DESIGN BUILD FLY

Preliminary Design Review

LEADS

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Aerodynamics

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Propulsion

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Outreach /
Lab Coordinator

OVERVIEW

- Missions Overview
- Score Optimization
- Trade Studies
- Design
- Aerodynamics
- Propulsion
- Outreach
- Conclusion

MISSIONS

2014 - 2015

3 MISSIONS **2** AIRCRAFT **1** BONUS MISSION

MISSIONS

2014 - 2015

Manufacturing Support Aircraft
Arrival Flight

Manufacturing Support Aircraft
Delivery Flight

Production Aircraft
Flight

Ground Mission
(bonus)

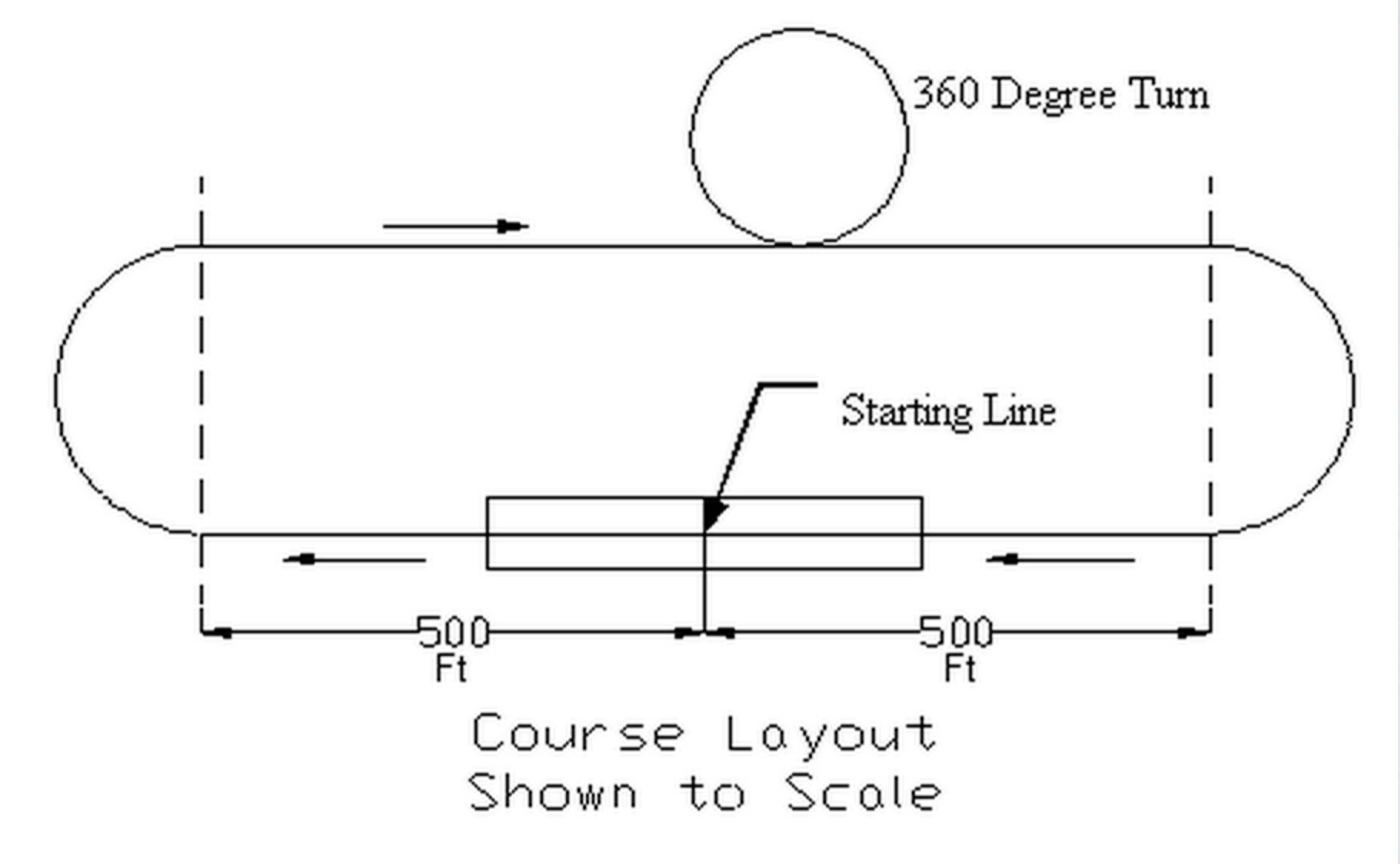
MISSIONS
DEFINITIONS

Subassemblies

Manufacturing Aircraft

Production Aircraft

1 Lap



MISSIONS

MISSION 1 REQUIREMENTS

- The manufacturing support aircraft shall take off within 100ft.
- The aircraft shall be unloaded
- The aircraft shall fly three laps within 5 minutes
- The aircraft shall complete a successful landing

MF1 = 2.0 (Complete)

MF1 = 0.1 (Incomplete)

MISSIONS

MISSION II REQUIREMENTS

- The Manufacturing aircraft shall takeoff, fly one lap and land with each subassembly of the production aircraft
- After each lap, the aircraft shall taxi to the payload change area
- The aircraft shall fly each subassembly of the production aircraft.
- The aircraft shall fly all subassemblies within 10 minutes
- The aircraft shall complete a successful landing for every landing

MF2 = 4.0 Aircraft flies all subassemblies within the time

MF2 = 2.0 Aircraft successfully flies some, but not all subassemblies

MF2 = 0.1 Aircraft does not complete a successful flight

MISSIONS

MISSION III REQUIREMENTS

- The production aircraft shall fly a full 32 oz. Gatorade internally
- The production aircraft shall takeoff within 100 ft.
- The aircraft shall fly 3 laps within 5 minutes
- The aircraft shall complete a successful landing

PF = 2.0 (Aircraft completes all laps within the time period)

PF = 1.0 (Aircraft does not complete required number of laps or goes over time)

PF = 0.1 (Aircraft does not complete a successful flight)

MISSIONS

BONUS MISSION REQUIREMENTS

- After completing the full mission 2 requirements, all production aircraft subassemblies shall be brought to the designated area
- The production aircraft shall be constructed from its subassemblies within 2 minutes
- The completed aircraft shall pass the wing tip lift test and the controls systems check

Bonus = 2.0 (Aircraft built within time limit and passes tests)

Bonus = 0 (Aircraft does not meet bonus mission requirements)

