# *Fixed Wing Aircraft Design I*

## *Classical Design Methods*

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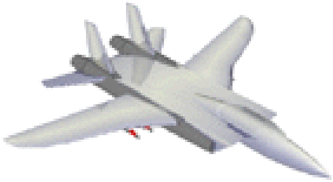


# What is Design?

"To plan out in systematic, usually graphic form" *(dictionary.com)*

"The intellectual engineering process of creating on paper a flying machine that either meets certain requirements and performance objectives, or explores new concepts, technologies and innovations" *(Anderson)*

"Creating the geometric description of a thing to be built" *(Raymer)*

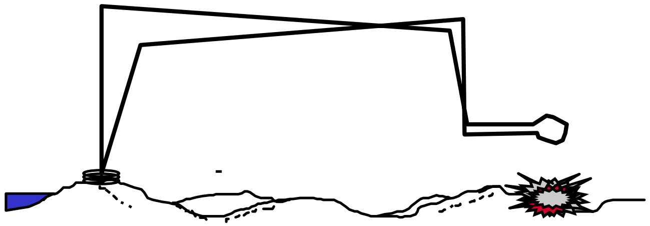
"Design is about creating something with a purpose" *(McGovern)*

# Characteristics of Design

Design can be characterized by the following *(Mattingly)*:

## Need

The design process is both started by and constrained by an identified need



## Non-Unique Solutions

Many legitimate solutions will exist for the same requirements. None can be identified as unique or optimum. The final accepted solution will always involve compromise and judgment

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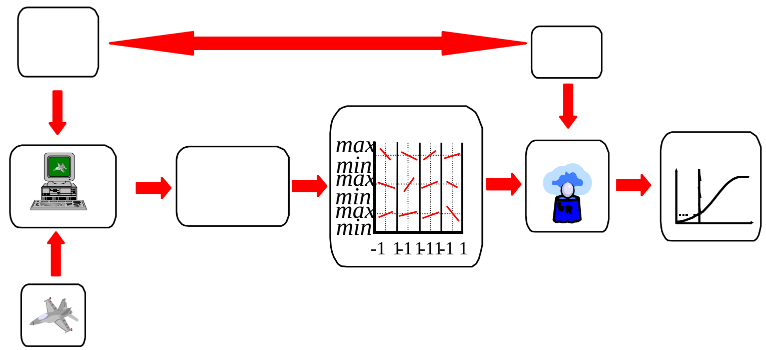
# Characteristics of Design

Design can be characterized by the following *(Mattingly)*:

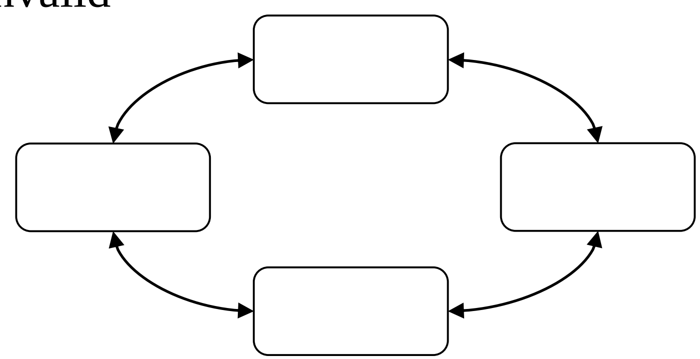
## Systematic

Because many solutions exist, it is necessary to use a systematic method to identify the “best” solution




## Iterative

The design process is iterative, and often requires returning to an earlier step if assumptions are found invalid



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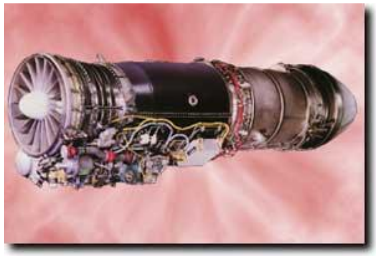
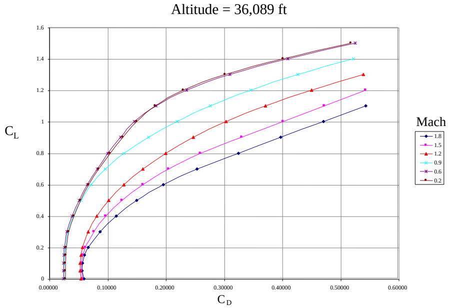
# Characteristics of Design

Design can be characterized by the following *(Mattingly)*:

## Interdisciplinary

By its very nature, the design process involves considerations and compromises between a variety of disciplines. Designers must have more than a basic understanding of all of the disciplines involved, and understand how they interact.






