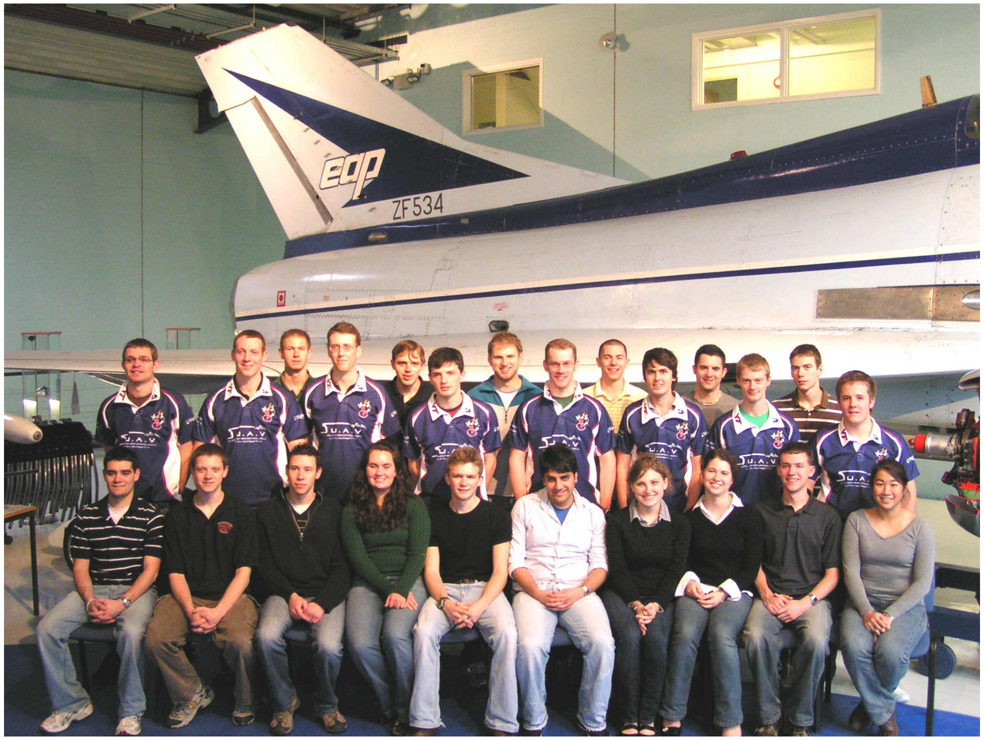
Collaborative Conceptual Design of a UAV



International Aircraft Design Team

November 29, 2007

Group Members

Virginia Tech:

- Alex Kovacic
- Jessica McNeilus
- Philip Pesce
- Megan Prince
- Anthony Ricciardi
- Michael Sherman
- Belle Bredehoft
- Amanda Chou
- Dennis Preus
- Robert Briggs
- Richard Duelley
- Erik Sunday

Loughborough University:

- Alex Humphrey
- Andrew Courtneidge
- Balraj Chand
- Ben Hanson
- Craig Dillon
- Daniel Marshall
- Daniel Jones
- Kris Hanna
- Peter Christie
- Rob Penn
- Rob Noble
- Stephen Bennett

Requirements

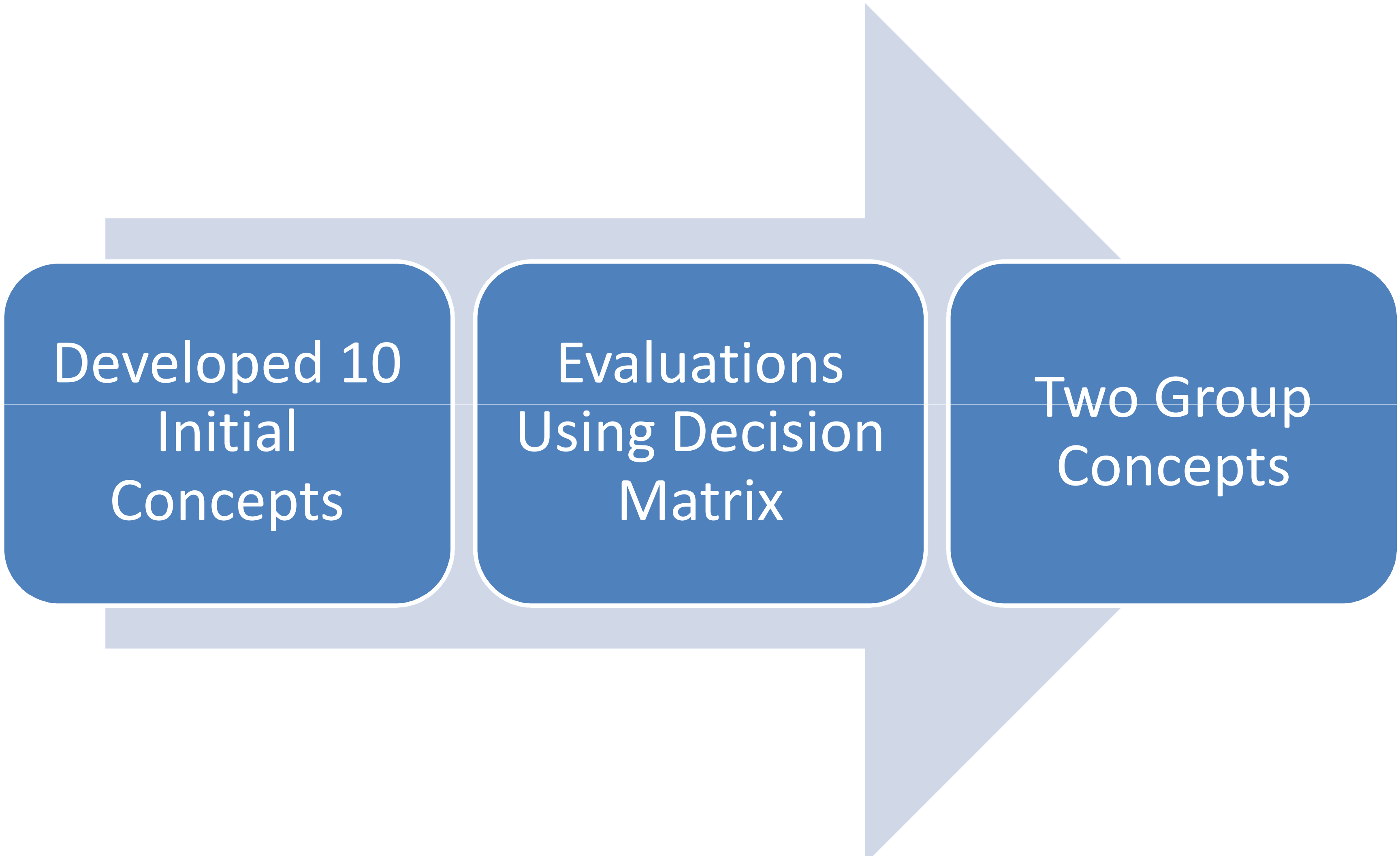
- **Endurance = 8 hours**
- **Minimum Payload of 30-45 lb. (13.6-20.4 kg)**
- **Cruise speed = 50 knots**
- **MTOGW of 300lb (136 kg)**
- **Top speed = 70 knots**
- Climb rate at least 200 ft/min (61 m/min) at sea level
- Range = 15 nm
- Service ceiling of 10,000 ft (3050 m) at half-fuel
- Normal operational altitude of 3000 ft (914 m) or 2000ft (610 m) (AGL)
- All weather operation with a 10 kt crosswind landing capability
- Rail catapult launch and 50 x 250 ft (15x76 m) “parking lot” recovery area

