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# The philosophy of airplane design

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# 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.

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# Military Aircraft (F-16, Lightweight Fighter Competition)



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# Civilian Aircraft (Airbus A-380)



# Experimental aircraft (X-1 and X-15)



NASA Dryden Flight Research Center Photo Collection  
<http://www.dfrc.nasa.gov/gallery/photo/index.html>  
NASA Photo: EC72-3431 Date: 1947 Photo by: USAF photo by Lt. Robert A. Hoover

X-1 in flight



NASA Dryden Flight Research Center Photo Collection  
<http://www.dfrc.nasa.gov/gallery/photo/index.html>  
NASA Photo: EC67-1731 Date: May 8, 1967 Photo By: NASA

X-15A-2 in flight. First flight with dummy ramjet attached. Flt. 2-51-92, Pete Knight-pilot.

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# 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in peoples' minds, ends when the finished product rolls out of manufacturer's door (when the last aircraft is withdrawn from use).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



USAF Photograph



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# Design process – F-16C Block 50

- Multirole fighter
- Weight: 19200 kg
- Engine power: 13158 kg





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# Design process – even beyond; F-16C Block 60

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



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# Design process

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

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# Conceptual design

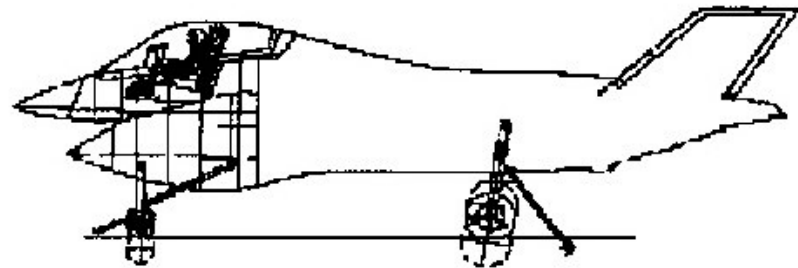
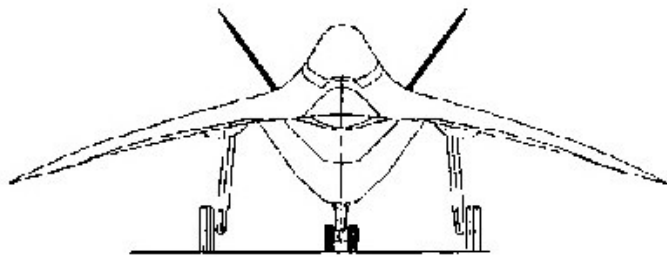
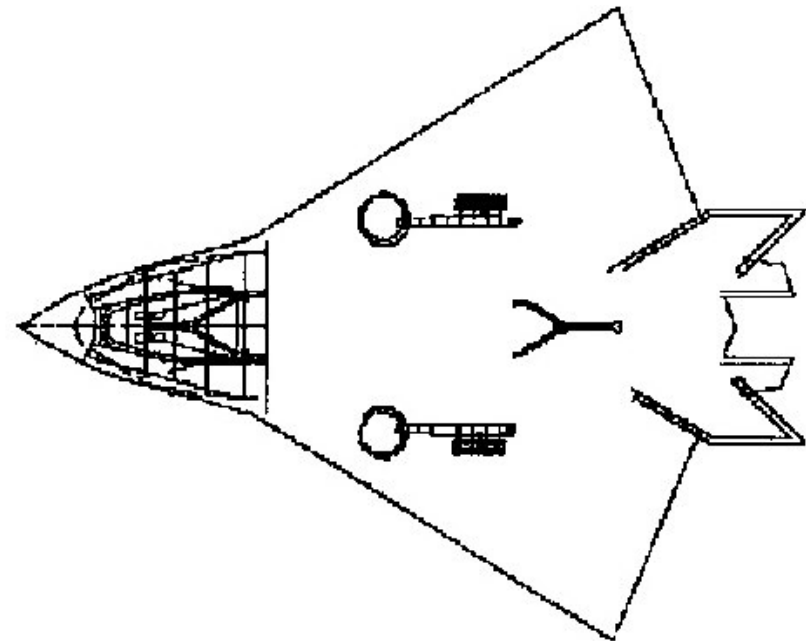
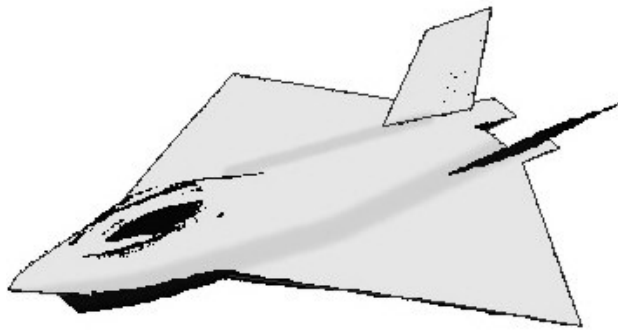
- A set of specifications for a concrete goal is given.
- Overall size, shape, weight and performance of the airplane are determined yielding the general layout.
- Shape and location of the wings, vertical and horizontal tails, engine type, size and placement.