## Teamwork

Above all, the design of a complex system requires participation and disciplined communication by everyone involved.

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# Conceptual Design

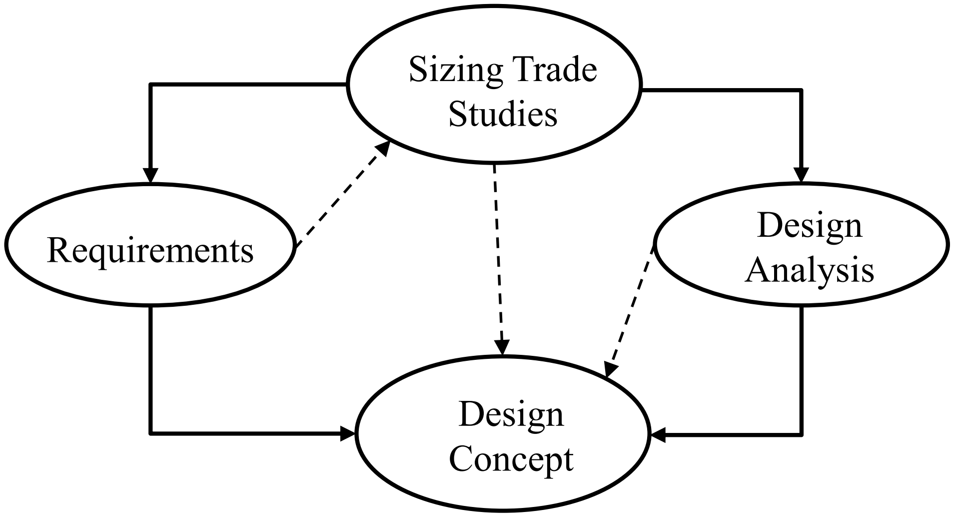
- Conceptual Design is the first step in the design process:
  - In response to a certain design goal (requirements or exploration)
  - Overall (fuzzy) shape, size, weight, performance of airplane configuration
  - Basic drivers are aerodynamics, propulsion, and performance
  - Some, but not much, consideration for stability/control, cost, no detailed design

Anderson's 7 Intellectual Pivot Points

Requirements
Weight-first estimate
Critical performance parameters:
- Clmax
- L/D
- T/W
- W/S

Configuration Layout
Better weight estimate
Performance analysis
Optimization

Raymer's Design Wheel





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# Preliminary Design

- Preliminary Design begins when major changes are over
  - Major design features locked in, only minor changes allowed
  - Substantial analyses begin to take place, including CFD and wind tunnel tests
  - By the end of this phase, the manufacturer will decide if the program is a "go" or "no-go"
  - Specialists in areas such as structures, landing gear, and control systems will start design/analysis
  - Testing begins in aerodynamics, propulsion, structures, and stability and control
  - Basic goal is to ready the design for the detailed design phase, also called "full stage development"

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# Detailed Design

- Detailed Design is when the actual pieces of the aircraft that are to be fabricated are designed
  - Precise and detailed decisions are made
  - All major disciplinary decisions have been locked in: propulsion, aerodynamics, etc.
  - Only very subtle details are left to make the design of a realistic vehicle capable of being manufactured
  - Production design occurs, in which specialists determine how the airplane will be fabricated, including subassemblies
  - Increased testing efforts. Actual aircraft structure is fabricated and tested. Control laws for the flight control system are tested on the “iron bird”, flight simulators are developed
  - This phase ends with the actual fabrication of the aircraft

# How the Phases Fit Together

Requirements

Conceptual Design

- Will it work?
- What does it look like?
- What requirements drive the design?
- What tradeoffs should be considered?
- What should it weigh and cost?

Preliminary Design

- Freeze the configuration
- Develop lofting
- Develop test and analytical base
- Design major items
- Develop actual cost estimate

Detailed Design

- Design the actual pieces to be built
- Design tooling and fabrication process
- Test major items-structure, landing gear, etc
- Finalize weight and performance estimates

# Traditional Development Process

## Advanced Design

Requirements

Conceptual Design

- Optimization
- Parametric
- 1st Level Analysis

- General Arrangement /Performance
- Representative Configurations
- General Internal Layout

Conceptual Baseline

Preliminary Baseline

- Sophisticated Analysis
- Problem Decomposition
- Multidisciplinary Optimization

## Project Design

- System Specifications
- Detailed Subsystems
- Internal Arrangements
- Process Design