Group Breakdown

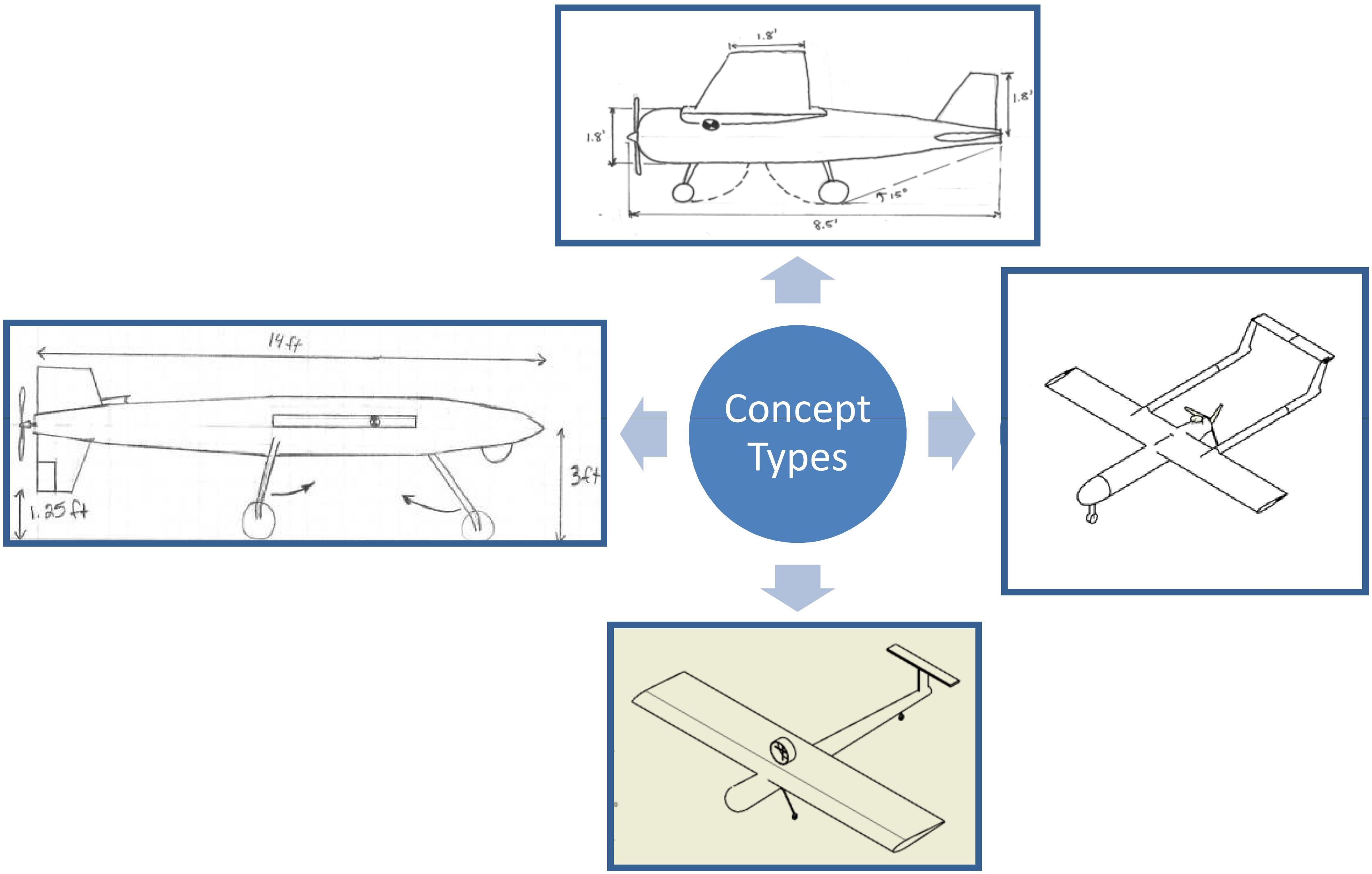
- Virginia Tech
  - Broke into 2 groups and each developed a concept
- Loughborough University
  - Developed two concepts as a group.

Comparative UAVs

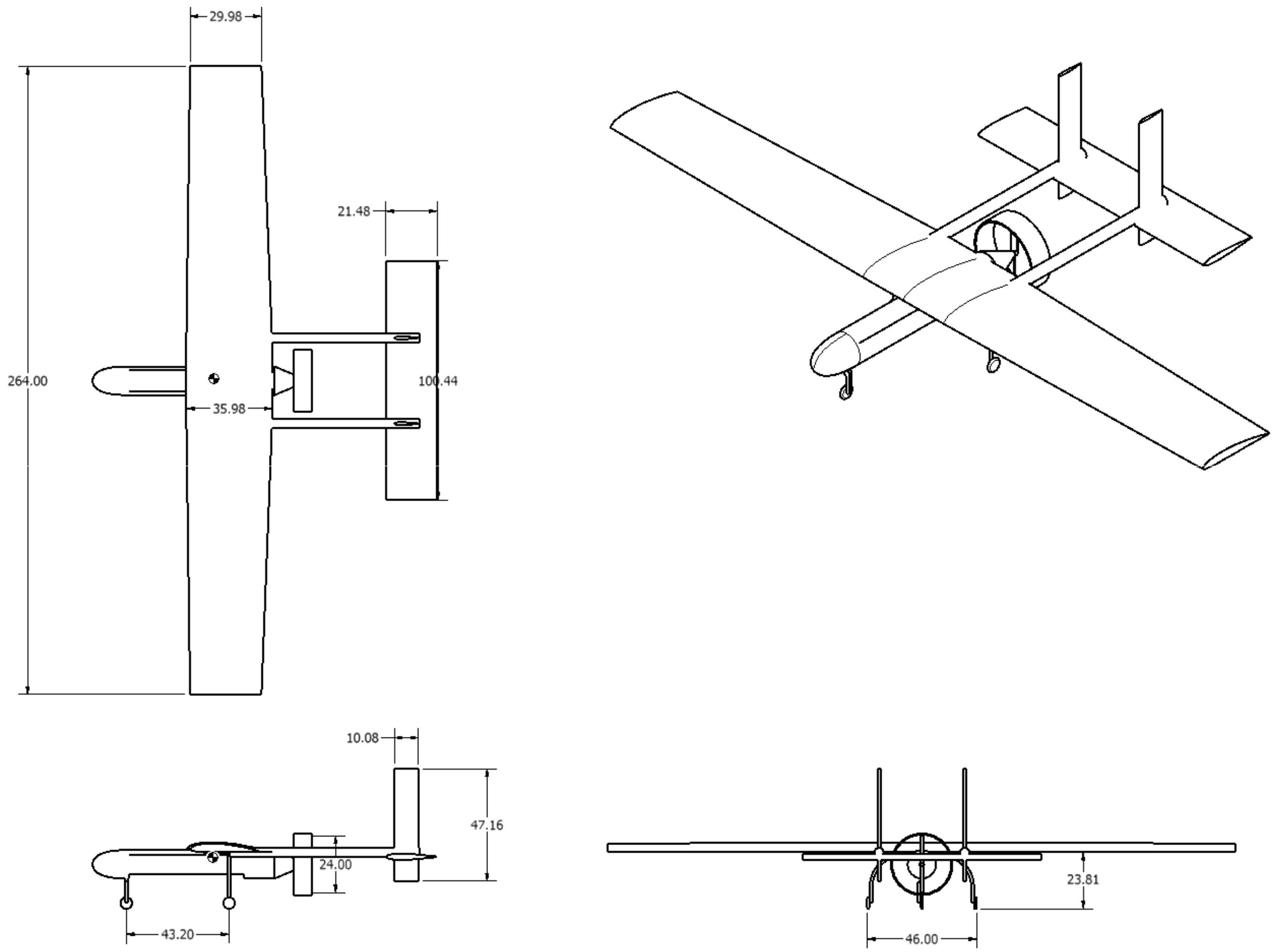
Next Step


Developed 10 Initial Concepts
Evaluations Using Decision Matrix
Two Group Concepts