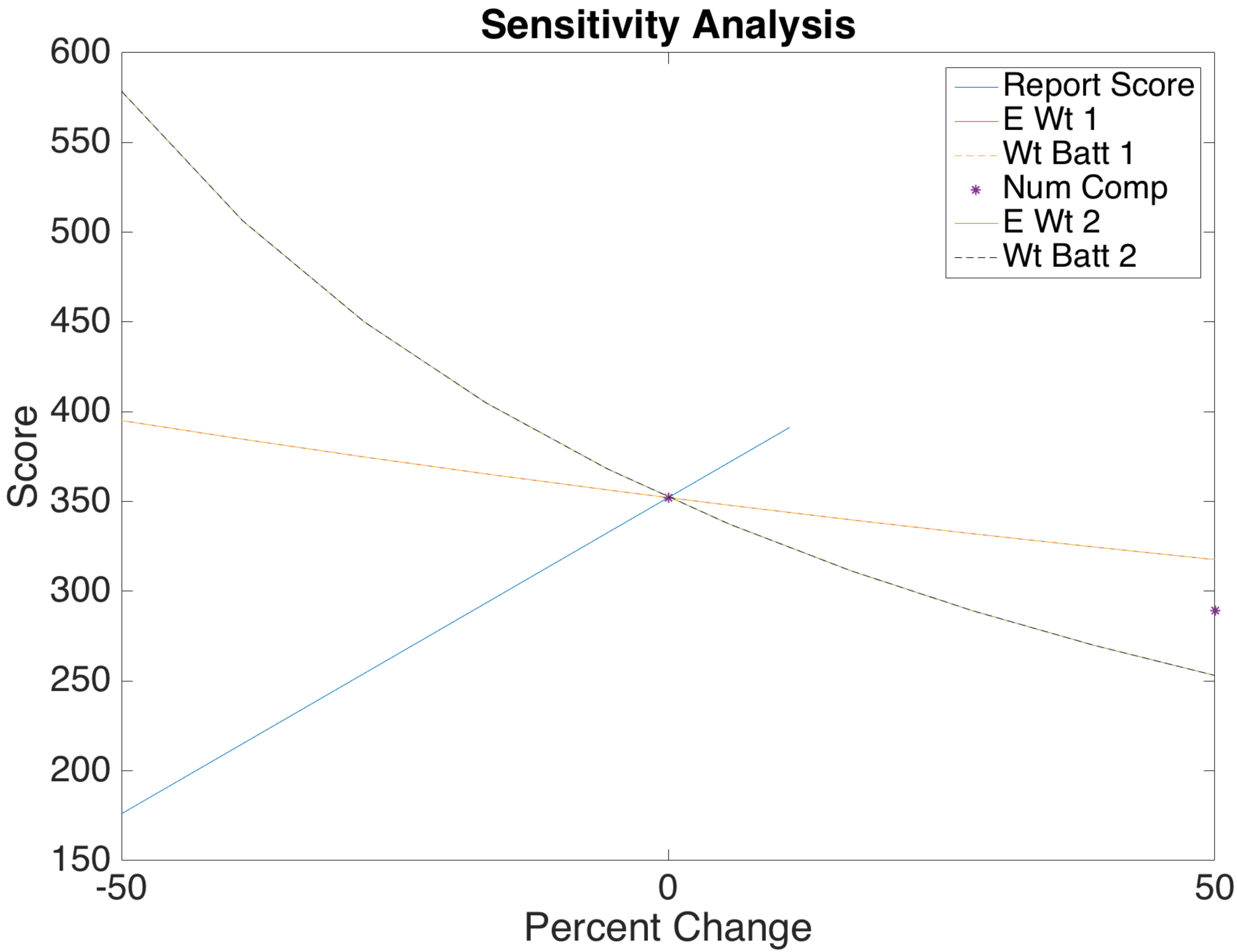
SCORING

$$Score = \frac{Written * Mission_{Total}}{RAC}$$

$$RAC = EW1 * Wt_{Battery1} * N_{Components} + EW2 * Wt_{Battery2}$$

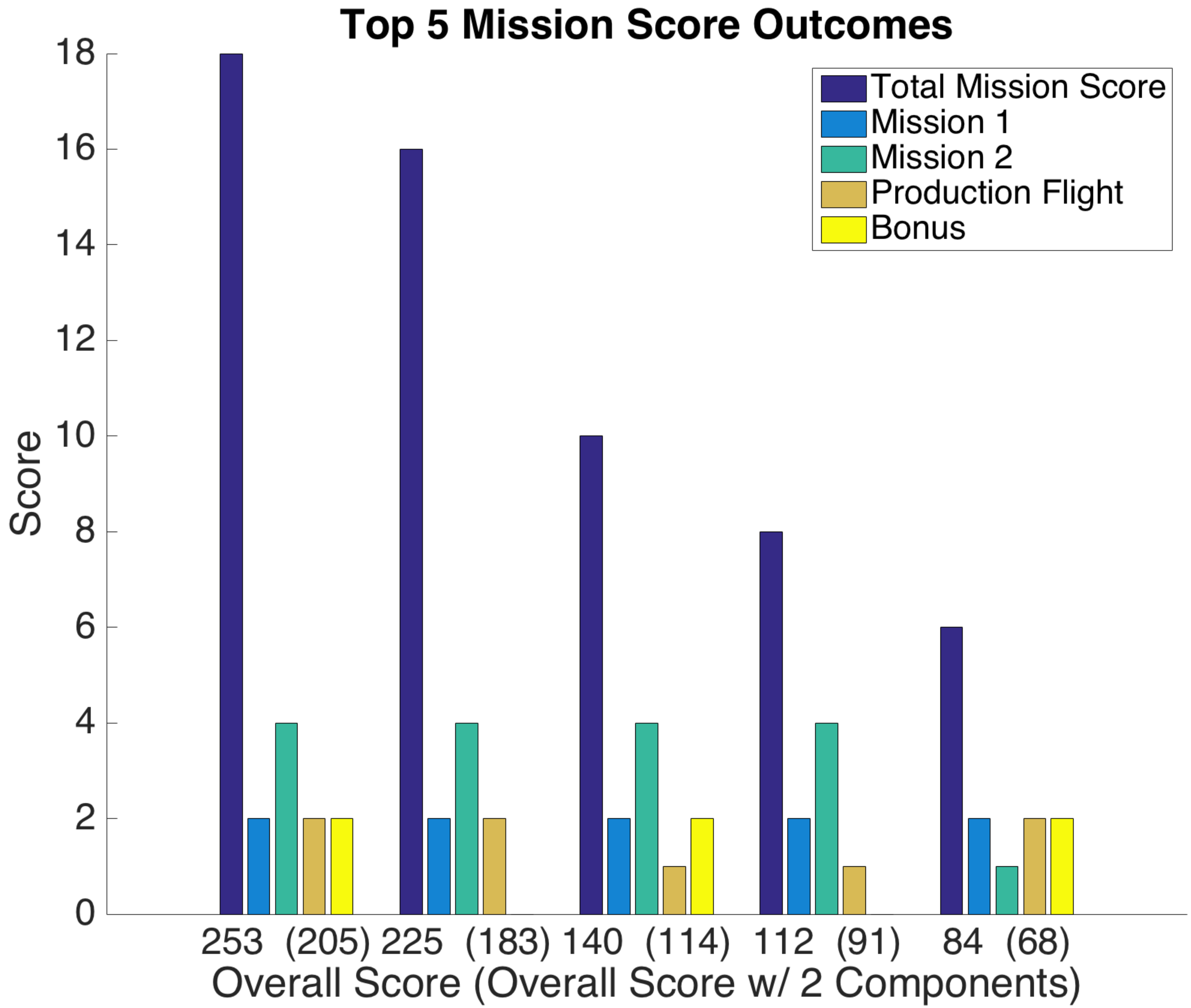
$$Mission_{Total} = MF1 * MF2 * PF + Bonus$$

SCORING



Sensitivity Analysis
Score
Percent Change
600
550
500
450
400
350
300
250
200
150
-50
0
50
Report Score
E Wt 1
Wt Batt 1
Num Comp
E Wt 2
Wt Batt 2

SCORING


Top 5 Mission Score Outcomes
Score
0
2
4
6
8
10
12
14
16
18
Total Mission Score
Mission 1
Mission 2
Production Flight
Bonus
253 (205)
225 (183)
140 (114)
112 (91)
84 (68)
Overall Score (Overall Score w/ 2 Components)

PRODUCTION AIRCRAFT

TRADE STUDIES

Parameter	Lift-to-Drag Ratio	Payload Suitability	Empty Weight
Configurations \ Parameter Weight	0.2	0.25	0.1
Conventional	4	5	3
Blended Fuselage	4	3	4
Flying wing	5	1	5
Box wing	5	5	2
Delta Wing	3	5	3
Pod (last year)	2	4	4

Parameter	Ease of Manufacturing/Heritage	Control Authority	Ease of Taking Apart	Overall Score
Configurations \ Parameter Weight	0.05	0.2	0.4	1.2
Conventional	3	5	2	4.3
Blended Fuselage	3	3	4	4.3
Flying wing	2	2	4	3.85
Box wing	3	4	1	3.8
Delta Wing	2	3	3	4.05
Pod (last year)	2	2	3.5	3.7

PRODUCTION AIRCRAFT

TRADE STUDIES

Paramter	Weight	Interference	Stability
Configurations \ Parameter Weight	0.3	0.3	0.4
Conventional	3	3	4
T-Tail	3	3	4
H-Tail	3	4	4
V-Tail	4	4	4
NO tail	5	5	1

Paramter	Volume Efficiency	Drag	Overall Score
Configurations \ Parameter Weight	0.4	0.3	1.7
Conventional	2	3	5.1
T-Tail	2	3	5.1
H-Tail	3	4	4.5
V-Tail	4	4	6.8
NO tail	5	5	6.9

MANUFACTURING AIRCRAFT

TRADE STUDIES

Parameter	Lift-to-Drag Ratio	Payload Suitability	Empty Weight
Configurations \ Parameter Weight	0.3	0.3	0.2
Conventional	3	2	3
Blended Fuselage	4	4	5
Flying wing	5	1	5
Box wing	5	3	3
Delta Wing	4	2	4
Pod	2	4	3

Parameter	Ease of Manufacturing/Heritage	Control Authority	volume Efficiency	Overall Score
Configurations \ Parameter Weight	0.05	0.2	0.3	1.35
Conventional	3	5	4	3.25
Blended Fuselage	2	2	4	3.9
Flying wing	2	2	1	3.3
Box wing	4	4	4	4
Delta Wing	3	3	2	3.35
Pod	3	4	3	3.35

MANUFACTURING AIRCRAFT

TRADE STUDIES

Tail Selection				
Paramter	Weight	Interference	Drag	Overall Score
Configurations \ Parameter Weight	0.4	0.3	0.3	1
Conventional	4	4	4	4
T-Tail	3	3	4	3.3
H-Tail	3	3	3	3
V-Tail	4	3	4	3.7
Canard	4	4	4	4
tail less	5	3	5	4.4

