Smead Aerospace Engineering Sciences

Glider Design Lab

Lab Overview / Milestone #1

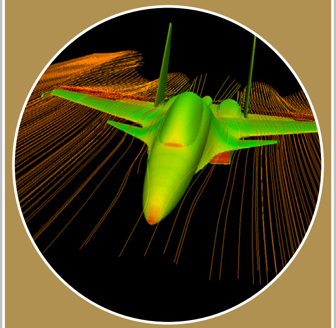
Lab Support / Course Support Introductions

- Lab Assistants
  - Jacob Wilson
- Teaching Fellows Support By Lab Section
  - Section 301/303
    - Natalie Link
    - Mia Abouhamad
    - Preston Tee
  - Section 302/304
    - Chandler Jeep
    - Jarrett Bartson (1st hr)
    - Anna Casillas (2nd hr)
    - Bre Gagliardi (2nd hr)

The Big Picture: Aircraft Life-Cycle Phases

Conceptual Design

- "Paper" Design (Drawing)
- Requirements Analysis
- Design Space Analysis
- Design is still "squishy"



Preliminary Design

- "Refined" Design (CAD)
- Risk Reduction
- Prototyping
- Sensitivity Analysis
- Optimization
- Major Changes Over

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Detailed Design

- "Production" Design (Component-level CAD)
- Production Plans

Manufacturing, Test, Certification

- Prototype Manufacturing
- Full Scale Testing
- Certification of Function

Production

- Full scale manufacturing
- Quality Control & Modifications

Operations

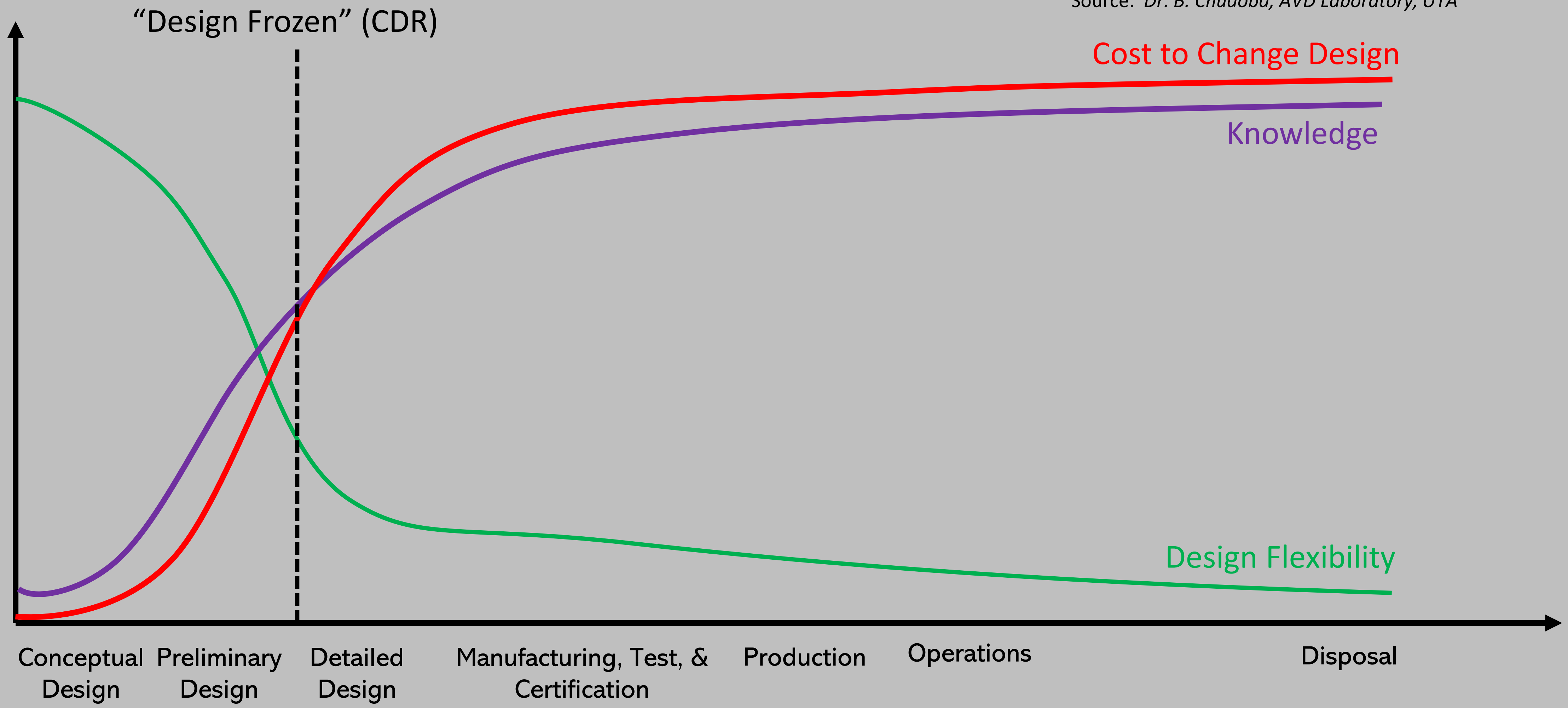
- Performance "in the wild"
- Sustainment & Upgrades