Virginia Tech's Initial Concepts



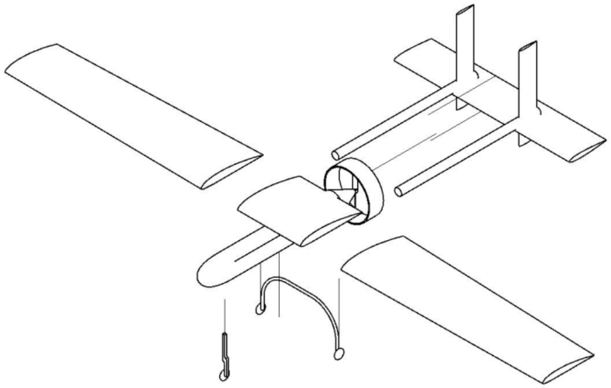
Group A – Initial Concept



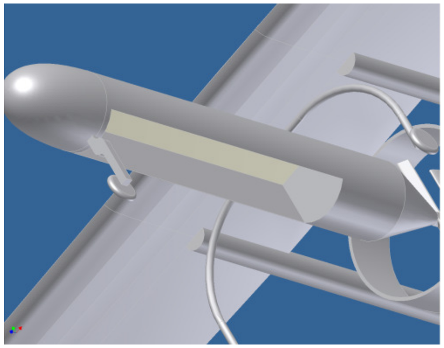
Design Characteristics

- Propulsion
  - Shroud
    - Increases efficiency of propellers
    - Significant decrease in noise
  - Aft Motor
    - Decrease likelihood of engine damage in crash
    - Exhaust deposited into airflow downstream of payload sensors, avoiding contamination
  - *Desert Aircraft DA-150*, outputting 16.5 hp
    - Fuel consumption allows for endurance of 10+ hrs. with only 25 lbs of fuel

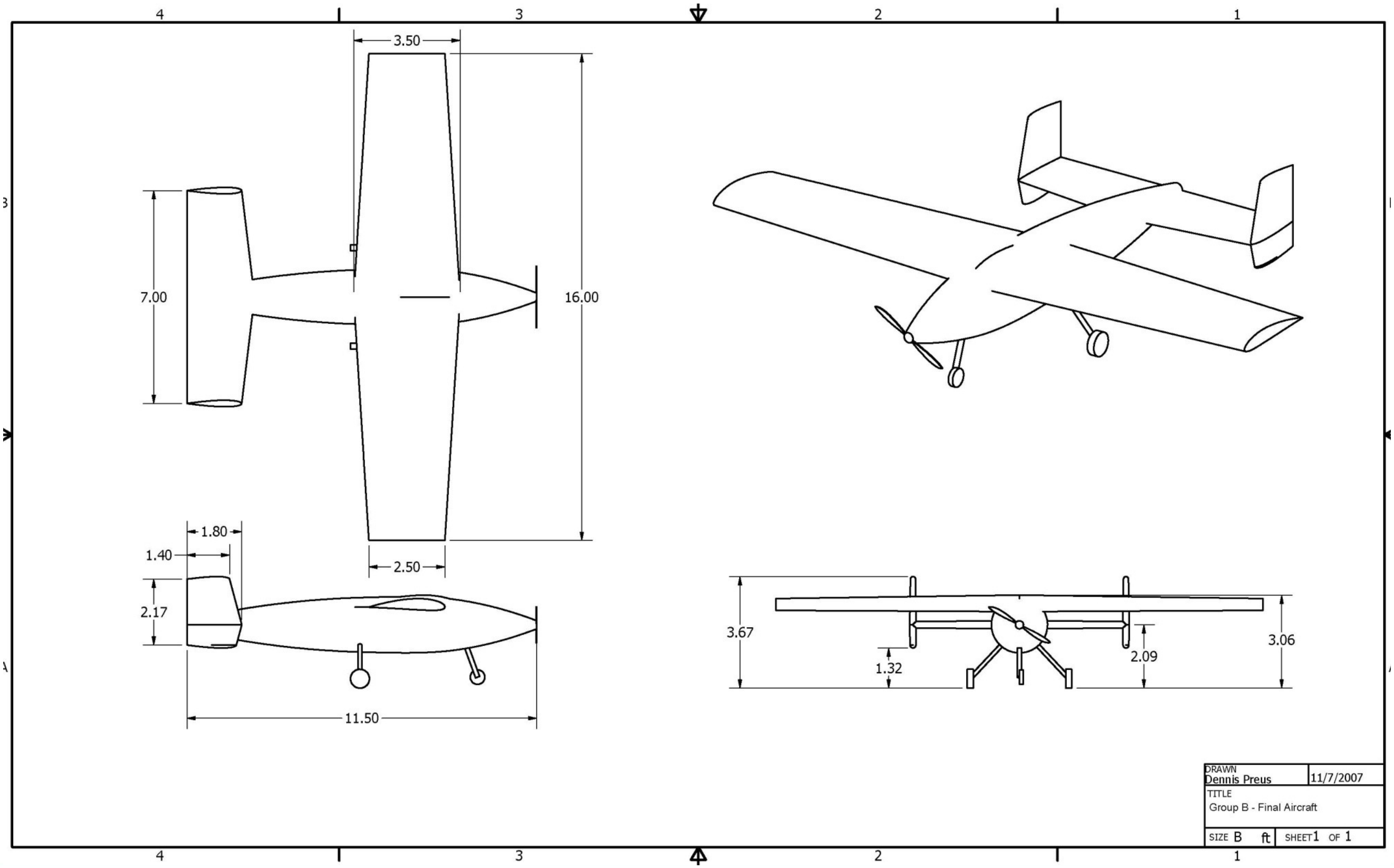
Design Characteristics



- Portability
- Tricycle Landing Gear
- Constant Applied Braking System
- Dual Boom Mounted H-Tail
- Payload Placement in Middle/ Removable Cartridge

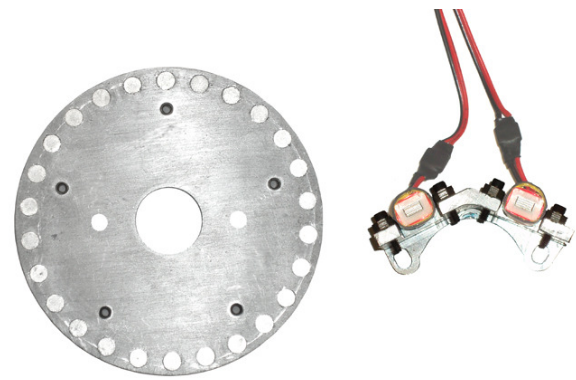


Group B – Initial Concept



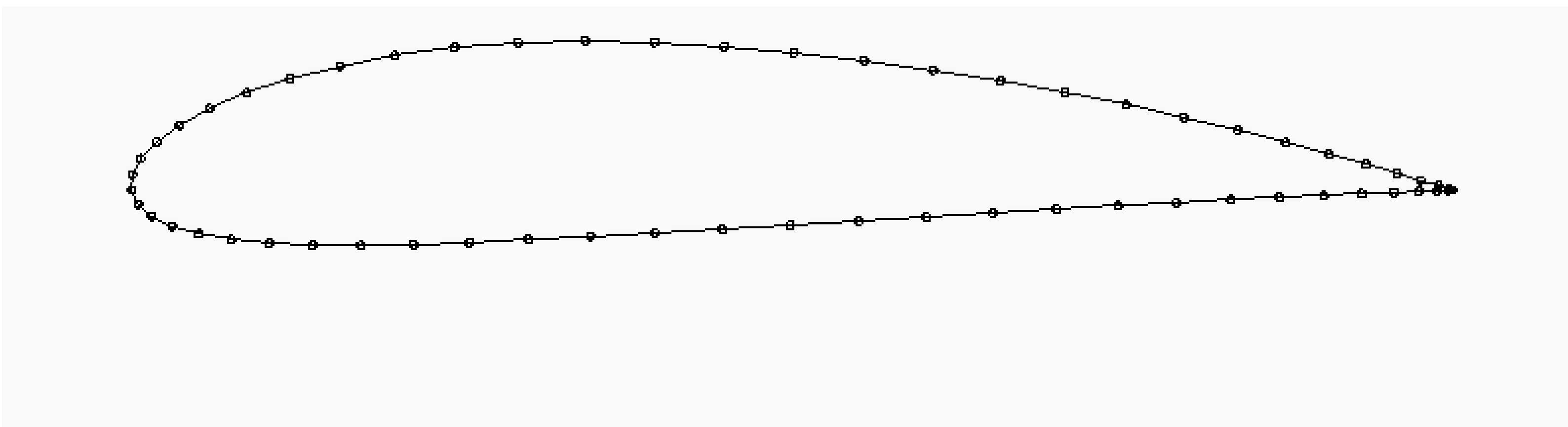
Design Characteristics

- Propulsion
  - Tractor to reduce the noise
  - *150D2-B*, outputting 15 hp
  - Starter and Alternator
- Conventional Fuselage
  - Ease of manufacturing
- H-tail
  - Redundancy to improve reliability