Allocated Baseline

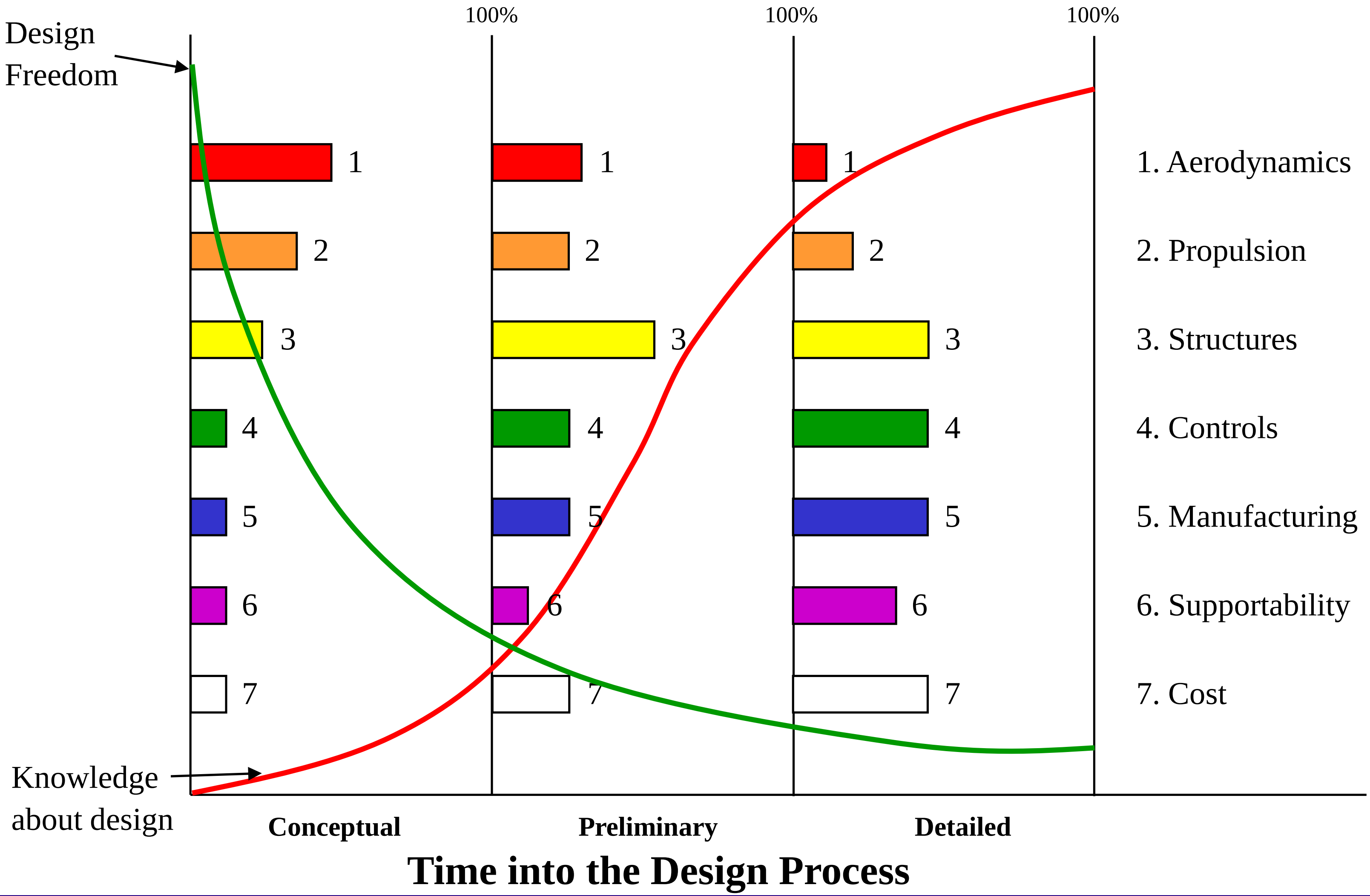
Detailed Design

Production Baseline

Production & Support

- Problems with not foreseeing design flaws
- Cannot rely on historical data
- Communication between manufacturing and engineers is poor