Disposal

- Removal from service
- Hazards and cost

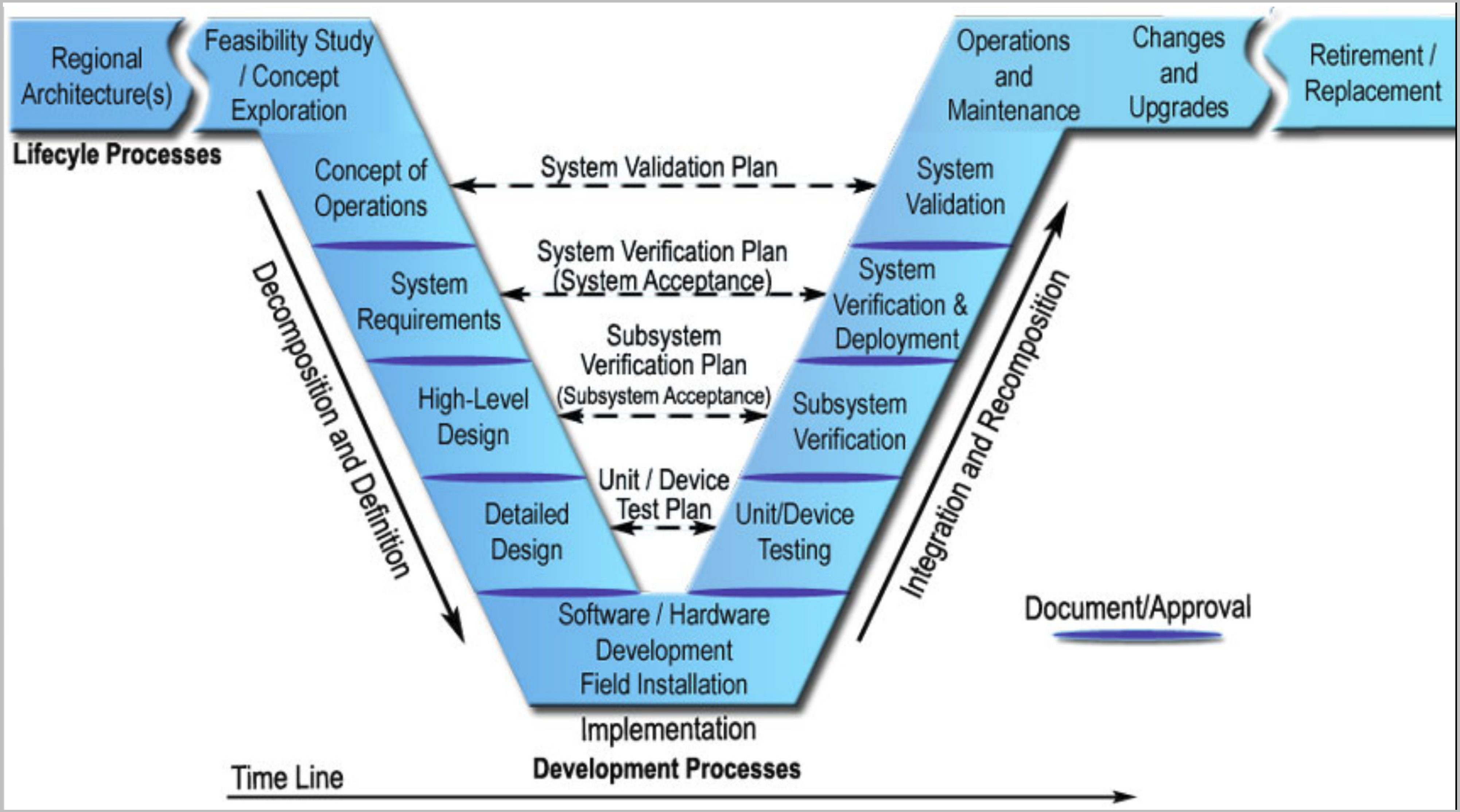
The Design Paradox: Here's the Problem…

Source: *Dr. B. Chudoba, AVD Laboratory, UTA*



THE DESIGN CHOICES YOU IN CONCEPTUAL DESIGN HAVE