Design Characteristics

- Retractable landing gear for camera visibility
- High wing for roll stability
- NACA 4415 Airfoil

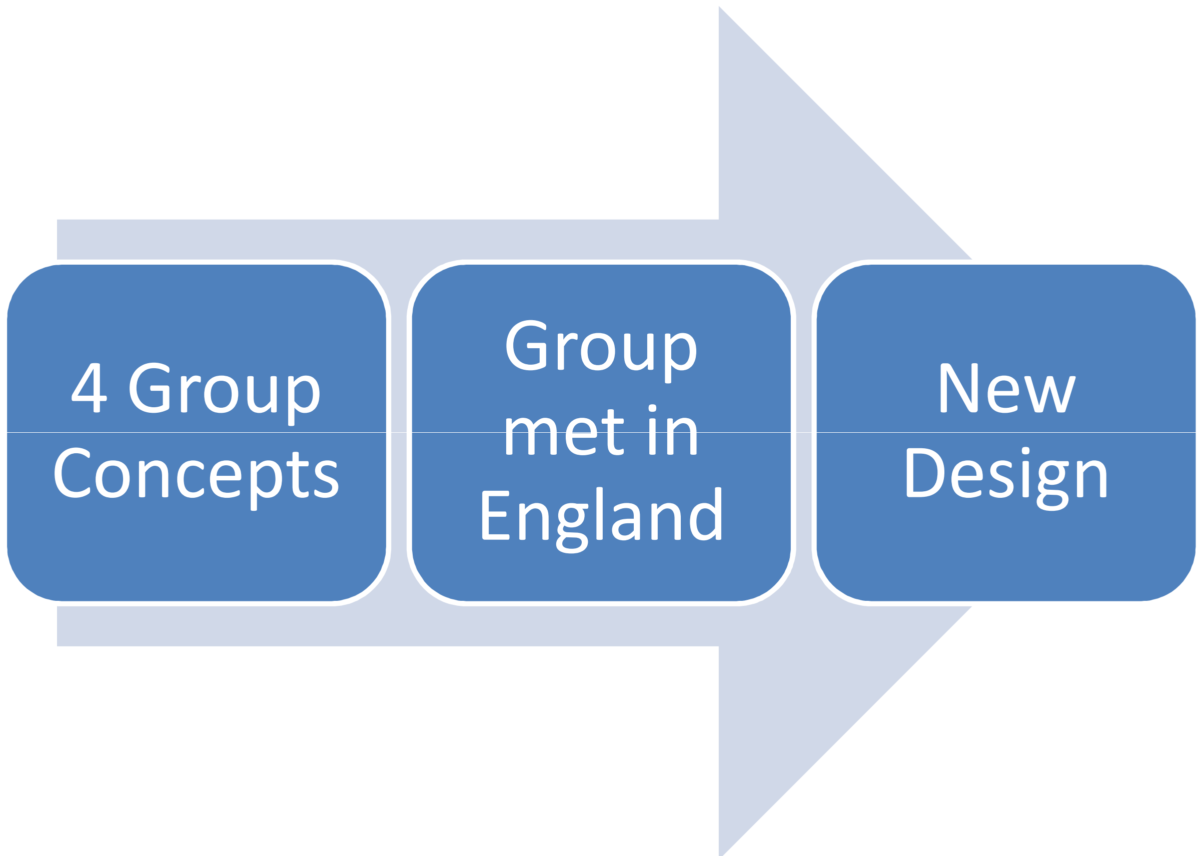


Loughborough University Concepts

Conventional Tractor

Pylon-Mounted Pusher

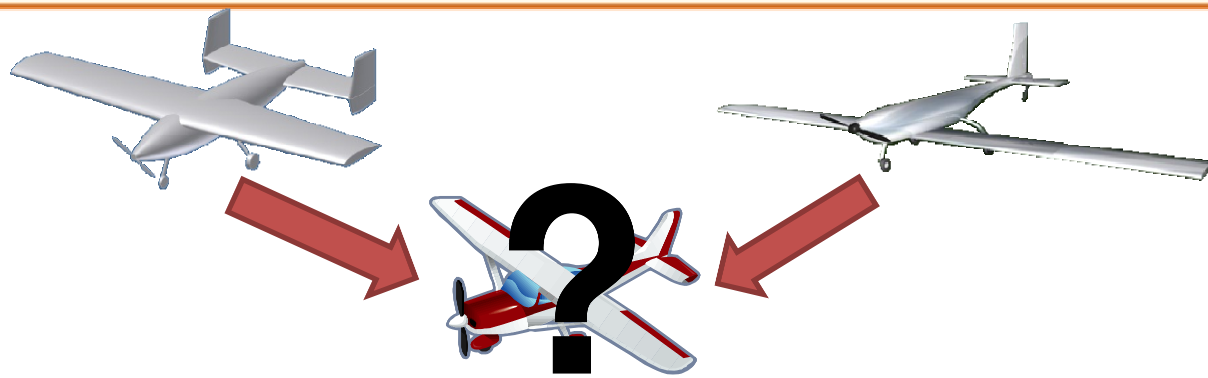
Moving Forward



Identification of Key Issues

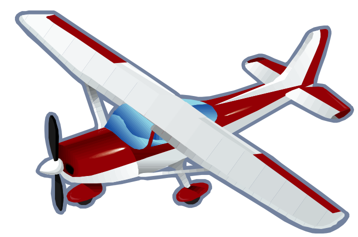
- Noise
- Pusher vs. Tractor Engines
- Loading on Structures at Launch
- Propeller protection from ground strikes
- Thrust line
- CG placement and shift
- Safety

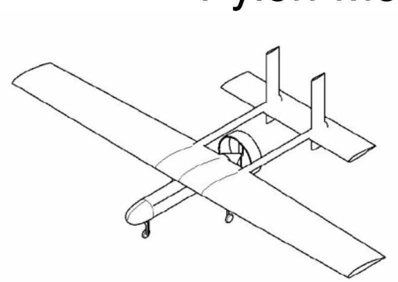
Selection Process



- Tail type and wing considered interchangeable for all concepts
- Landing gear configuration changeable

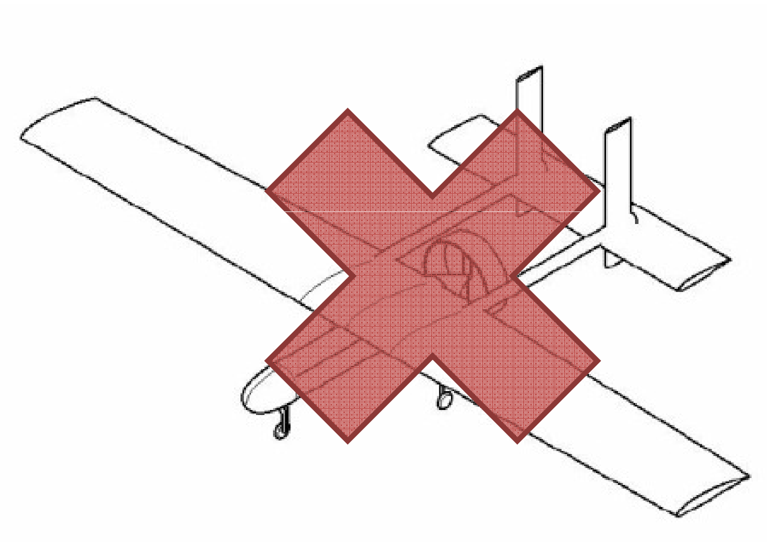
1. Combination of conventional concepts to reduce to 3 choices:
   - Conventional
   - Twin-Tail Boom Pusher
   - Pylon-Mounted Pusher