# Uneven Distribution of Knowledge Effects

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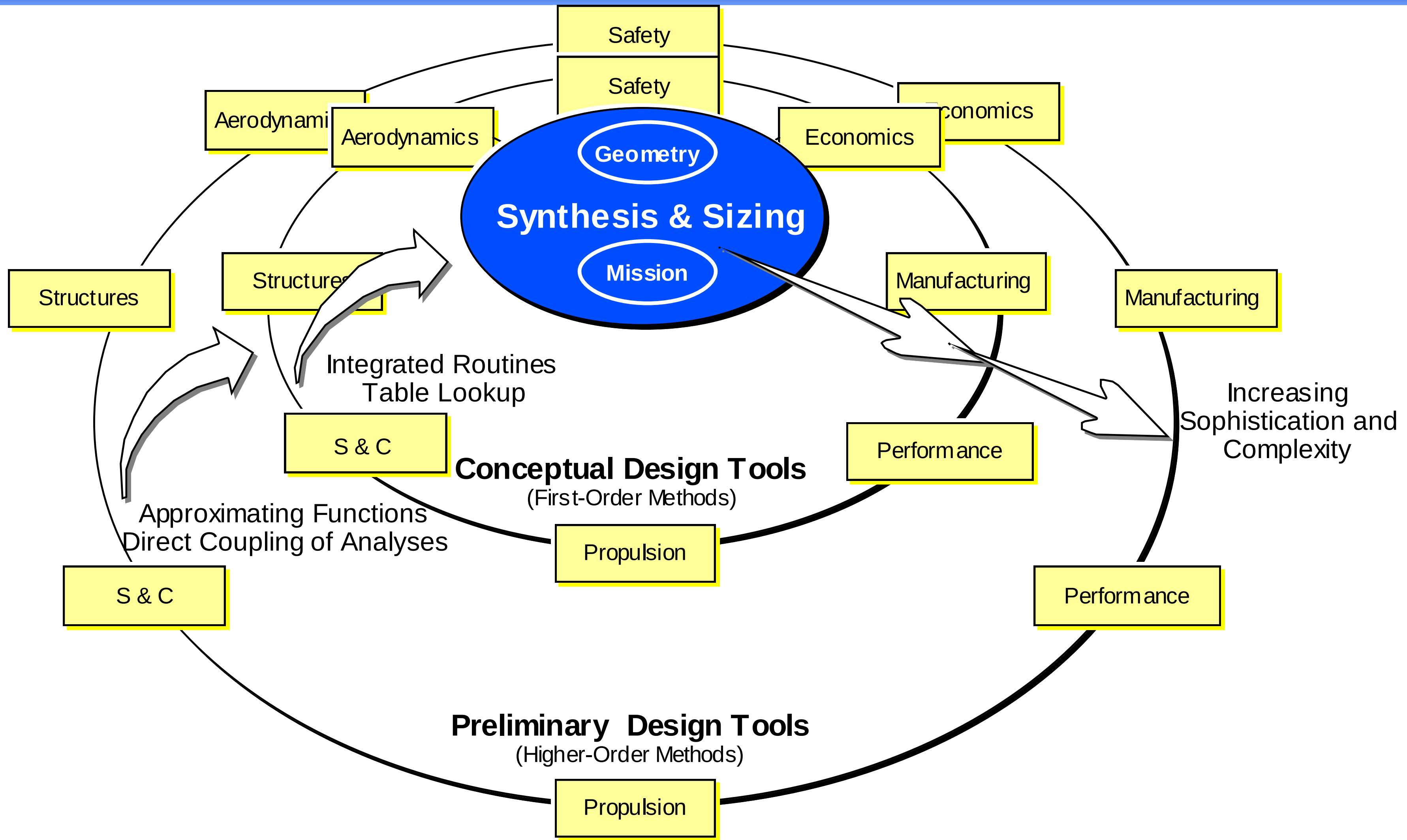
# Sizing & Synthesis, A Critical Need

## Creation of a Physics-Based M&S Environment

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# Back to Conceptual Design

*This class teaches* ***Classical Design*** *Methods for* ***Conceptual Design.*** *You will learn how to augment this process with the* ***Modern Design Methods*** *of* ***AE 6373: Advanced Design Methods I.***

Let’s now spend more time looking at the Conceptual Design Process...

