pod
Design process

• Variations in characteristics necessiated:
  • Redesign of the engine inlet for greater mass flow
  • Bigger and stronger landing gears
  • Structural reinforcement, etc.
Conceptual design

• A set of specifications for a **concrete goal** is given.
• Overall **size, shape, weight and performance** of the airplane are determined yielding the general layout.
• Shape and location of the wings, vertical and horizontal tails, engine type, size and placement.
Conceptual design

• Major drivers:
  • Aerodynamics
  • Propulsion
  • Flight performance

• Can the design meet the specifications?

• If yes, is it the best design meeting the specifications (is the design optimized)?
Conceptual design, Boeing X-32
Preliminary design

• **Minor changes** are made to the conceptual design.
• Involves **structural and control system analysis**, detailed **wind tunnel testing and CFD calculations**.
• In the end configuration is **frozen**.
• Decision for committing to manufacturing.
Preliminary design, Boeing X-32

<table>
<thead>
<tr>
<th>Boeing Joint Strike Fighter</th>
<th>Conventional Take Off and Landing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length:</td>
<td>47' 5&quot;</td>
</tr>
<tr>
<td>Wingspan:</td>
<td>36' 0&quot;</td>
</tr>
<tr>
<td>Height:</td>
<td>13' 4&quot;</td>
</tr>
</tbody>
</table>
Detail design

- Precise design of each individual structural element.
- The size, number and location of fasteners.
- Manufacturing tools are designed.
- Simulators for aircraft are developed.
- Production design!
Detail design, Boeing X-32
Detail design, manufacturing tools
Design phases

Fig. 2.3  Design phases: front wing spar.
The pivot points for conceptual design

• Pivot points are the aspects that anchor the conceptual design process.
• They allow different, more detailed thinking from each pivot point.
• Fixing the pivot points will create an intellectual framework for the design.
The pivot points for conceptual design

• Requirements,
• First estimate of the weight of the airplane,
• Critical performance parameters, 
  \( C_{L,max}, L/D, W/S, T/W \) (or \( P/W \))
• Configuration layout,
• Better weight estimate,
• Performance analysis, does the design meet the requirements?
• Optimization.