PRODUCTION AIRCRAFT

Objectives

Volume Efficiency

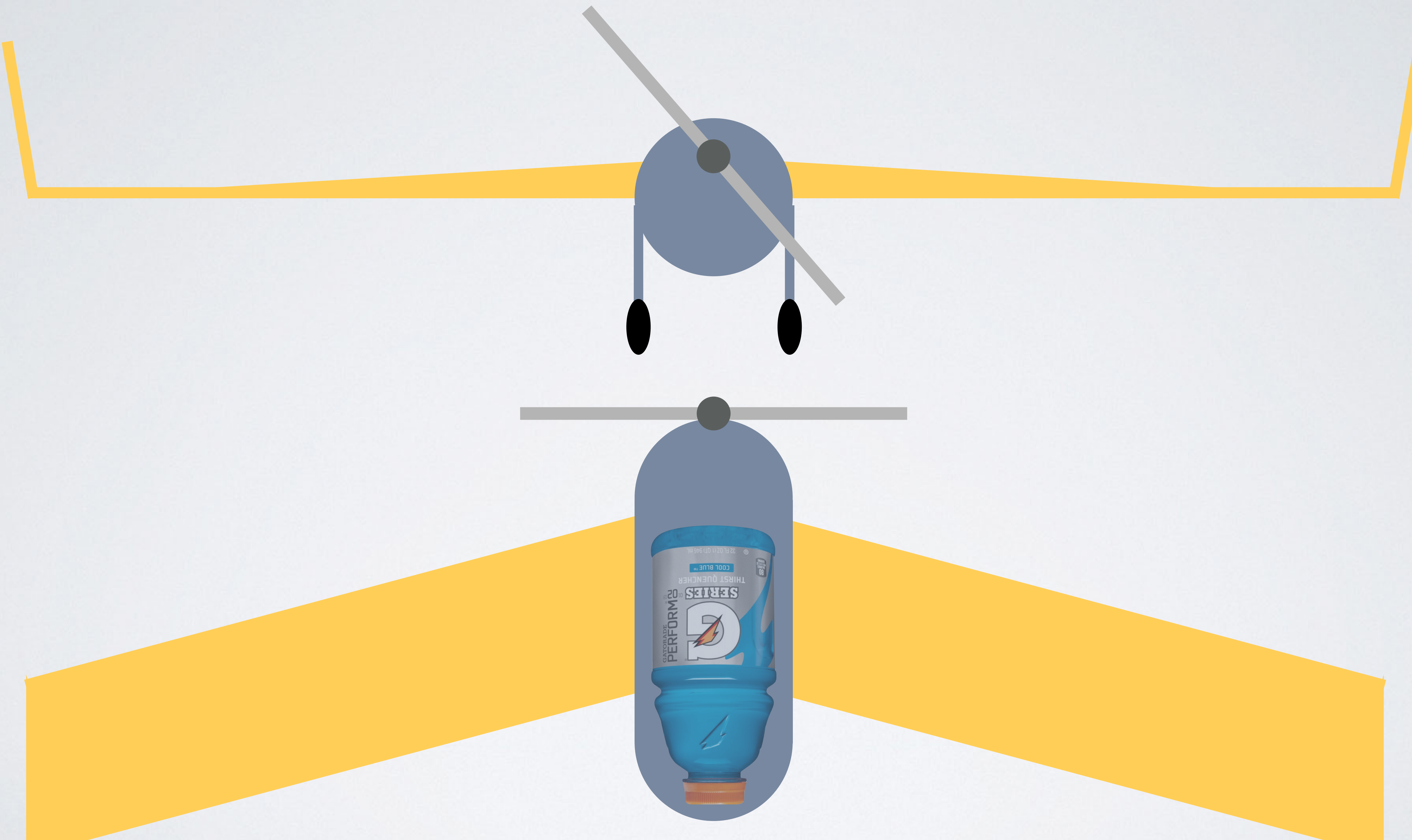
- Payload Accommodation
- Propulsion Hardware Accommodation
- Landing Gear
- Universal Structural Hub

Lightweight & Rigid Construction

- Universal Structural Hub

PRODUCTION AIRCRAFT

CONFIGURATION

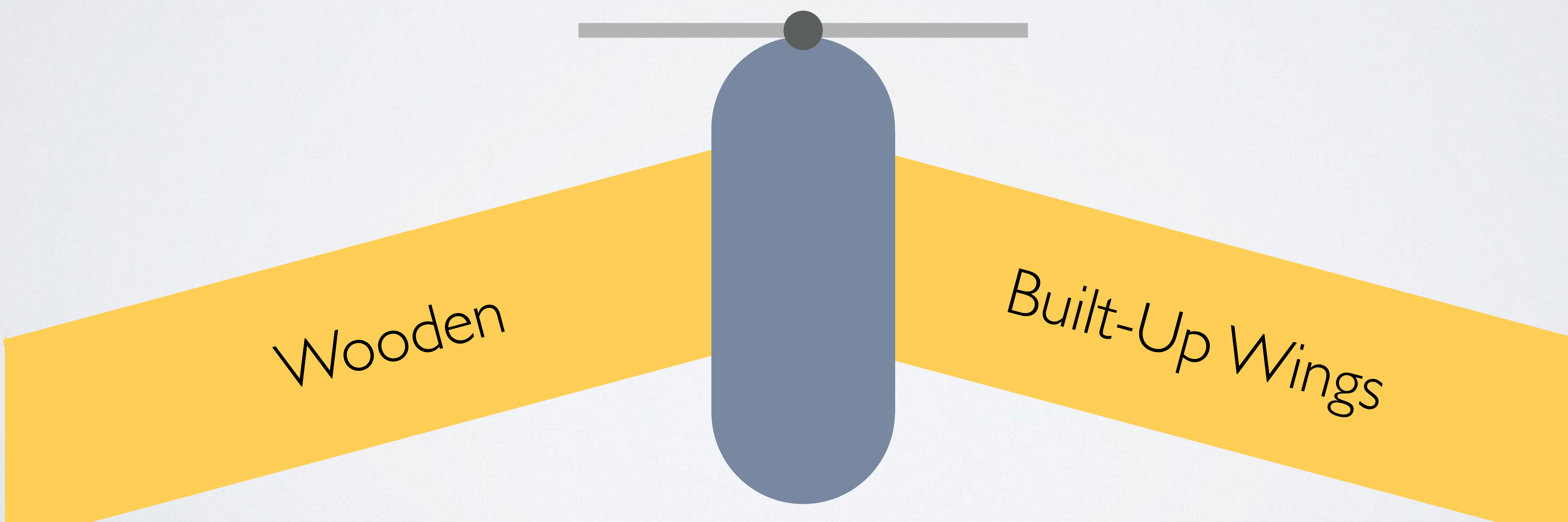


PRODUCTION AIRCRAFT

MATERIALS

Carbon Fiber
Monocoque Fuselage

Single Rigid
Body

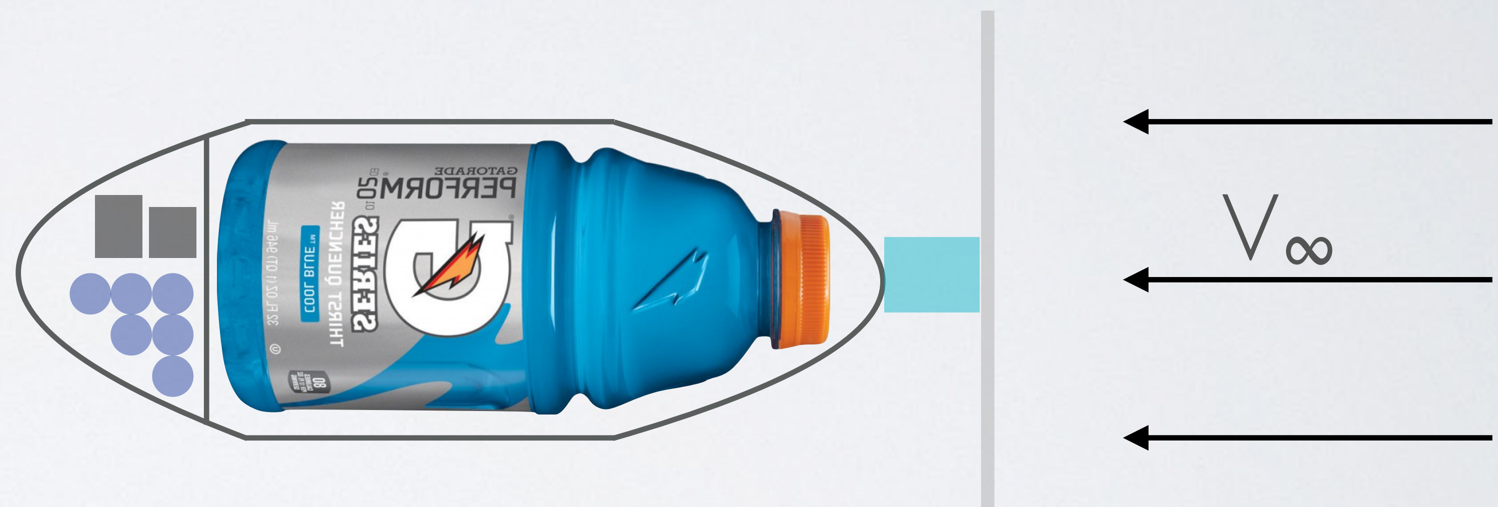


PRODUCTION AIRCRAFT

PAYLOAD ORIENTATION

Backwards

Forwards



PRODUCTION AIRCRAFT

PAYLOAD ORIENTATION

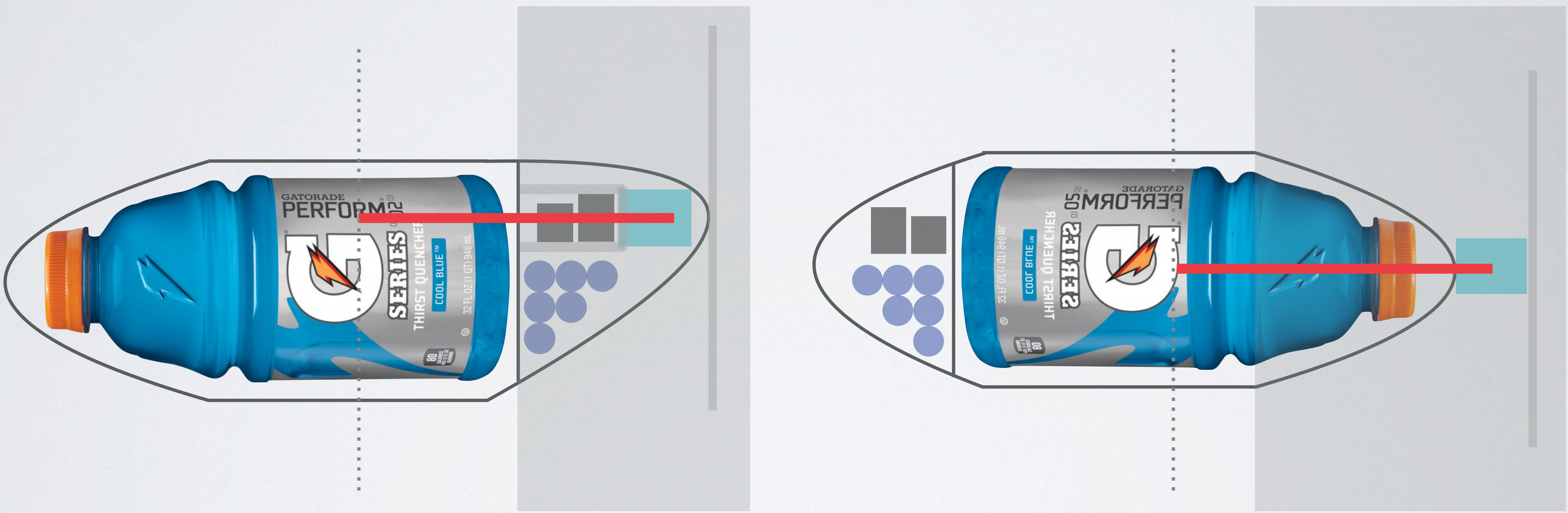
- Additional Prop Clearance
- Easier to load/unload
- Less Load-Bearing Structure
- CG ?