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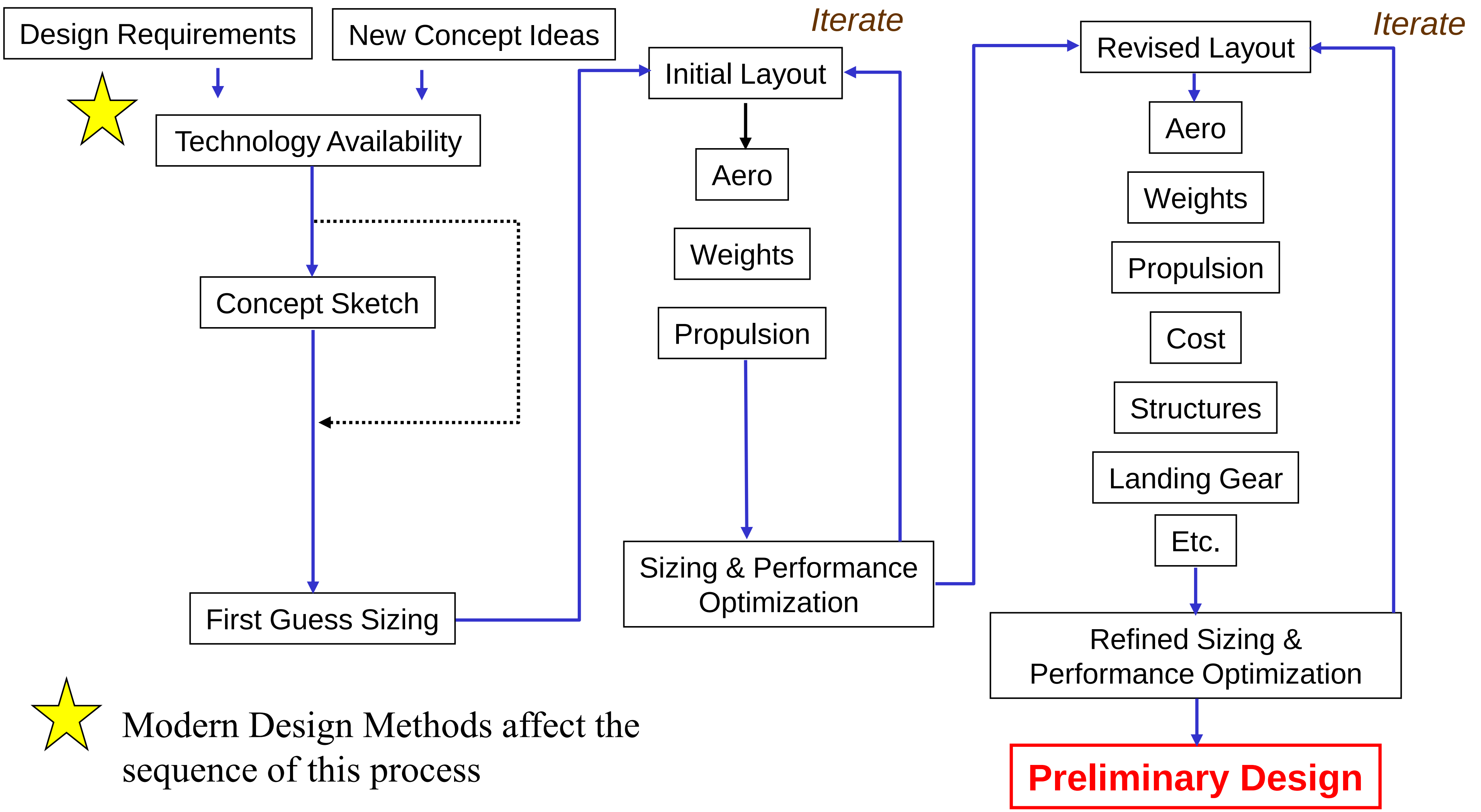
# Traditional Conceptual Design Process




Modern Design Methods affect the sequence of this process

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# Design Requirements

- The conceptual design process begins with a defined set of requirements
  - These requirements lay out specific constraints and design goals that the finished system must be capable of achieving
  - It is written by the customer, not the engineer

- These goals and constraints are often presented in a document called a Request for Proposal, or RFP
  - Payload type of payload
  - Range/loiter requirements
  - Cruise speed and altitude
  - Field length for takeoff/landing
  - Fuel reserves
  - Cost goals
  - Climb requirements
  - Maneuvering requirements
  - Mission profile
  - Certification base (experimental, FAR 23, FAR 25, military)

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# Request for Proposal (RFP)

- Establishing the Need
  - Often an RFP will start with a few paragraphs that establish the need for the new aircraft/system
    - This is usually the result of the customer's market analysis that defines a particular niche that the aircraft/system will fulfill
  - For a good design to result, it is imperative that the design team have a thorough understanding of the need for the aircraft/system
    - Design trades will have to be made, and how these trades affect the overall purpose of the aircraft/system is crucial

# FARs

- Federal Aviation Regulations (FARs)
  - The body of regulations established and administered by the FAA (Federal Aviation Administration) that governs civil aviation and aviation-related activities in the United States

- Every new aircraft will have a "certification base":
  - FAR 23 – normal, utility, aerobatic, commuter
  - FAR 25 – commuters
  - Military – has own set of requirements, referred to as Mil-Specs
  - Experimental – homebuilts

http://www.risingup.com/fars/ Searchable database of FARs
http://www.tisco.com/aviation/FAA/ Listed by parts