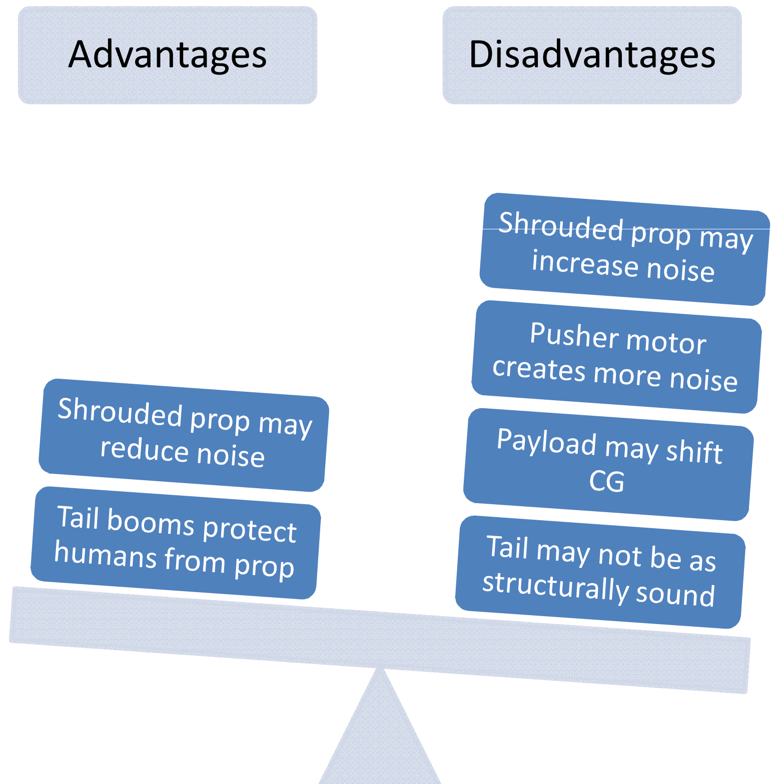




Selection Process

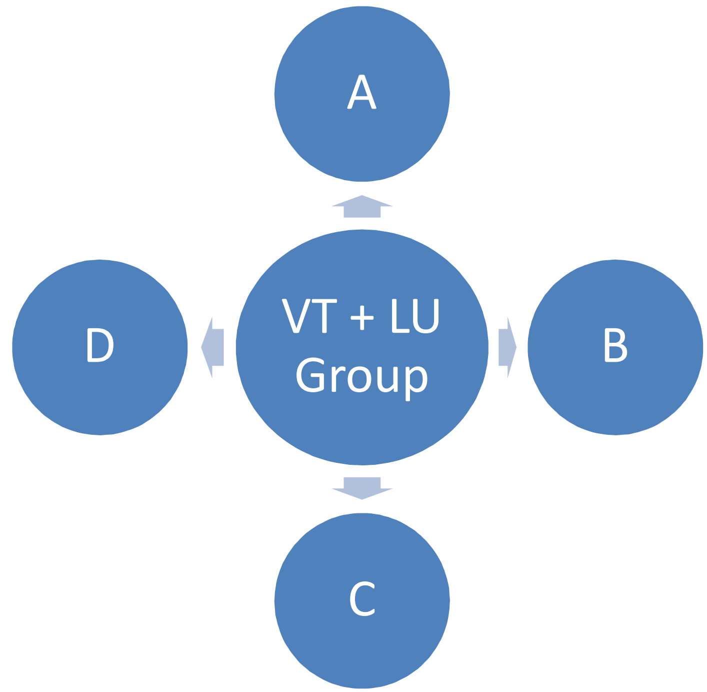
2. Listing of Advantages and Disadvantages
   - Elimination of Twin-Tail Boom Pusher
   - Last 2 choices: Conventional, Pylon-Mounted





Selection Process

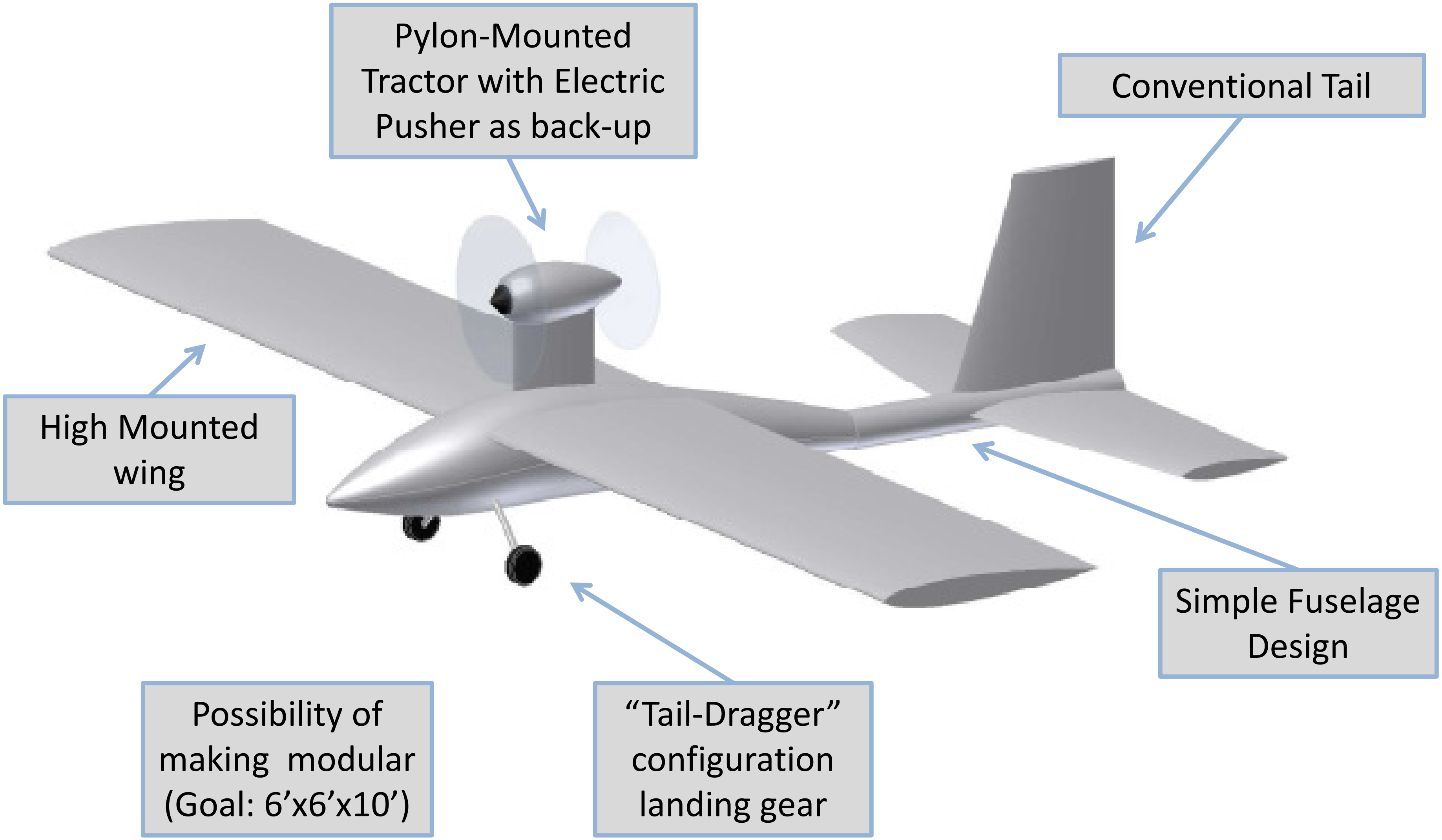
3. Small Group Discussion
   - Broke into 4 small groups of up to 6 people
   - Discussed advantages and disadvantages, concerns
   - Decided on **Pylon-Mounted Pusher** but with modifications