PRODUCTION AIRCRAFT

CG

Backwards

Forwards

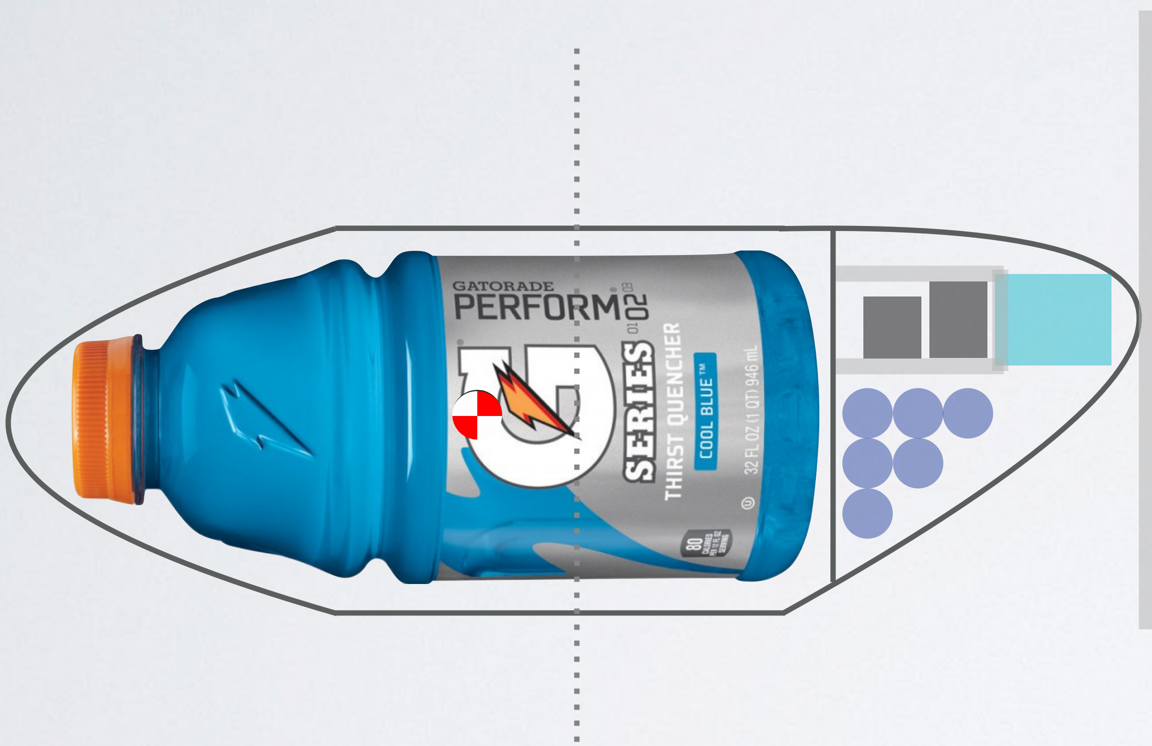


Slightly shorter moment arm
from geometric center
to motor

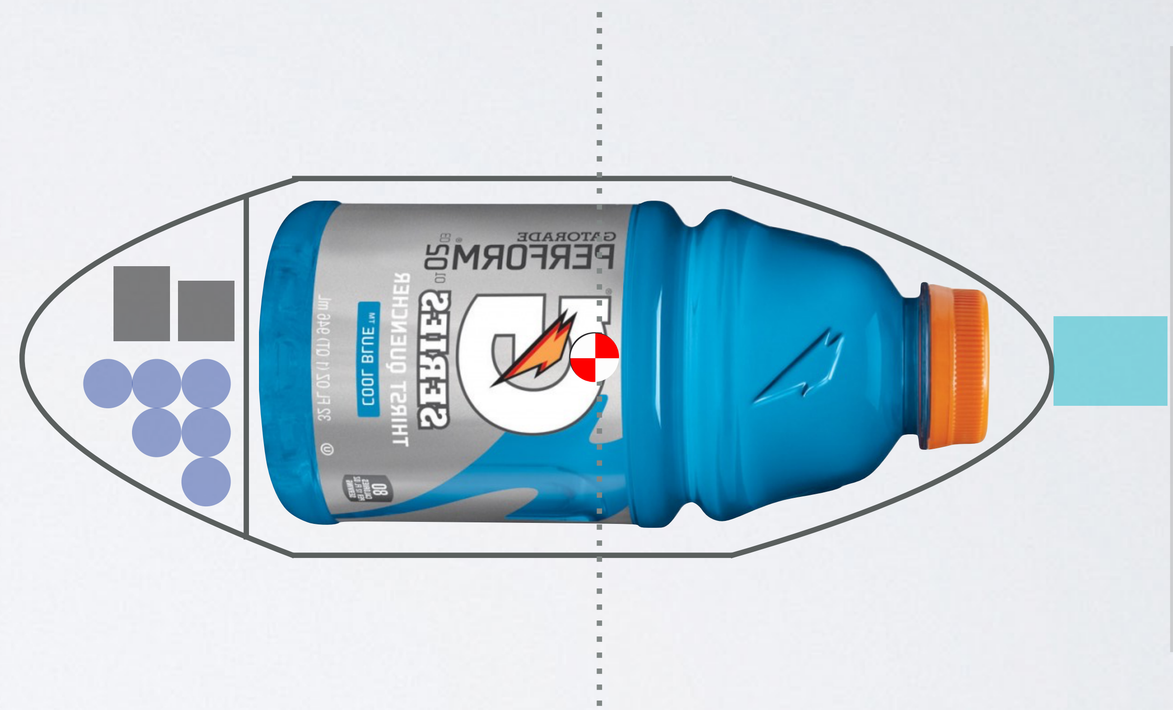
PRODUCTION AIRCRAFT

CG

Backwards



Forwards

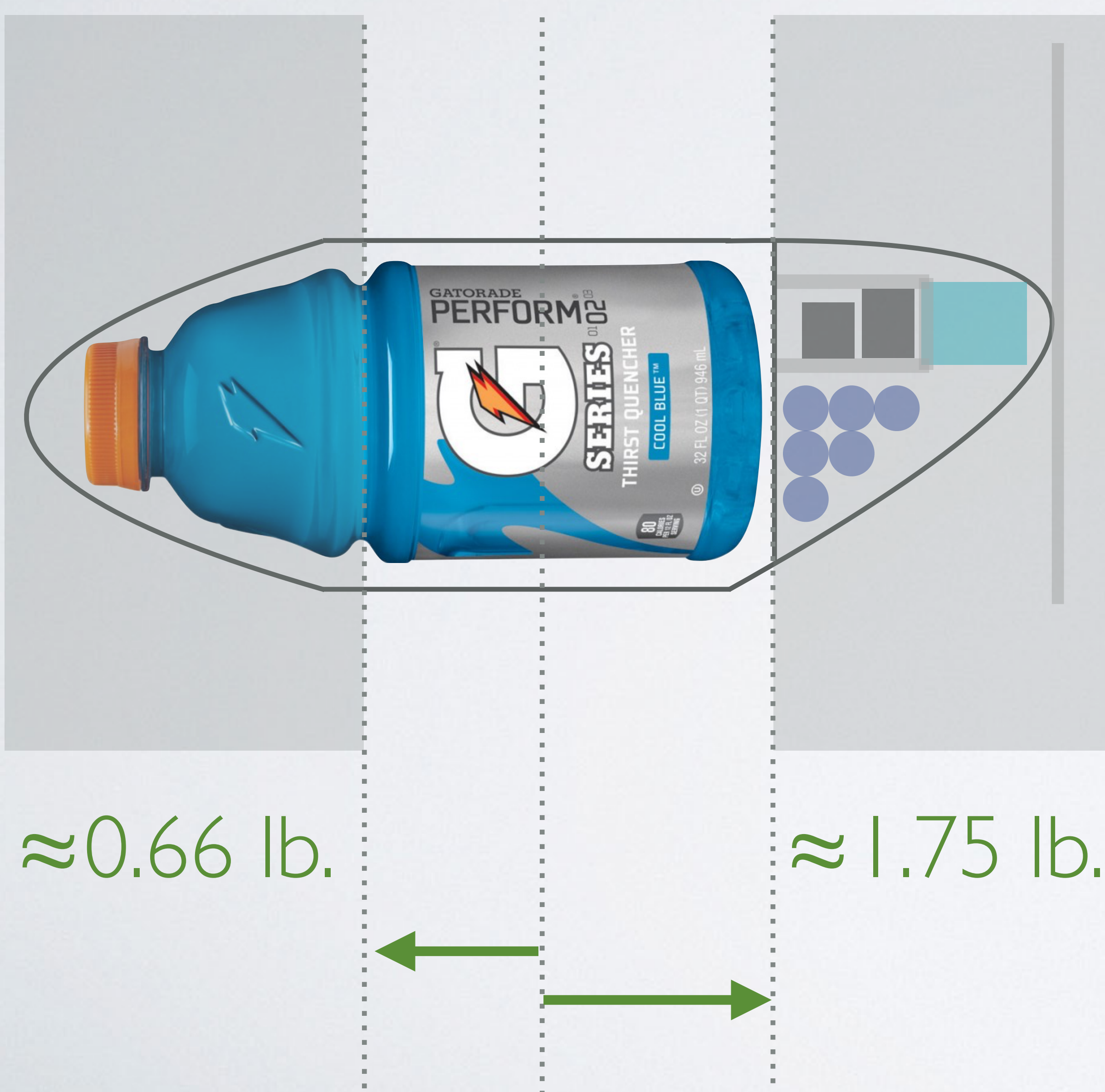


Gatorade CG Back

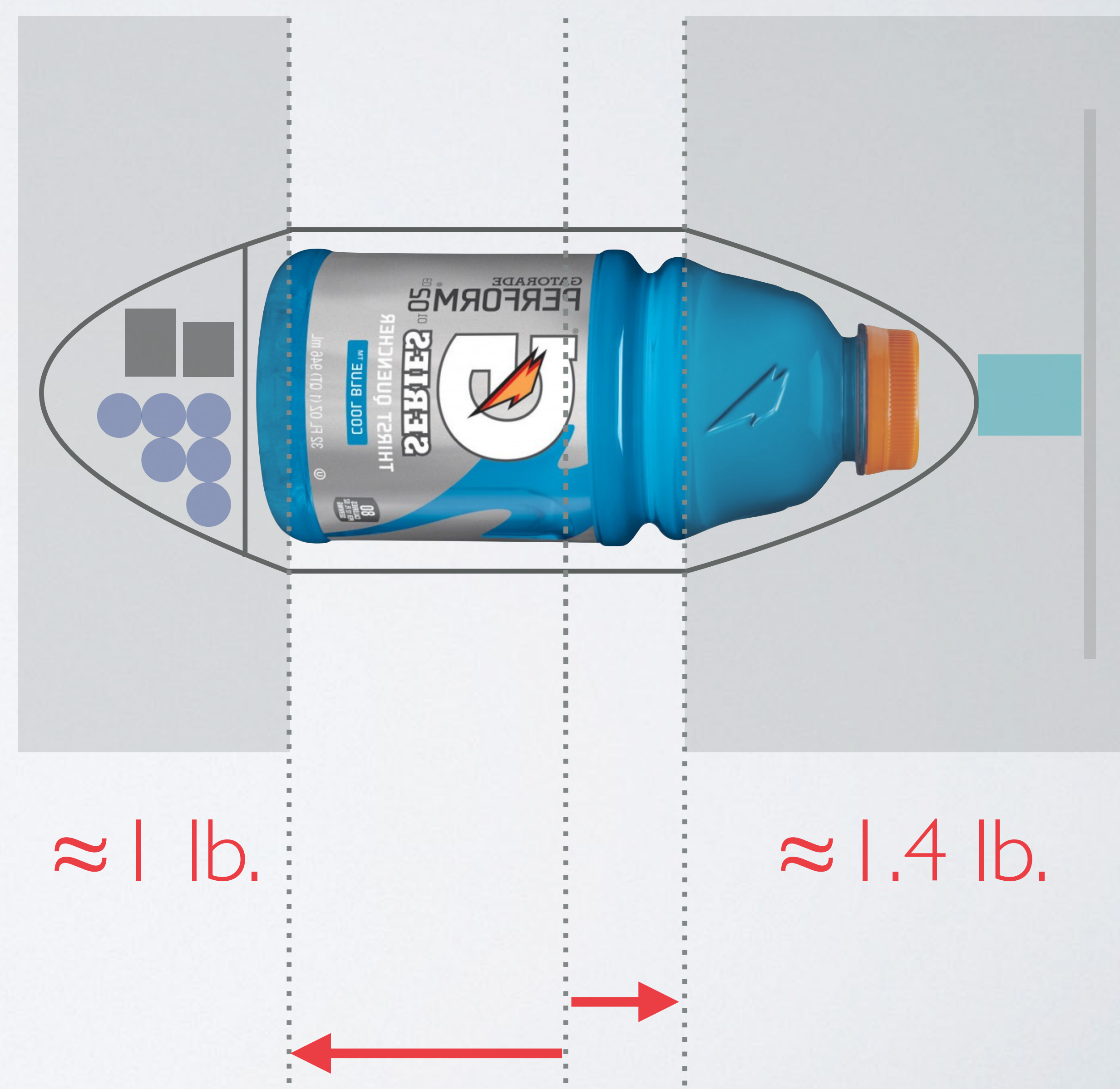
PRODUCTION AIRCRAFT

CG

Backwards



Forwards



PRODUCTION AIRCRAFT

PAYLOAD ORIENTATION

Backwards

Forwards

- Additional Prop Clearance
- Easier to load/unload
- Less Load-Bearing Structure
- **Unknown** CG Difference