# Mission Profile

- The RFP will specify a mission profile or sizing mission for the aircraft/system
  - This is a series of chronological events or capabilities that the aircraft/system must complete
  - Even though the aircraft/system will be capable of accomplishing other tasks and goals, this primary mission profile will be the one that the aircraft is sized to
- Example:

Each of these segments is called a "phase"

1. Engine start and warm up
2. Taxi
3. Takeoff
4. Climb
5. Cruise 1500 nm
6. 30 minute loiter
7. Descent
8. Dash
9. Drop bombs
10. Dash out
11. Landing, taxi, shutdown

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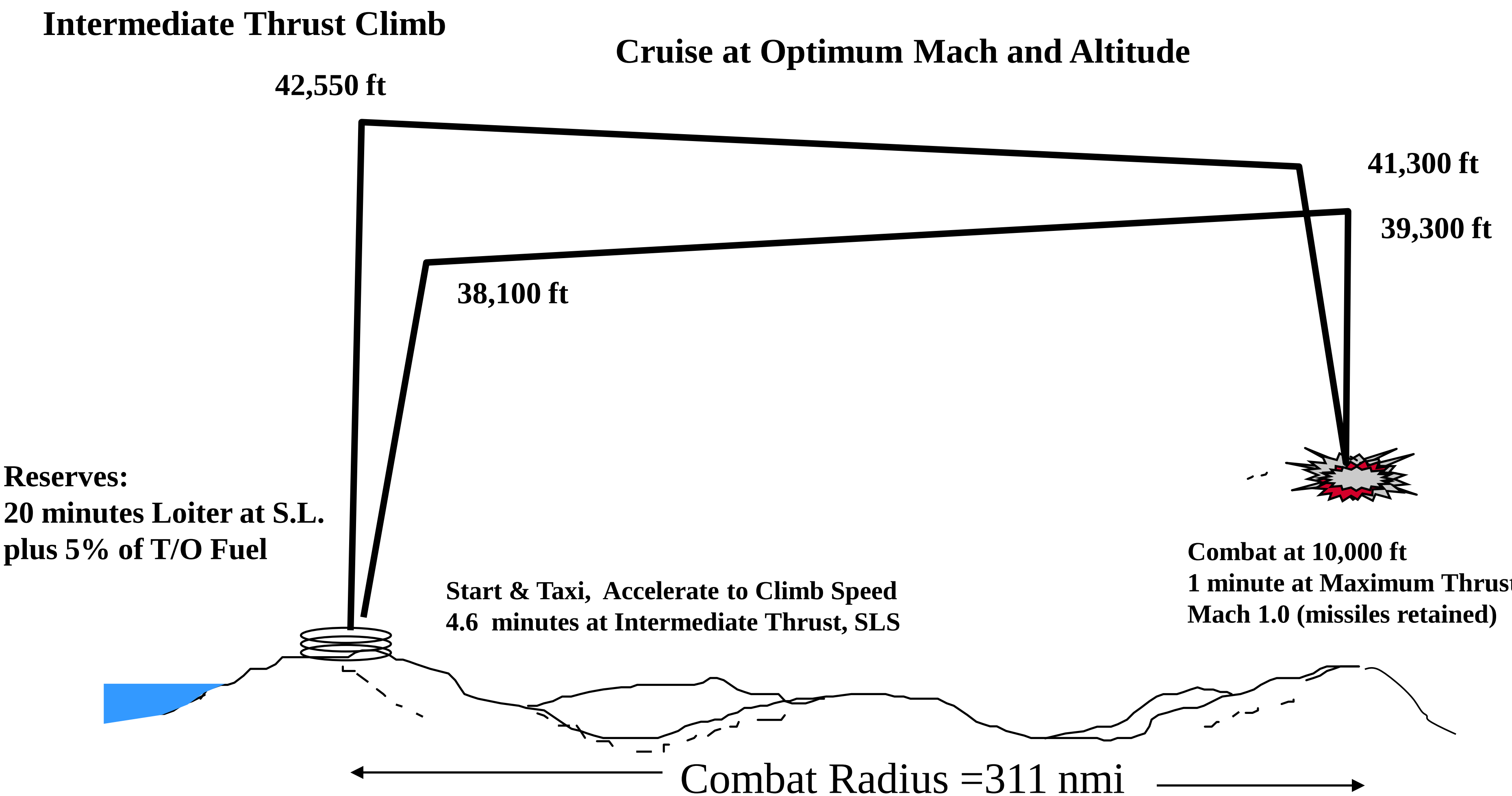
# Example Mission Profile: F-18