LARGE AND LASTING IMPACTS OVER THE ENTIRE LIFE-CYCLE OF YOUR PRODUCT!

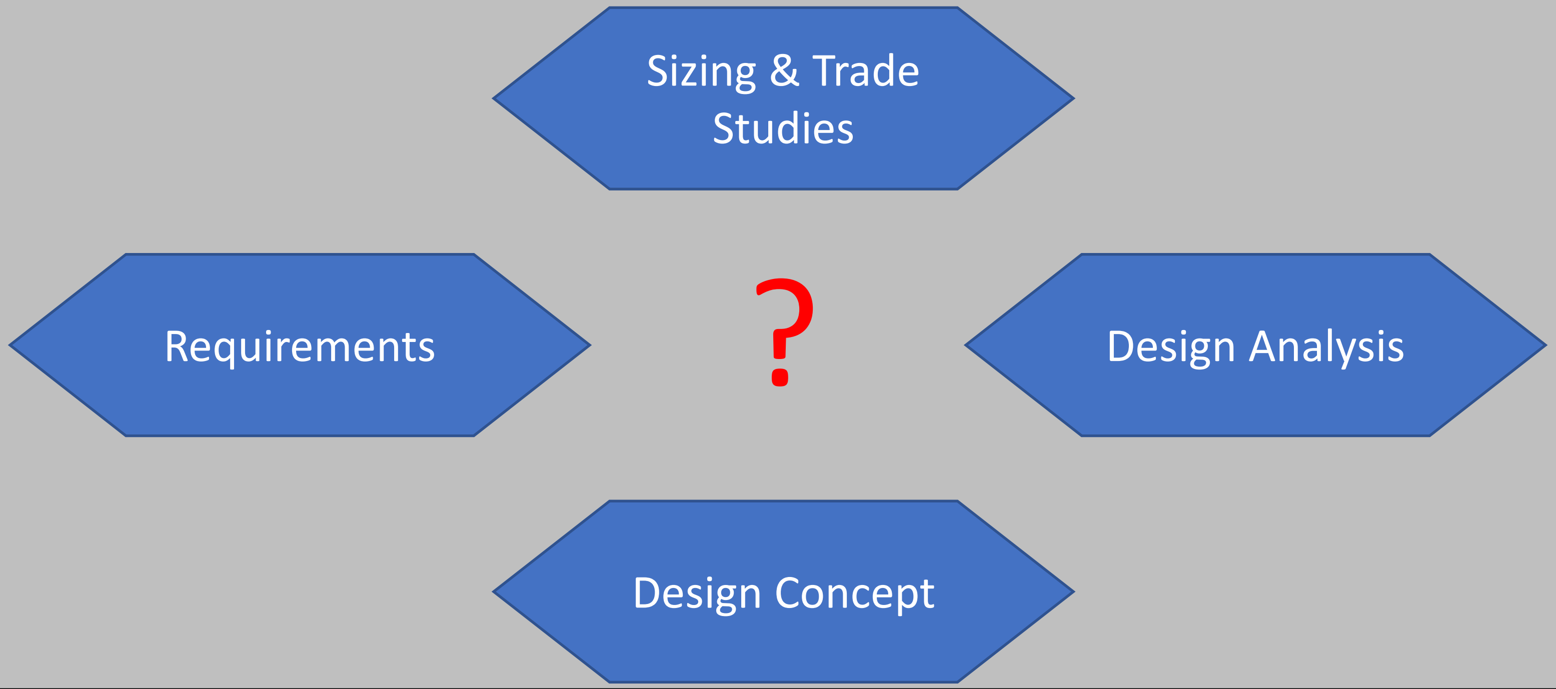
Macro Design Framework: Systems Engineering Approach to Product Development



Aircraft Design Process: Where do you start?