PRODUCTION AIRCRAFT

BASIC LAYOUT

Side View

Space Efficient

Aerodynamic Shape

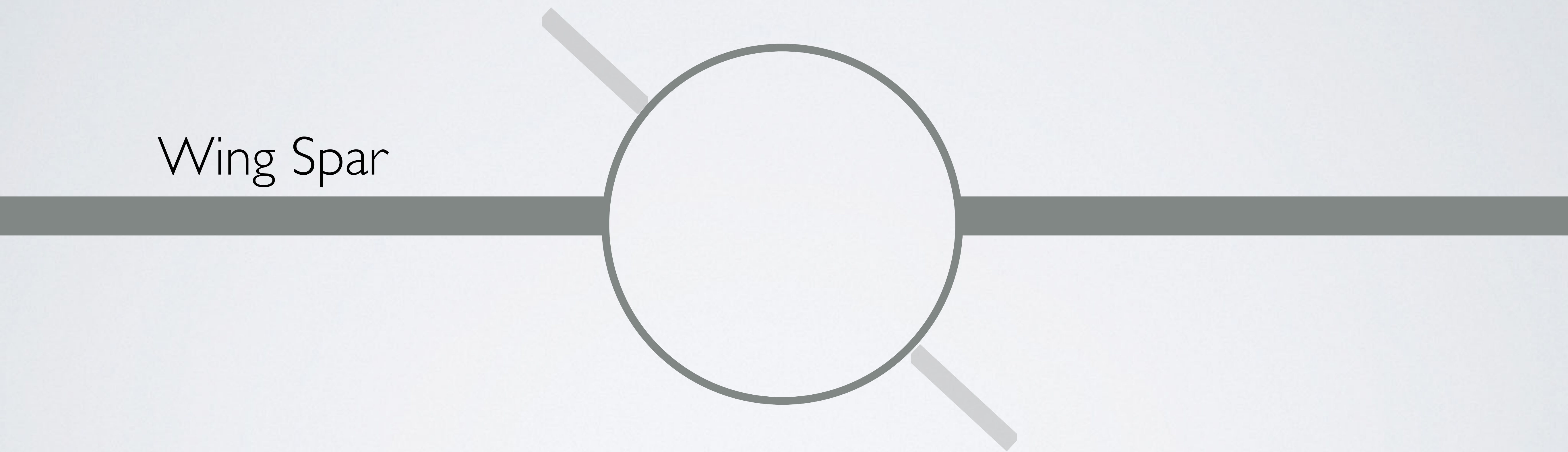
Limited Structure

Easily Optimize Nosecone Volume

PRODUCTION AIRCRAFT

BASIC LAYOUT

Back View

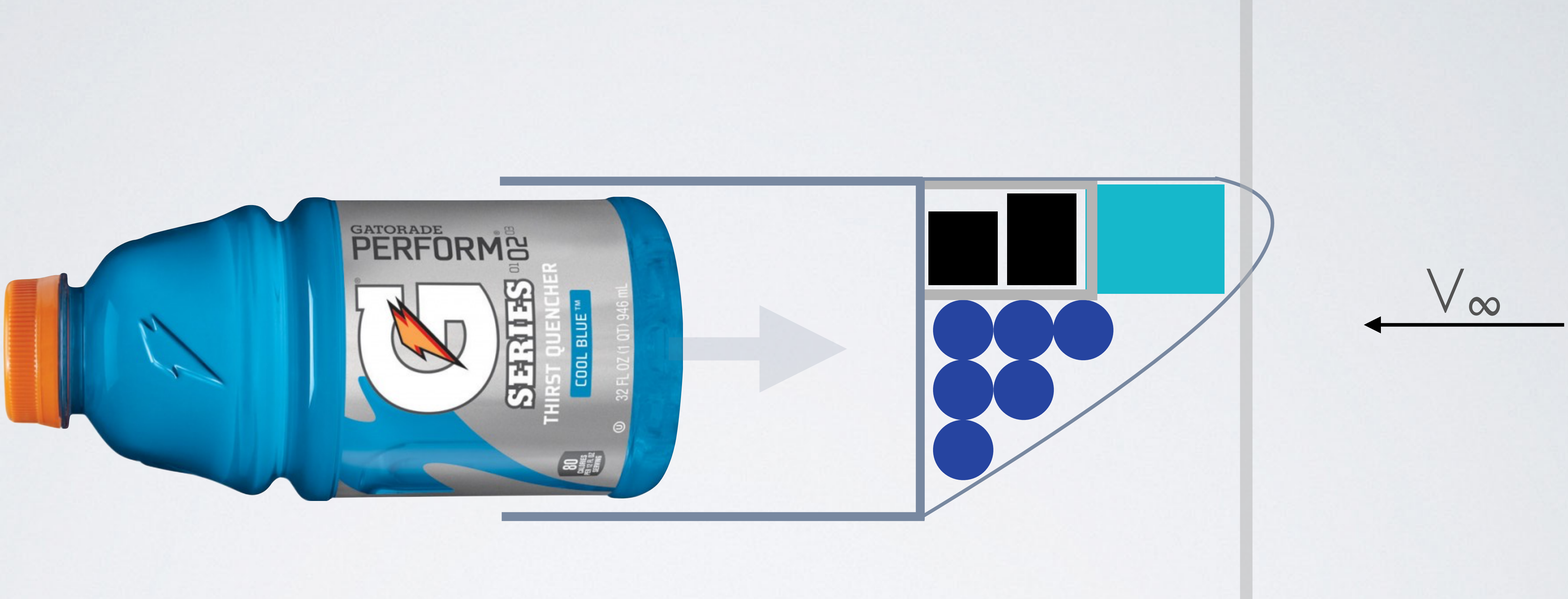


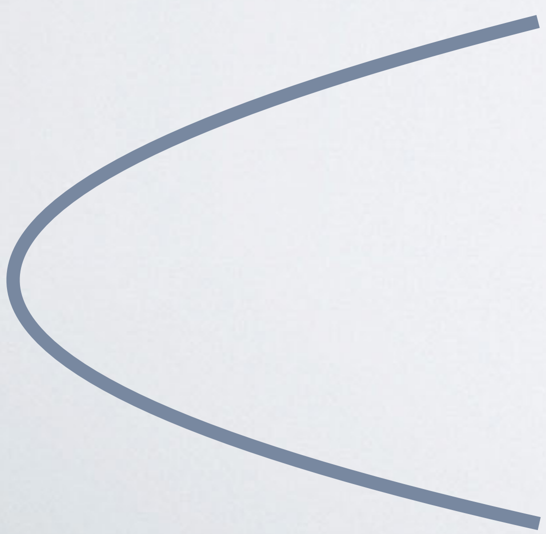
Rigid Carbon Fiber Tube to
Support Wing Loading