Another way to represent a mission profile is graphically

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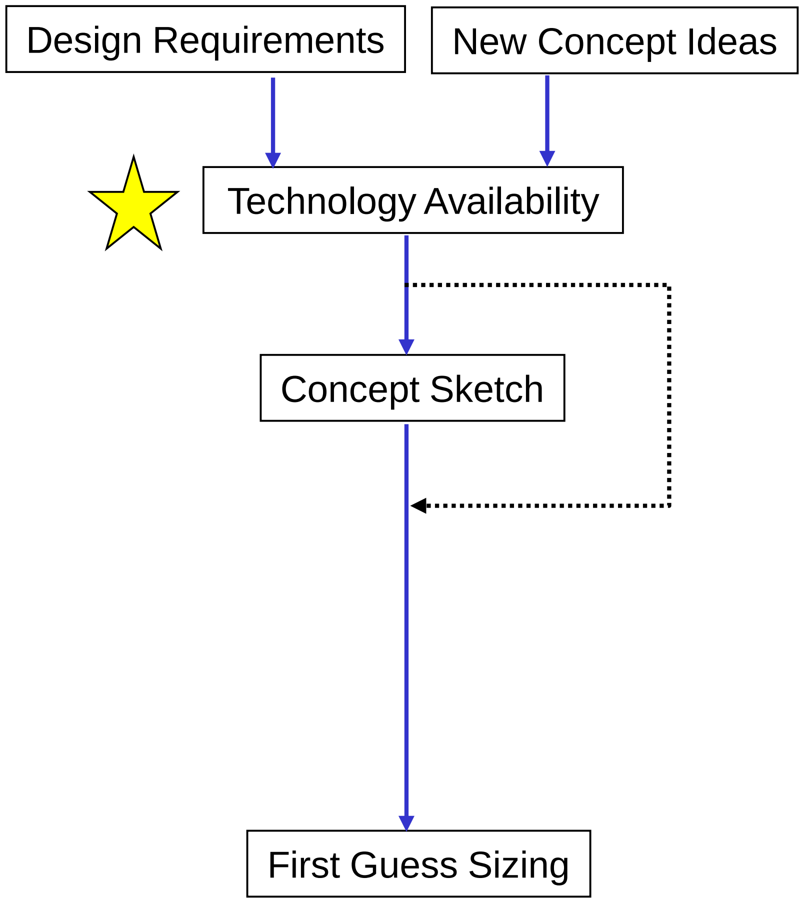
# New Concept Ideas




- After thoroughly reading and understanding the RFP, the next step is to consider new concept ideas
  - These are basically unique or unusual configurations that deserve exploration
- Sometimes, a design will be built solely on its merits as an "innovative idea" as opposed to a specific RFP or market niche
  - These designs usually occur primarily as research opportunities

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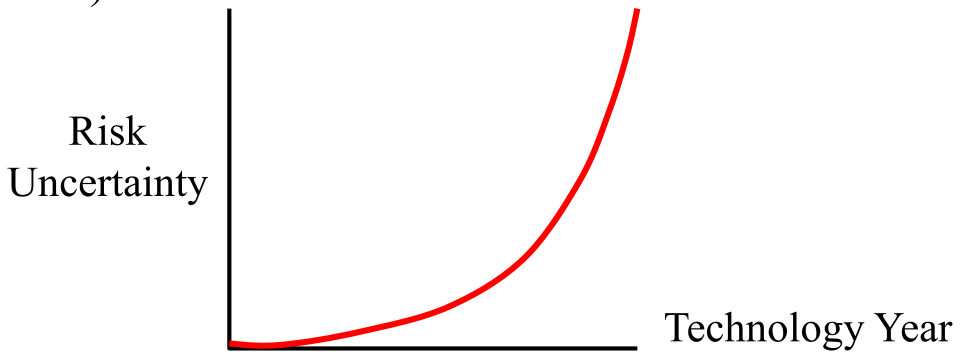
# Technology Availability