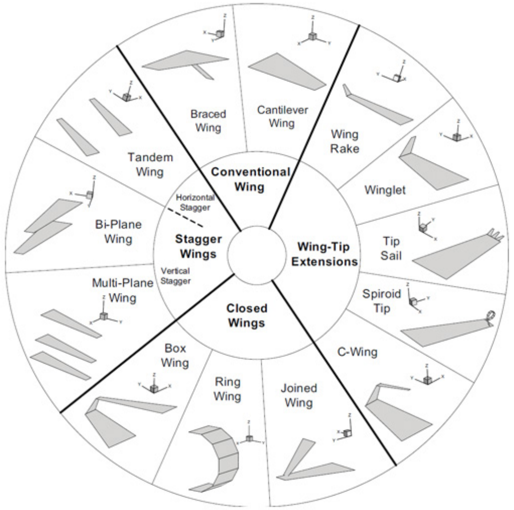
"Those involved in design can never quite agree as to just where the design process begins. The designer thinks it starts with a new airplane concept. The sizing specialist knows that nothing can begin until an initial estimate of the weight is made. The customer, civilian or military, feels that the design begins with requirements. *They are all correct."*

-- Daniel Raymer, Aircraft Design: A Conceptual Approach



Aircraft Design Process: Parametric Sizing Iterations

Design General Configuration & Analyze Drag Polar



Source: *Advanced Aircraft Design Lab, Royal Military College of Canada*

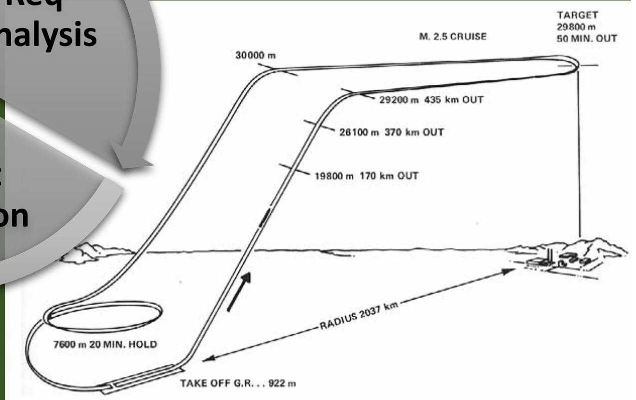
Aerodynamic & Prop Analysis

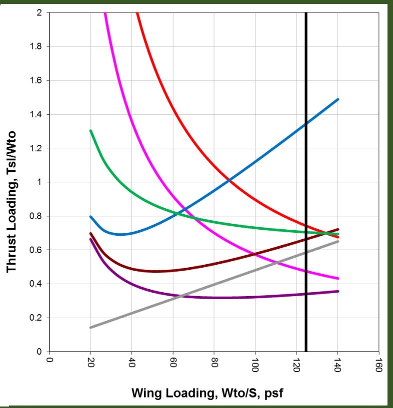
- 3-D Finite Wings Concepts
- Whole Aircraft Drag Polar Concepts
- Thrust and Power Curves

Parametric Sizing: W/S and T/W

Mission Performance Requirements

- Range & Endurance
- Climbs & Ceilings
- Takeoff & Landing
- Turn Performance
- Energy Analysis





Aero Analysis

Req Analysis

Weight Estimation

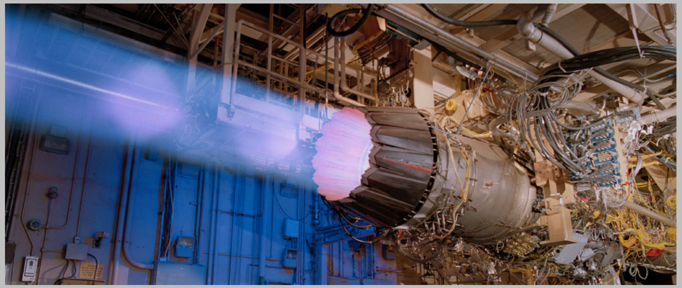
Weight Estimation (Empirical or Analytical)

$$W_{TO} = W_{airframe} + W_{engine} + W_{payload} + W_{fuel}$$

$$\frac{W_{TO}}{S} = \frac{W_{airfrm}}{S} + \frac{W_{engn}}{S} + \frac{W_{payld}}{S} + \frac{W_{fuel}}{S}$$

Where do you start in this cycle?