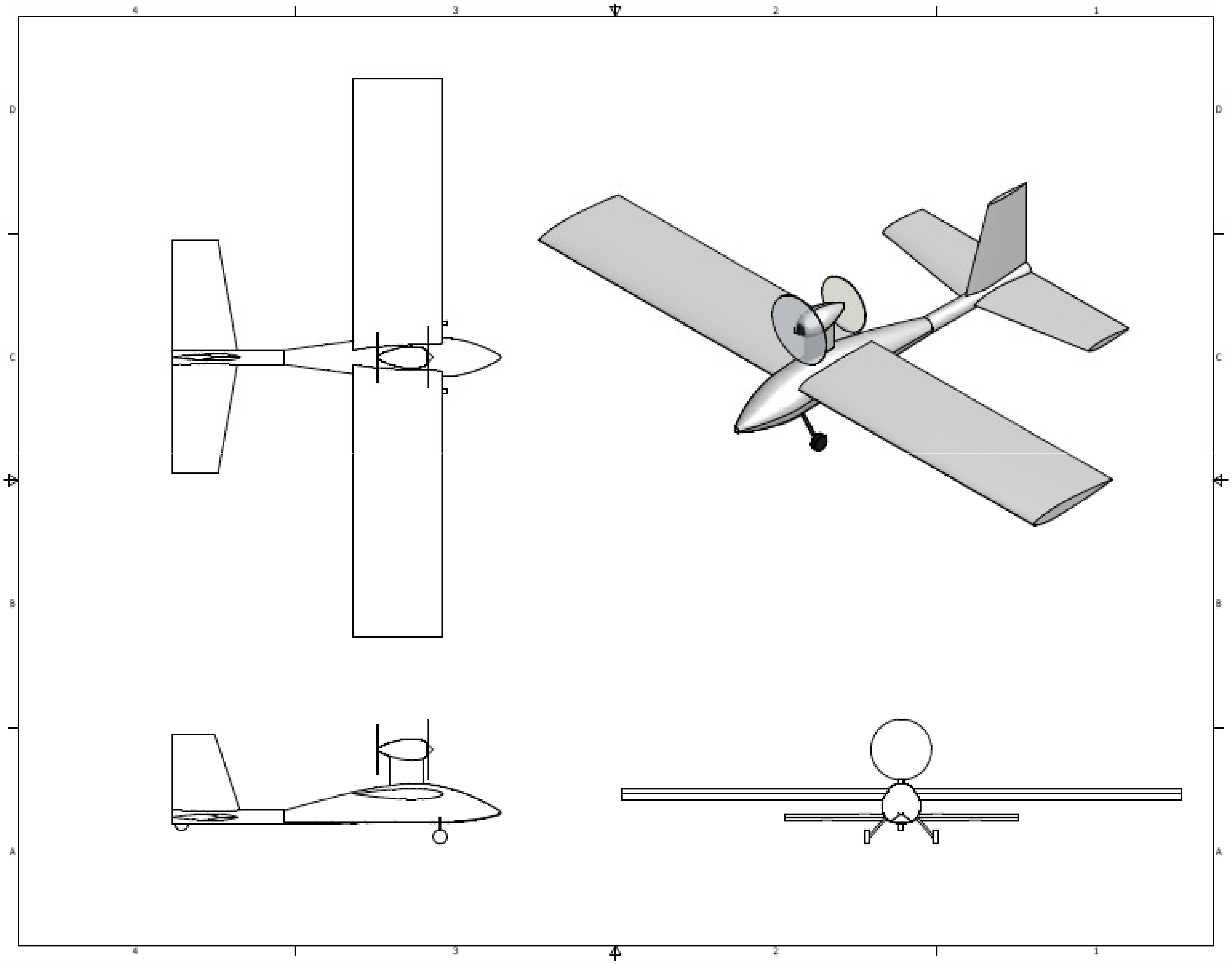
Modifications Suggested:

- Use a tractor prop
- Use a conventional tail
- Mount the wing high on the fuselage

Final Concept Selected



Final Concept Selected



Final Wing Sizing

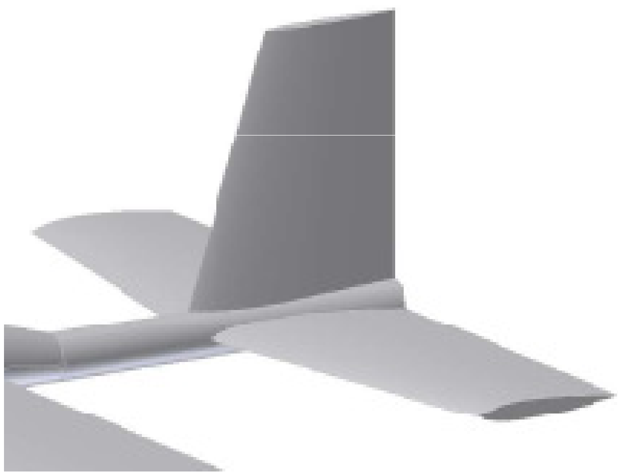
- **Started with C_L for cruise of 0.4**
- **Found wing area and used target aspect ratio (AR = 6) to find dimensions of wing**

Span (ft)	20
Chord (ft)	3.2
Area (ft^2)	64
Aspect Ratio	6.25
Wing Loading (lb/ft^2)	3.125

Final Tail Sizing

- **Using Raymer's Equations with a moment arm of 8 ft.**

$$S_{ht} = \frac{C_{ht} c_{wing} S_{wing}}{L_{ht}} \qquad S_{vt} = \frac{C_{vt} b_{wing} S_{wing}}{L_{vt}}$$



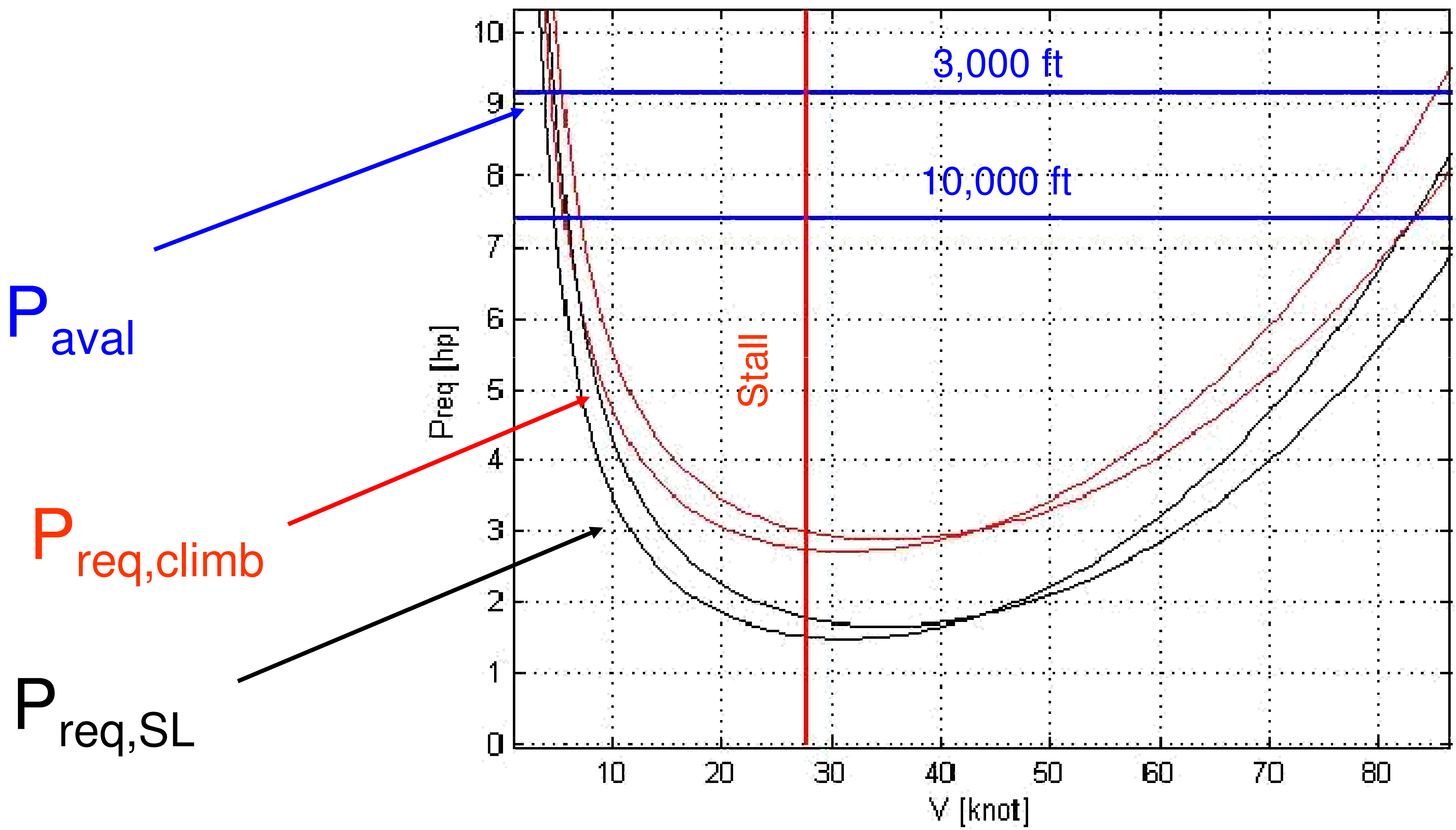
Horizontal Tail	
Span (ft)	8.35
Area (ft^2)	16.66
Root Chord (ft)	2.36
Tip Chord (ft)	1.63