PRODUCTION AIRCRAFT

LOADING

Side View





Removable Tail Cone

PRODUCTION AIRCRAFT

LANDING GEAR

4 Wheel Layout

Easily Varied Landing Gear Height

PRODUCTION AIRCRAFT

CONCERNS

CG Location ⟶ Tipping Backwards

Close Set Wheels ⟶ Tipping Side to Side

PRODUCTION AIRCRAFT

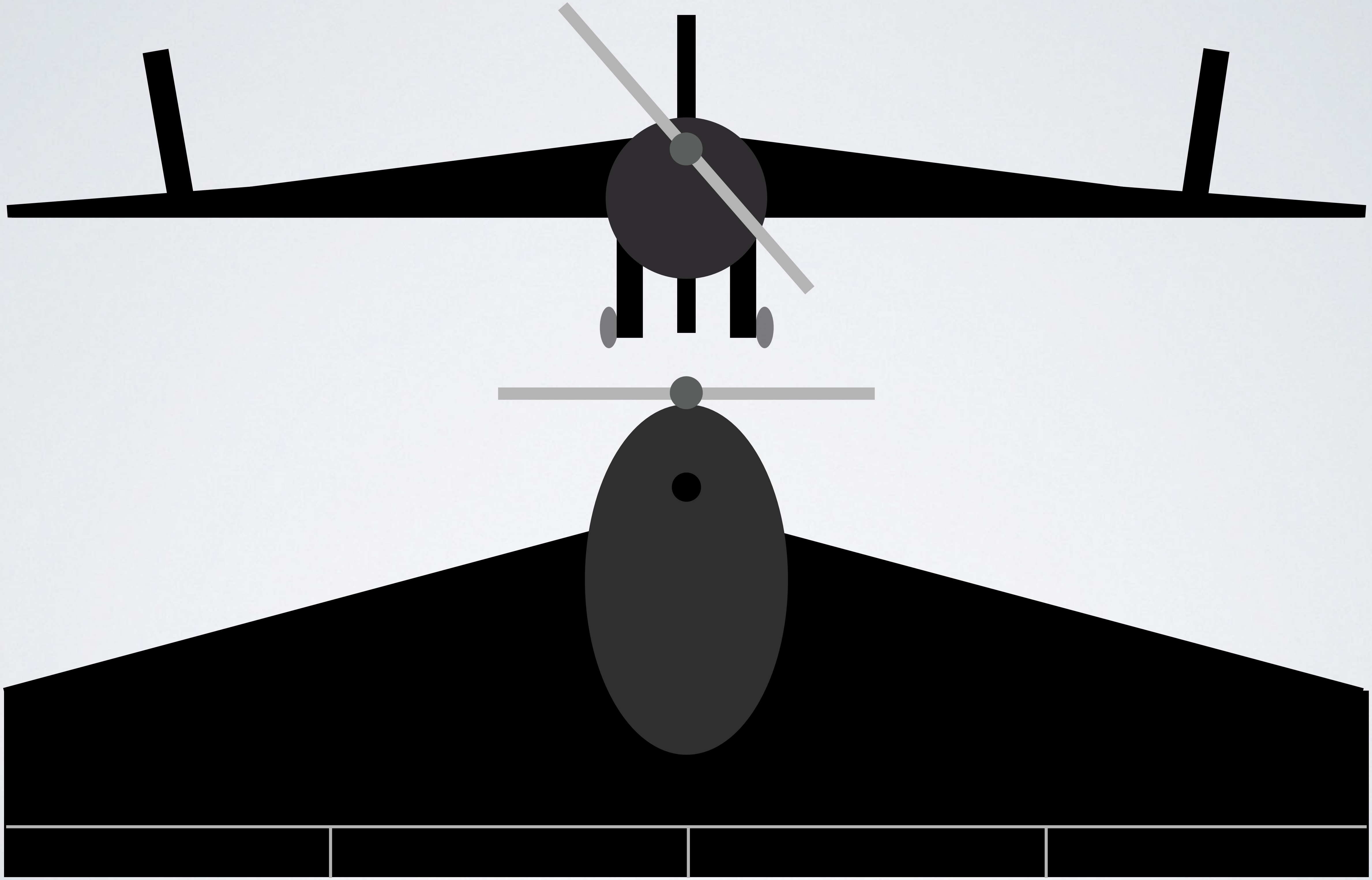
CONCERNS

Tipping Backwards → Move Propulsion Forward

Tipping Side to Side → Wing Tip Skids

MANUFACTURING AIRCRAFT

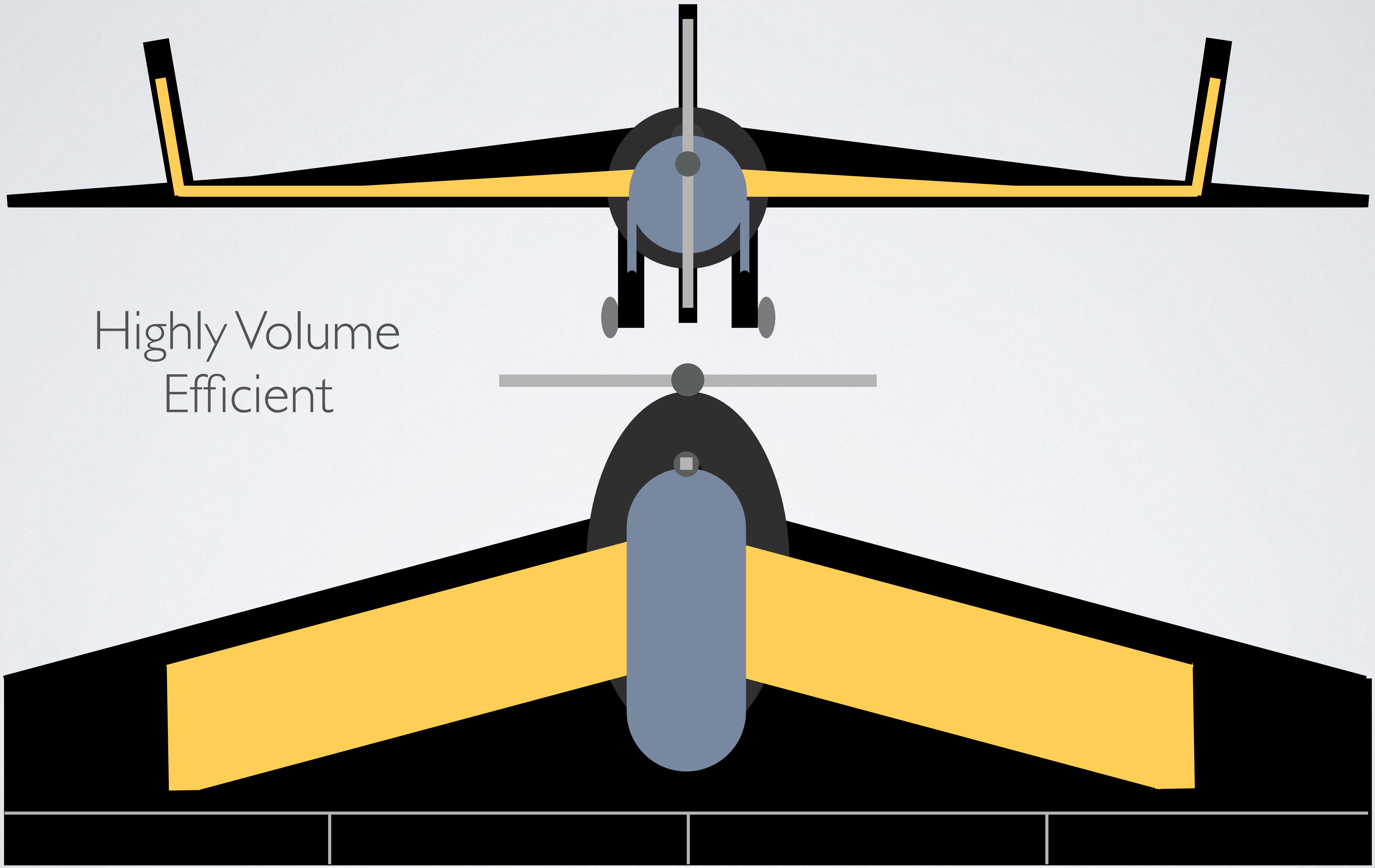
CONFIGURATION



MANUFACTURING AIRCRAFT