Intro to Key Aero Design Ratios: T/W, L/D, W/S



- ***Thrust-to-Weight Ratio (T_{SL}/W_{TO})***
  - "Thrust Loading"
  - Measure of thrust capacity/availability

- ***Lift-to-Drag Ratio (L/D)***
  - Measure of aerodynamic efficiency
  - Encapsulates the advantages of having wings vs. direct lift

- ***Weight-to-Planform Area (W_{TO} / S)***
  - "Wing Loading"
  - How much weight of the aircraft must be carried per unit area of wing
  - Sizing parameter for aircraft
  - Performance indicator
    - Low wing loading = lower stall speeds, shorter takeoff/landing distances, increased turn performance
    - Larger wing loading = faster velocities required or greater AoA to sustain weight, more stability in gusts, higher max speed

Aero Lab Overall Objectives

Learning Objectives

1. Demonstrate an adaptive engineering mindset and good engineering judgement towards the open-ended design of a basic aerospace system
   a) Engineering Judgement: Be able to explain the advantages and limitations of theoretically and empirically derived first-order aerodynamic models for estimating the lift characteristics, drag polar and performance in the design of new aircraft
   b) Adaptive Mindset: Demonstrate the ability to identify assumptions and unknowns and seek out knowledge to apply new and theoretically sound models when needed
2. Practice the application of a structured design methodology towards a complex engineering problem.
3. Reinforce understanding of aerodynamic coefficients (lift, drag, moments) and the underlying impact and inter-related aspects of key aerodynamic parameters and design variables such as:
   A. Reynolds Number
   B. Wing planform geometry and airfoil
   C. Oswalds and span efficiency factor
   D. Weight
   E. Wing Loading and Thrust-to-Weight Ratios
4. Understand and describe the basic concepts of longitudinal and lateral stability through the design, fabrication, and test flight of a sub-scaled glider.

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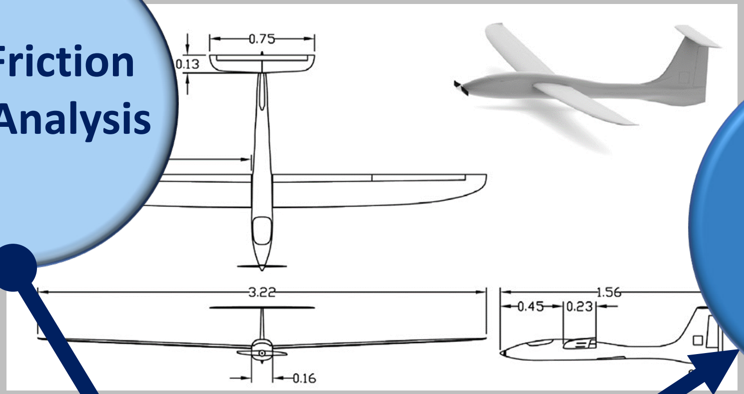
» Milestone 1: Benchmarking Aerodynamic Models

Given:
Known Aircraft

Skin Friction
Drag Analysis

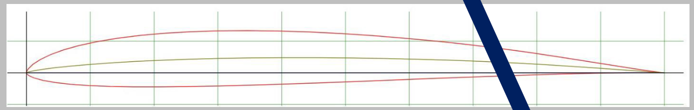


Model
Validation

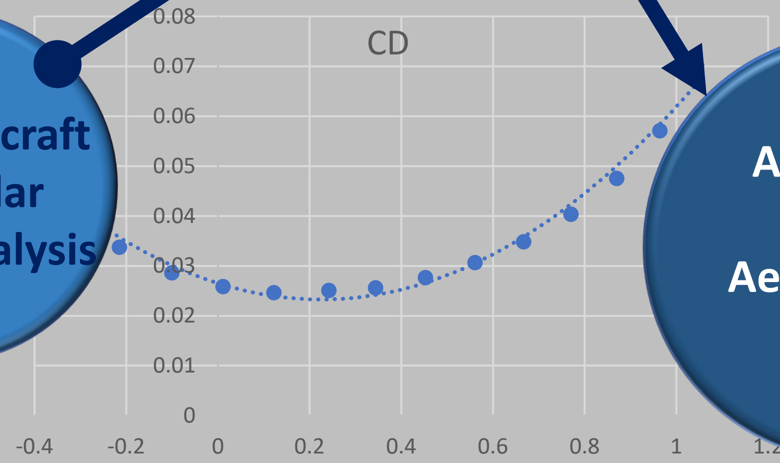
Table 1 Performance characteristics of the Tempest UA