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# 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



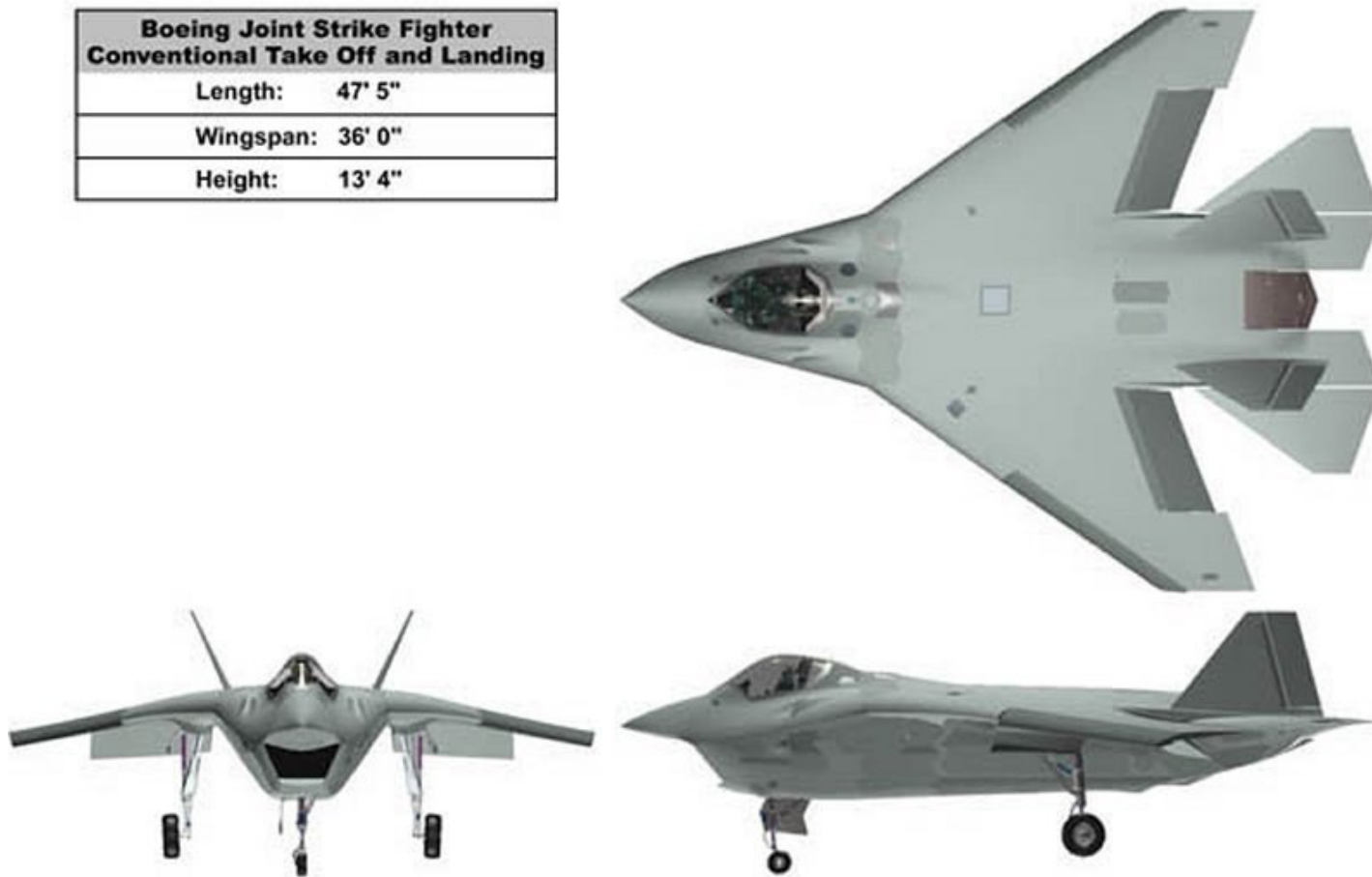
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# Preliminary design

- 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

Boeing Joint Strike Fighter Conventional Take Off and Landing	
Length:	47' 5"
Wingspan:	36' 0"
Height:	13' 4"





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# 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.

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# Detail design, Boeing X-32



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# Detail design, manufacturing tools



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# 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.

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# The pivot points for conceptual design

- Requirements,
- First estimate of the weight of the airplane
- Critical performance parameters  
 $C_{L,max}$ ,  $L/D$ ,  $W/S$ ,  $T/W$
- Configuration layout
- Better weight estimate
- Performance analysis, does the design meet the requirements?
- Optimization