PAYLOAD ACCOMODATION

Highly Volume
Efficient

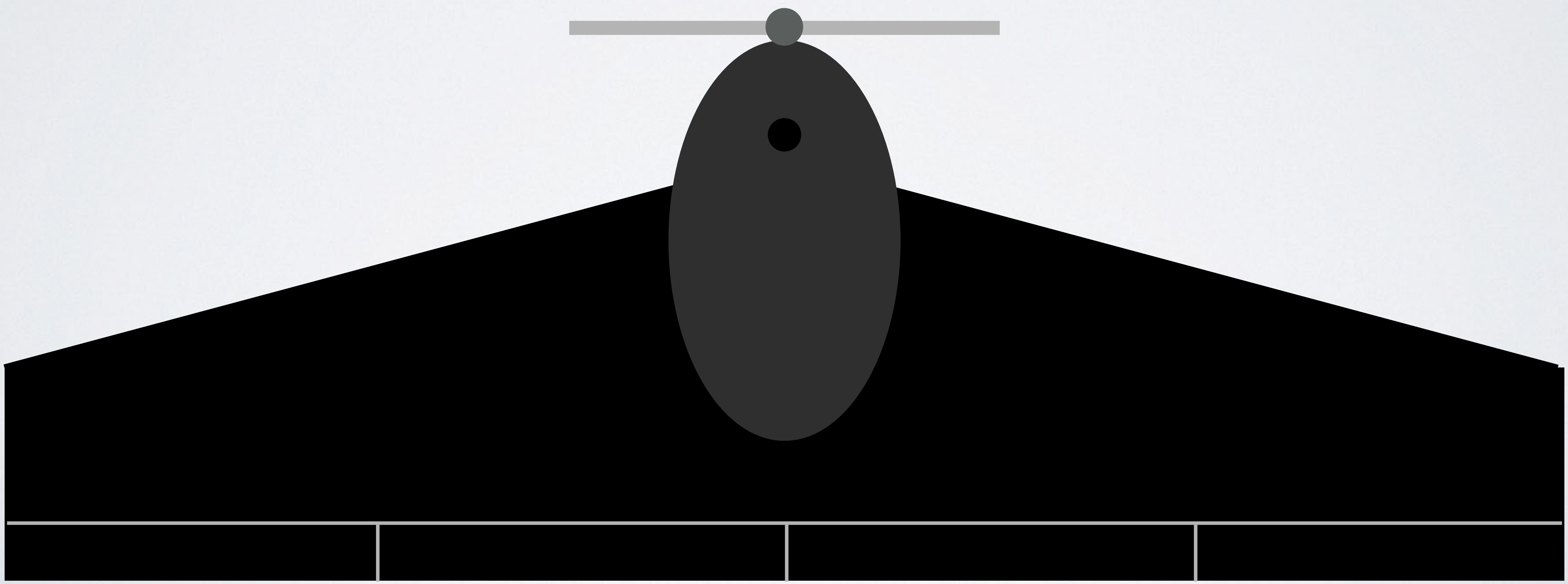


MANUFACTURING AIRCRAFT

CONFIGURATION

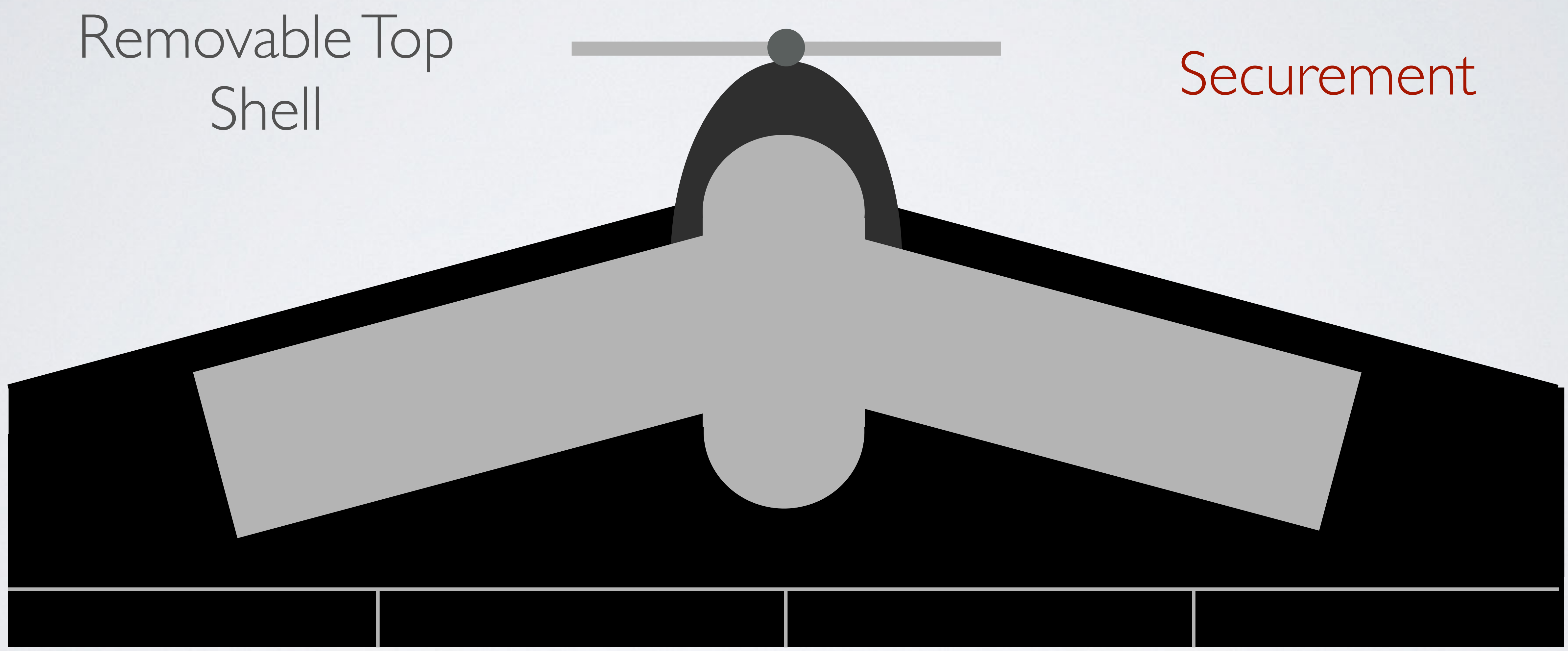
Entirely Carbon
Fiber Monocoque

Accurate
Shell Fitting

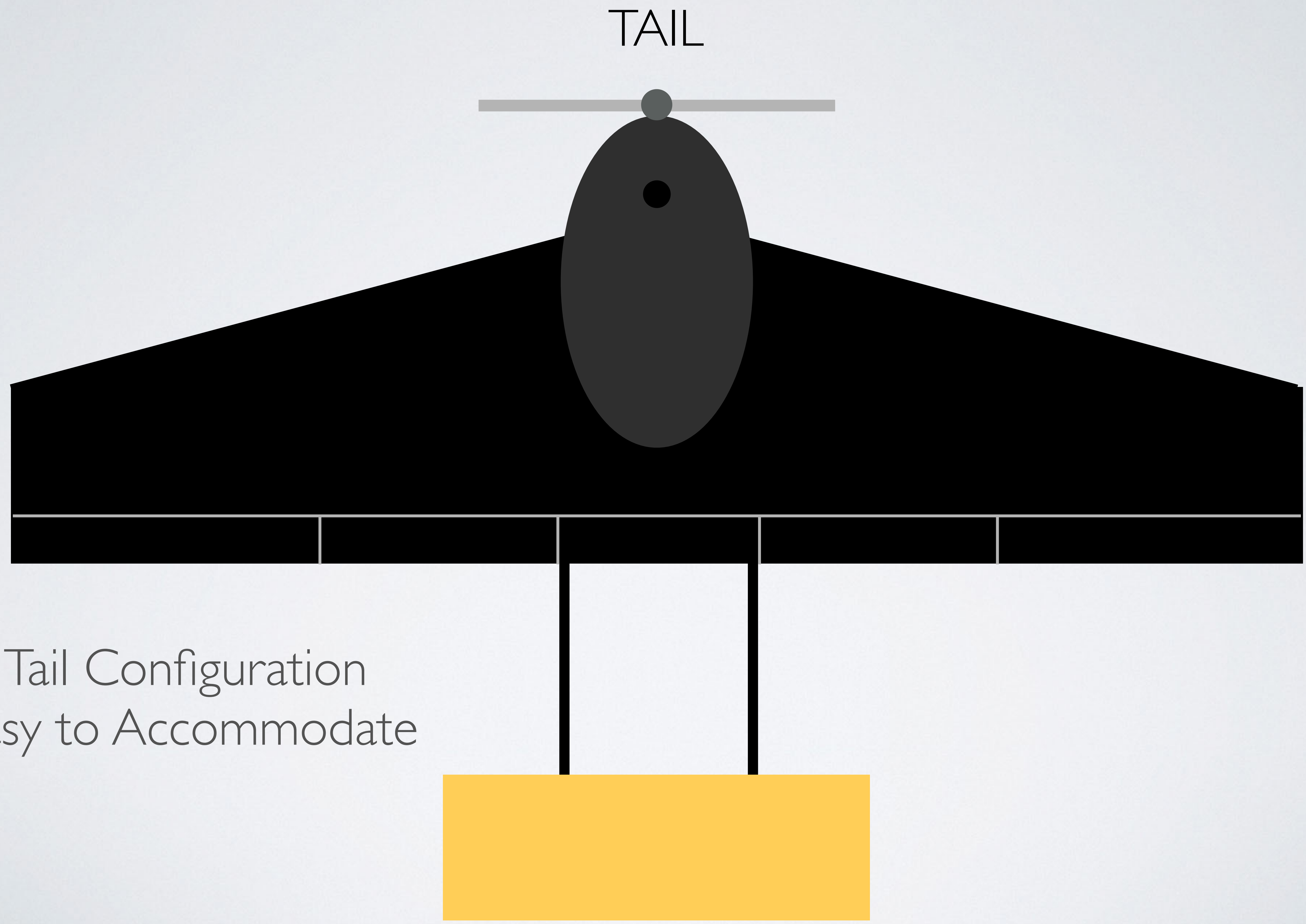


MANUFACTURING AIRCRAFT

LOADING / UNLOADING



MANUFACTURING AIRCRAFT



Tail Configuration
Easy to Accommodate

AERODYNAMICS

OVERVIEW

- Choose an Airfoil
  - Based on relative sizing to other airfoils
- Determine Wing Planform Size
  - Based on relative weights