Vertical Tail	
Height (ft)	3.00
Area (ft^2)	6.00
Root Chord (ft)	2.50
Tip Chord (ft)	1.50

Power Analysis

- Power required for straight and level flight
- Power required for 200 ft/min climb
- Power available from 10 hp engine
  - at 3,000 and 10,000 ft MSL
  - Weight = 200 lbs

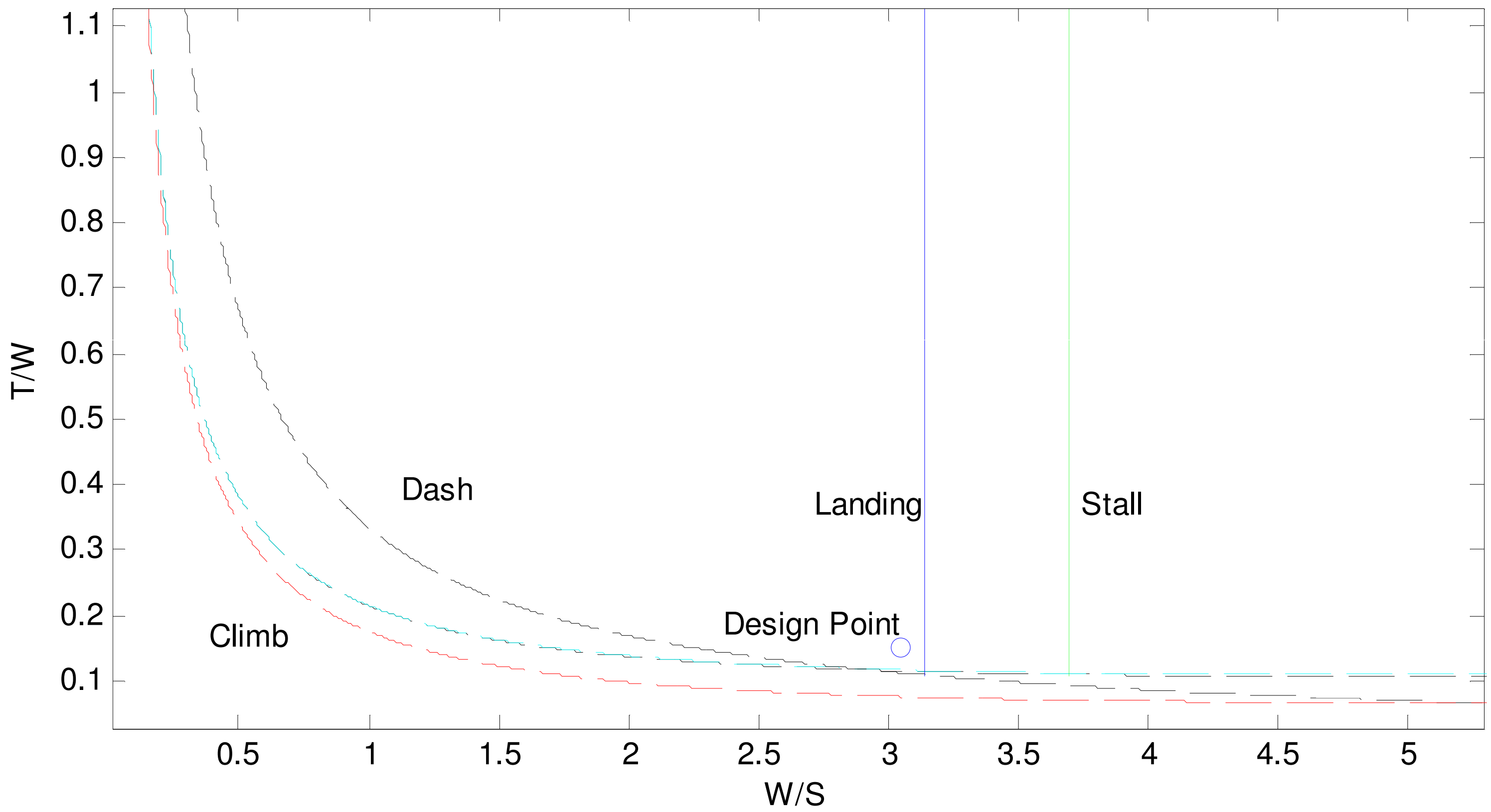
Power Analysis



Constraint Analysis

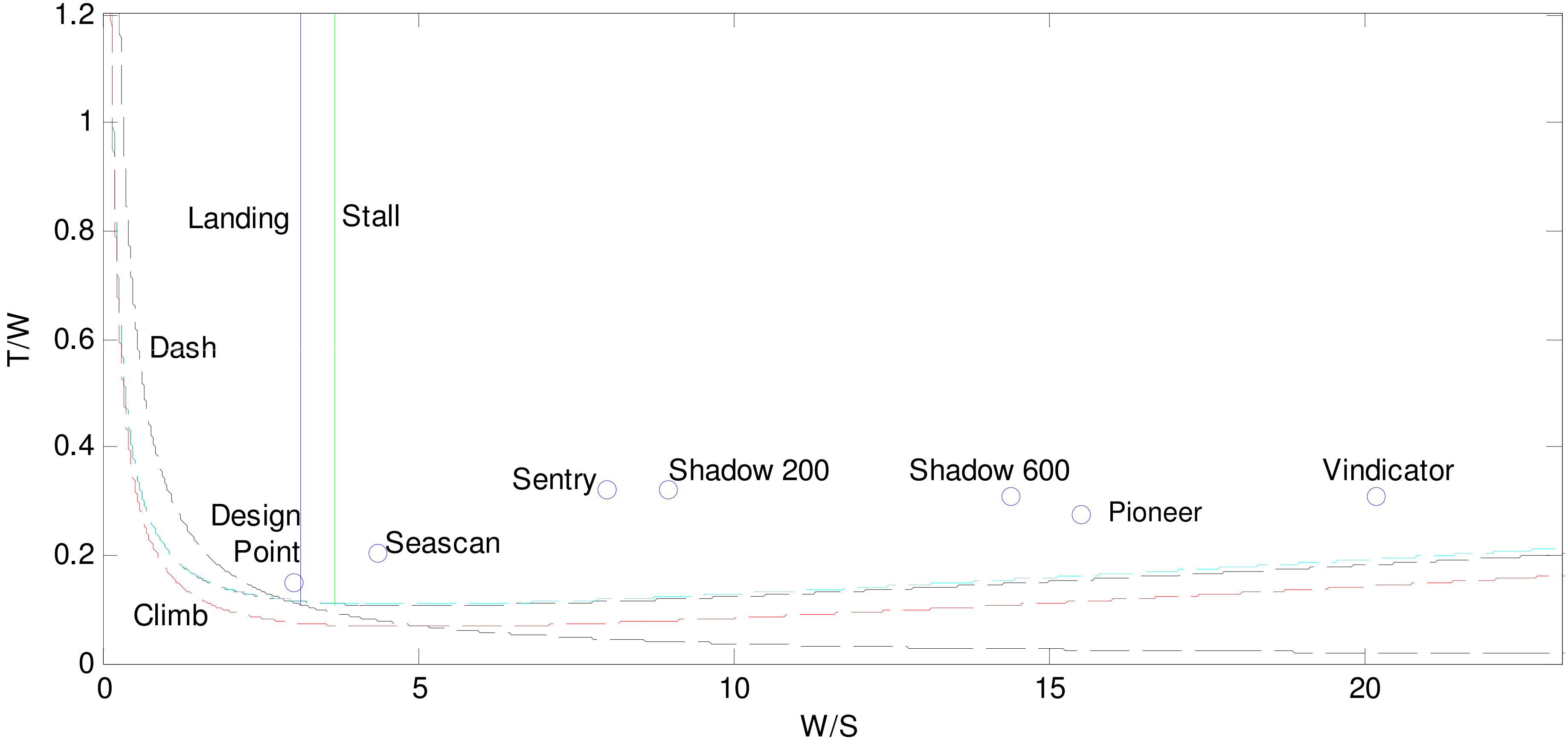
Assumptions

e=0.9, AR=6.25, CD_o = 0.02, C_{Lmax} = 1.3, Landing Weight = 0.85 MGTOW



W/S = 3.1, T/W = 0.14

Competitors



Reliability

Addressed as **the** key issue.

Goal: 1 or less uncontrolled crashes per 100,000 hours

Ways to improve reliability:

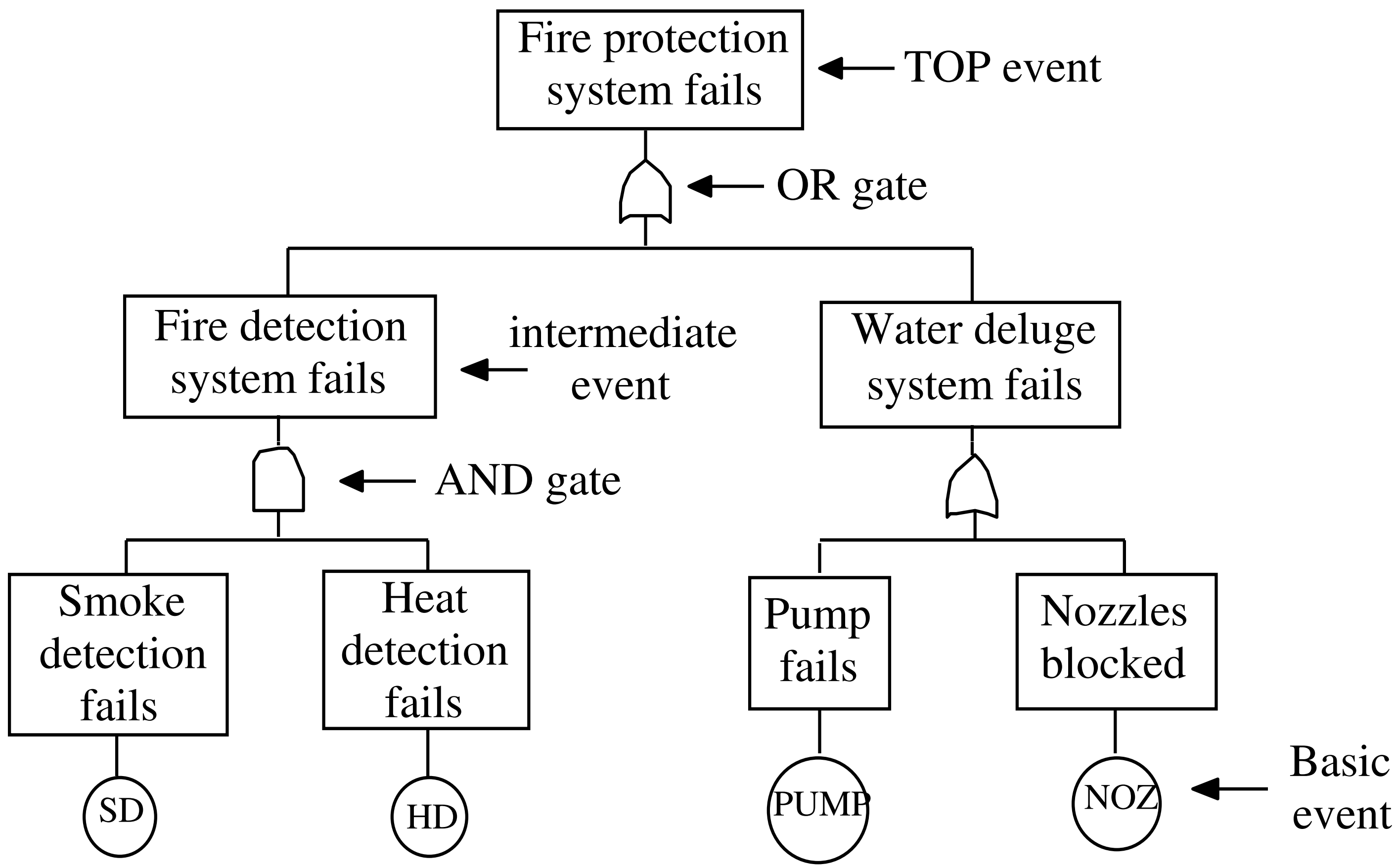
- Redundancy
- Diversity
- Better components
- Better maintenance

Tradeoffs:

Reliability costs money………

but so does downtime and maintenance

FTA



Fire protection system fails
TOP event
OR gate
Fire detection system fails
intermediate event
Water deluge system fails
AND gate
Smoke detection fails
Heat detection fails
Pump fails
Nozzles blocked
SD
HD
PUMP
NOZ
Basic event

FME(C)A

IDENTIFICATION	FUNCTION	FAILURE MODE	FAILURE EFFECT		FAILURE DETECTION METHOD	COMPENSATING PROVISIONS	SEVERITY