Characteristic	
Wingspan	3.22 m
Wing area	0.63 m^2
Aspect ratio	16.5
Airfoil	MH 32
Length	1.56 m
Empty weight (with propulsion)	4.5 kg
GTOW[a]	6.4 kg
Max load factor	14
Wing loading	33.3 oz/ft^2 (10.2 kg/m^2)
Stall speed	12 m/s
Cruise speed	17–25 m/s
Endurance (with reserve)	45 min
Range	40 km
Typical climb rate	500–2300 ft/ min (2.5–11.5 m/s)

[a]Gross takeoff weight.



Whole Aircraft
Drag Polar
Model Analysis



Lift
Analysis

Assess and
Update
Aerodynamic
Model

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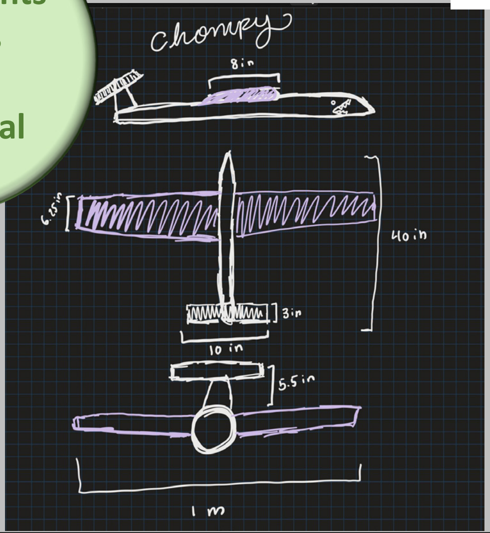
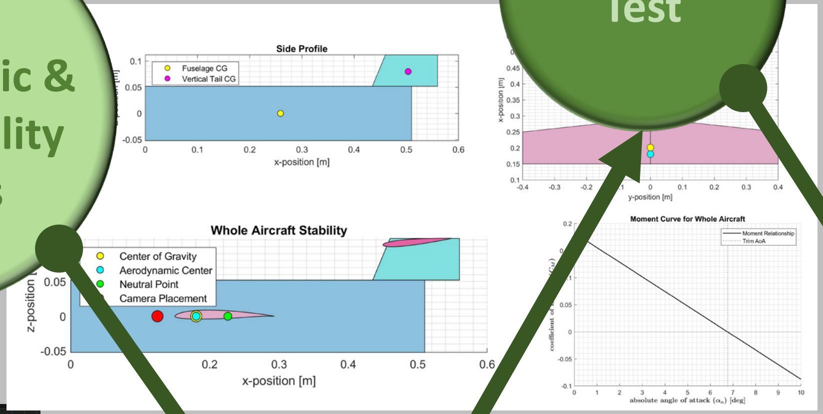
» Milestone 2: Application to Glider Design/Build/Fly

Updated Aerodynamic Model + New Design Requirements

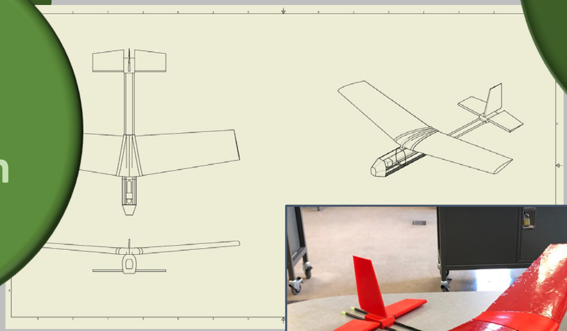
Requirements Analysis of Conceptual Designs