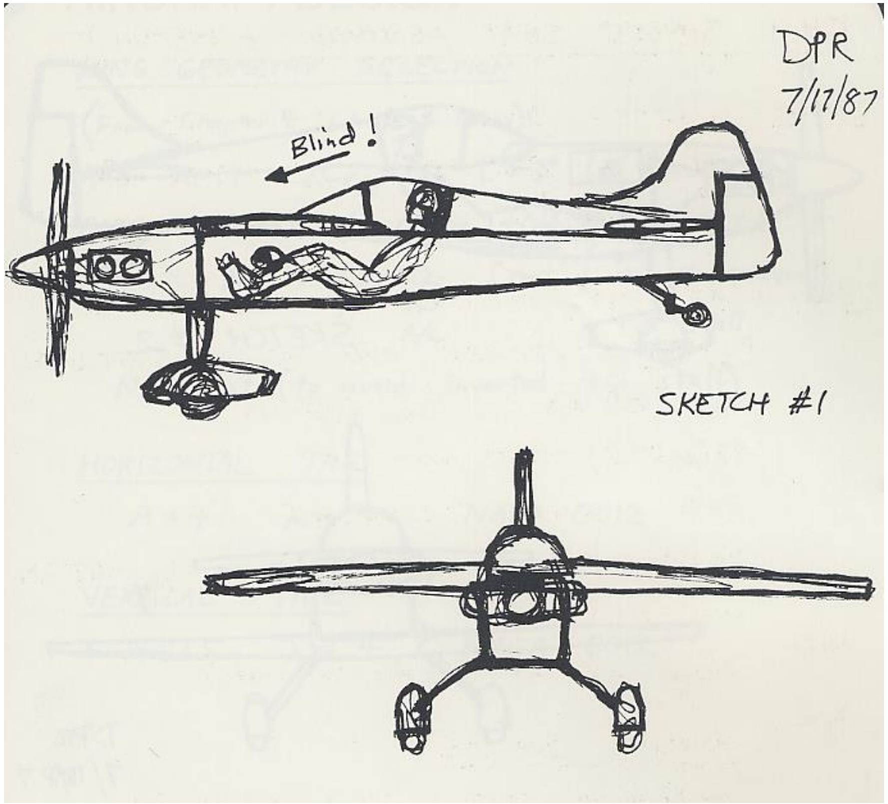
- In classical design, the decision must be made as to the technology level to be used, sometimes called "technology year". This is often specified in the RFP
- Technologies may only be incorporated that are robust in that year
- For example, if it is specified that an aircraft have "current technology", only currently available engines, avionics, and concepts may be used
- If a technology year is specified, an estimate of the technological state of the art must be made for that year. This implies both risk and uncertainty. Advanced design methods are available to help minimize both risk and uncertainty when considering the application of new technologies (AE 6373)

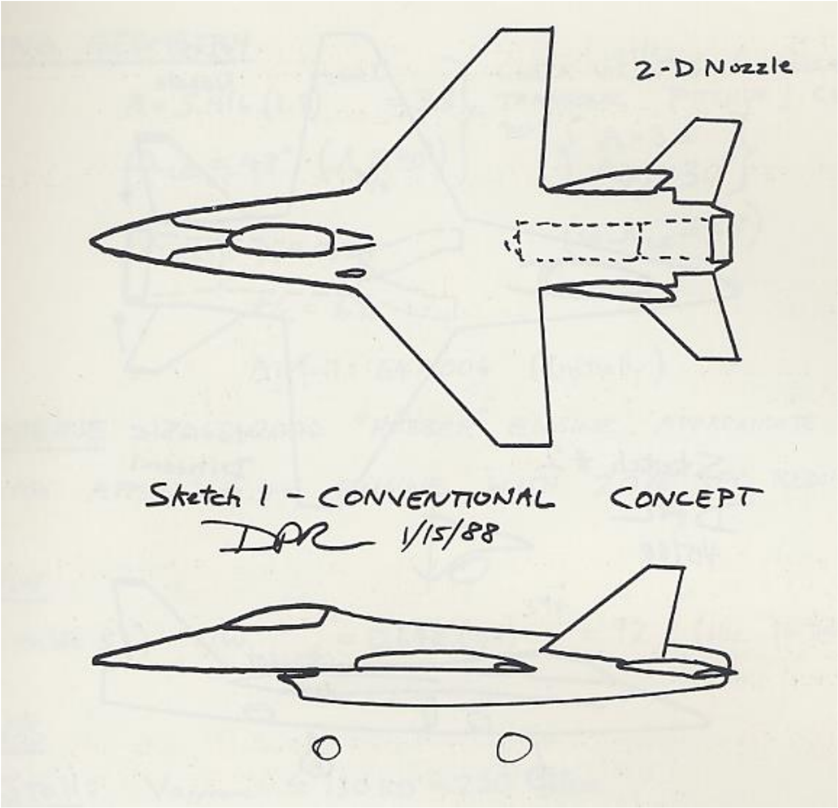
*As the technology year gets farther away from present day and present technology, the risk and uncertainty increase dramatically.*



# Conceptual Sketch

- After considering the design requirements, new concept ideas, and technology year, the next step is a rough conceptual sketch. You need to have some idea of what you are trying to size, so basic configuration decisions are made. This DOES NOT LOCK IN YOUR DESIGN!! It is merely a place to start. This step combines your engineering knowledge, and your creativity

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