			LOCAL EFFECT	SYSTEM			
1.4 Vaporiser Heater	Gasify liquid Butane	1.4/1 Heater unit failure	Liquid Butane passes through Vaporiser	1) System Trip 2) Liquid Butane vented into compound	Low level temperature sensor on line out of vaporiser	Low level trip system on vaporiser outlet	Catastrophic
		1.4/2 Leaks	Liquid Butane leaks	Potential fire / explosion	People in area would observe leak	Isolation of ignition sources and evacuation systems	Catastrophic

FAILURE MODE	LOSS FREQUENCY			$Cm = \alpha\beta\lambda pt$	DATA SOURCE	REMARKS
	λp	α	β			
1.4/1 1.4/2	73 73	0.9 0.1	0.8 0.01	0.46 0.0006	Loughborough University Reliability Data Handbook	

Work Breakdown

Task	Team Member(s)	
Structures/Manufacturing	Ricky Duelley	Rob Penn
Propulsion	Dennis Preus	Daniel Jones
Reliability	Erik Sunday	Balraj Chand
Aerodynamics	Anthony Ricciardi	Ben Hanson
Performance	Megan Prince	Steve Bennett
Stability/ Control	Phil Pesce	Andy Courtneidge, Peter Christie
CAD	Alex Kovacic, Michael Sherman	Alex Humphrey
Systems Integration	Belle Bredehoft	Rob Noble
Costs	Jessica McNeilus	Kris Hanna
Ground Support	Robert Briggs	Craig Dillon
Leadership/Planning	Amanda Chou	Daniel Marshall

Questions?