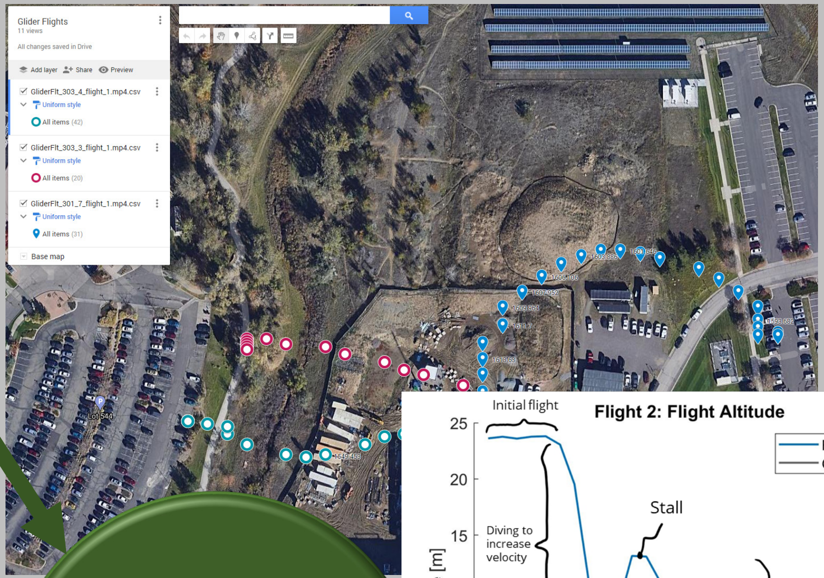
Design Aerodynamic & Static Stability Analysis



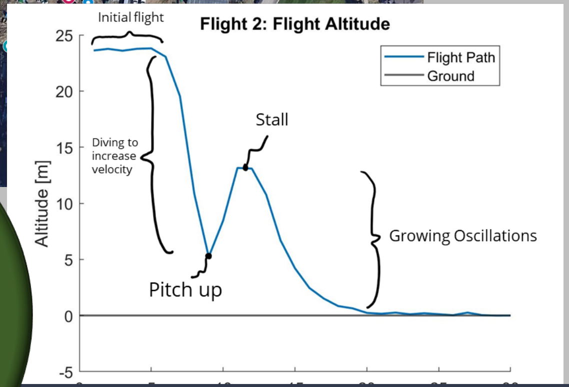
Final Design Fabrication



Flight Test



Validation & Verification Analysis of Flight Test vs Models



culated Glider Design Performance vs. light Test Performance

	Calculated	Flight Test
Max Range [m]	453	300*
L/D Max	20.6	13.6
Velocity for L/D Max [m/s]	10.1	11.1
Stall Velocity [m/s]	6.8	

*Max Range includes extrapolated data from after striking the tree in flight test #2, the glider struck the tree after traveling 137m and was still at 11.9m in altitude

Aero Lab Roadmap Overview

- **Aero Lab Milestone #1: Drag Polar Benchmarking Report (Weeks 1 – 3)**
  - Individual Effort and Deliverable (peer discussion is encouraged however)
  - Develop your own tools/models to design and analyze an aircraft (lecture & labs)
  - Benchmark those tools/models against a known aircraft
    - Finite Wing Analysis
    - Whole Aircraft Drag Polar Analysis
  - Summarize results of your analysis
- **Aero Lab Milestone #2: New Glider Design (Weeks 4– 7)**
  - ***Within your team, determine what engineering model from milestone 1 you will all use***
  - Design a new glider against specific performance requirements
    - Leverage tools benchmarked in Milestone 1
    - Apply knowledge of aircraft design variables to meet design requirements
    - Research & analyze different / innovative designs to maximize performance
    - Present your engineering model and finalized design
  - ***Fabricate prototype to validate design and models used***
    - Flight test design
    - Crush your competition!

Aero Lab Milestone #1: Benchmarking (Validating Models)

» Motivation for Milestone #1

- » This isn’t just an academic lab meant to demo lecture concepts
- » Near-term correlation to requirements for senior projects course design
- » Long-term, the principles involved apply to real-world methodologies and implications on design of new air vehicles

“…early in the program, Lockheed Martin began construction with glowing optimism. The company decided to build the Air Force’s F-35A first because it was considered the simplest model, then move on to the difficulties of the F-35B short-takeoff and vertical-landing version and then the F-35C, which can land on an aircraft carrier — a decision that turned out to be a mistake. Once Lockheed’s engineers proceeded with the more demanding design of the F-35B, ***they found that their initial weight estimates were no longer accurate and the B model was on track to be 3,000 pounds too heavy*** **to meet specifications. The company was forced to begin an extensive redesign project that added an 18-month delay to the program.”**

Your Task for Rest of Today

- Read the handout and develop an understanding of the complete milestone task
- Get to know each other!
  - Start discussions on lab teams with your classmates
  - All team members must be in your same lab section
  - Must be groups of 4, limited number of groups of 5
  - We will assign or re-arrange groups as required
  - Teams will be finalized before the beginning of milestone 2
- Ask Questions!