AIRFOIL SELECTION

PRODUCTION AIRCRAFT

High Lift

Small Wing Span

High $C_{L,MAX}$

Small C_M

AIRFOIL

ASSUMPTIONS

- Based on general equations that govern TW,PW, wing loading
- Used constraints for competition
- Average Cruise Velocity of 50 [ft/s]
- Max Load Factor of 2.5 [G's]
- e = 0.8

TOP AIRFOILS

PRODUCTION AIRCRAFT

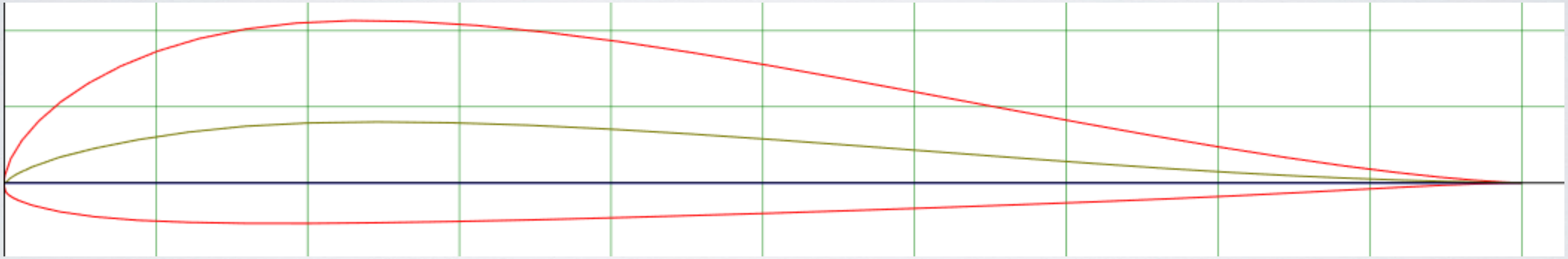
AR = 4

Airfoil Name	$C_{L, Max}$	$C_{M\ \alpha = 0}$	Power Required [W]
MH82	1.63	-0.02	209
GOE 528	1.65	-0.12	250
S7055	1.20	-0.07	176

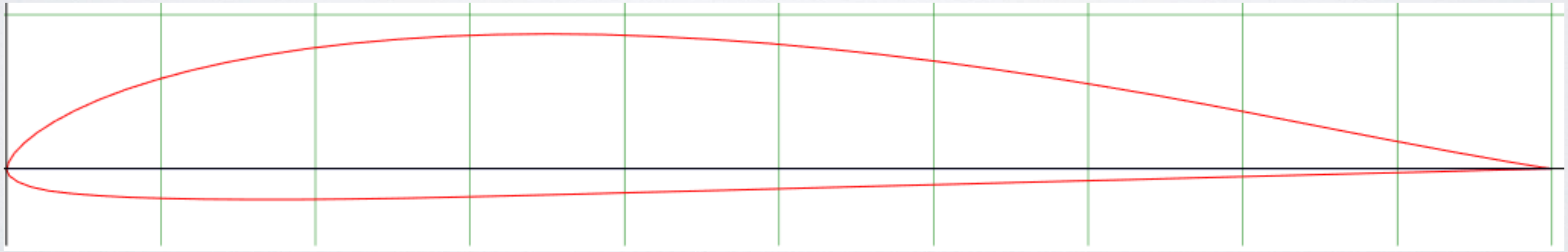
TOP AIRFOILS

PRODUCTION AIRCRAFT

MH82



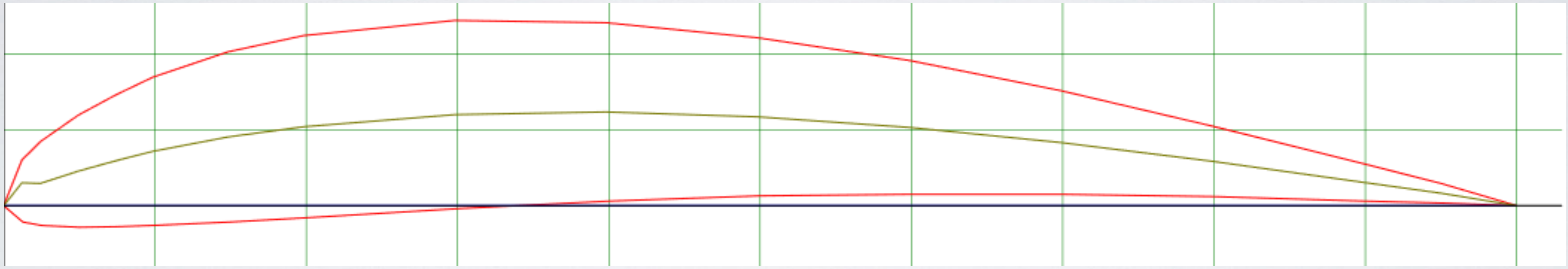
S7022



TOP AIRFOILS

PRODUCTION AIRCRAFT

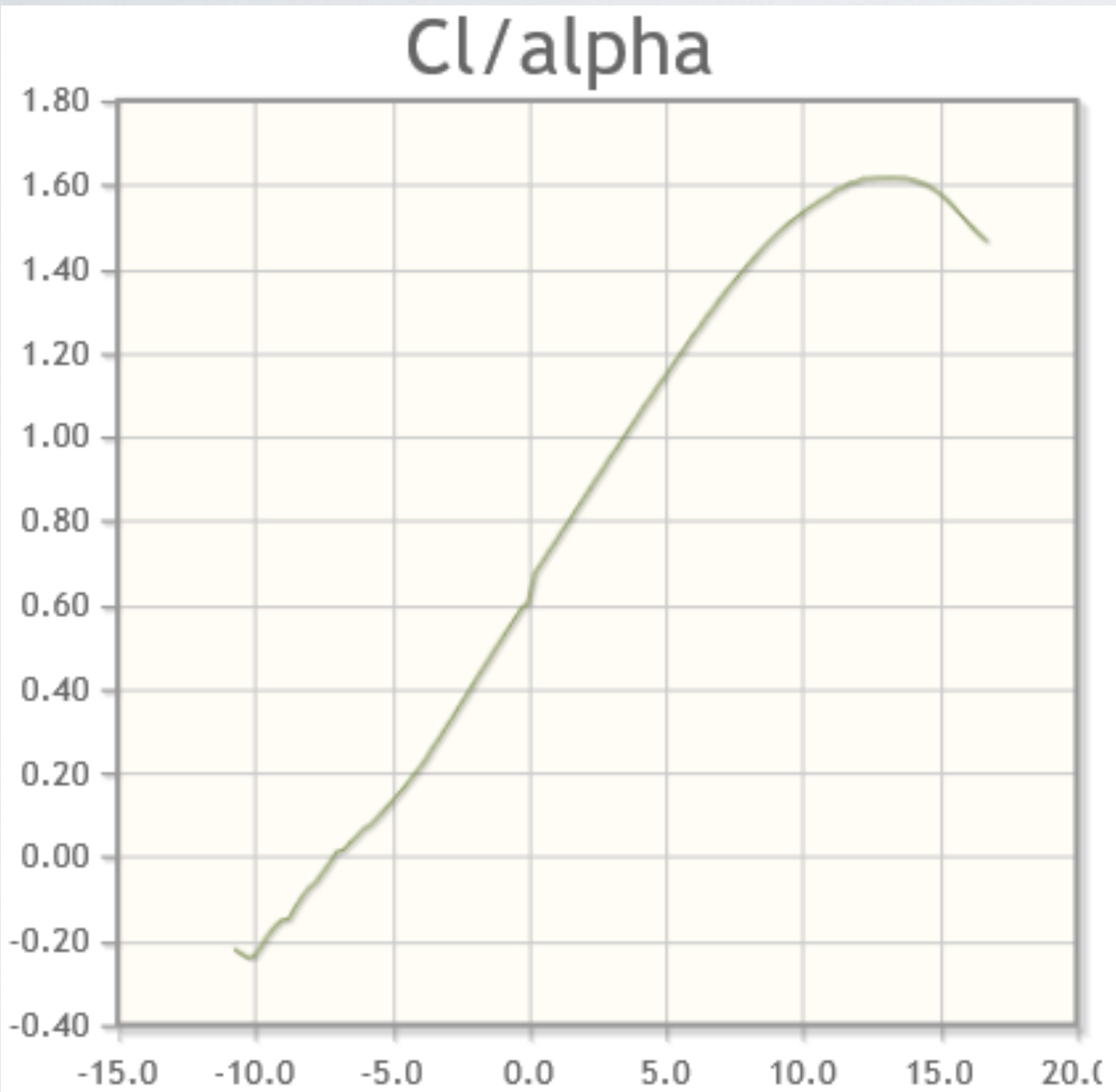
GOE 528



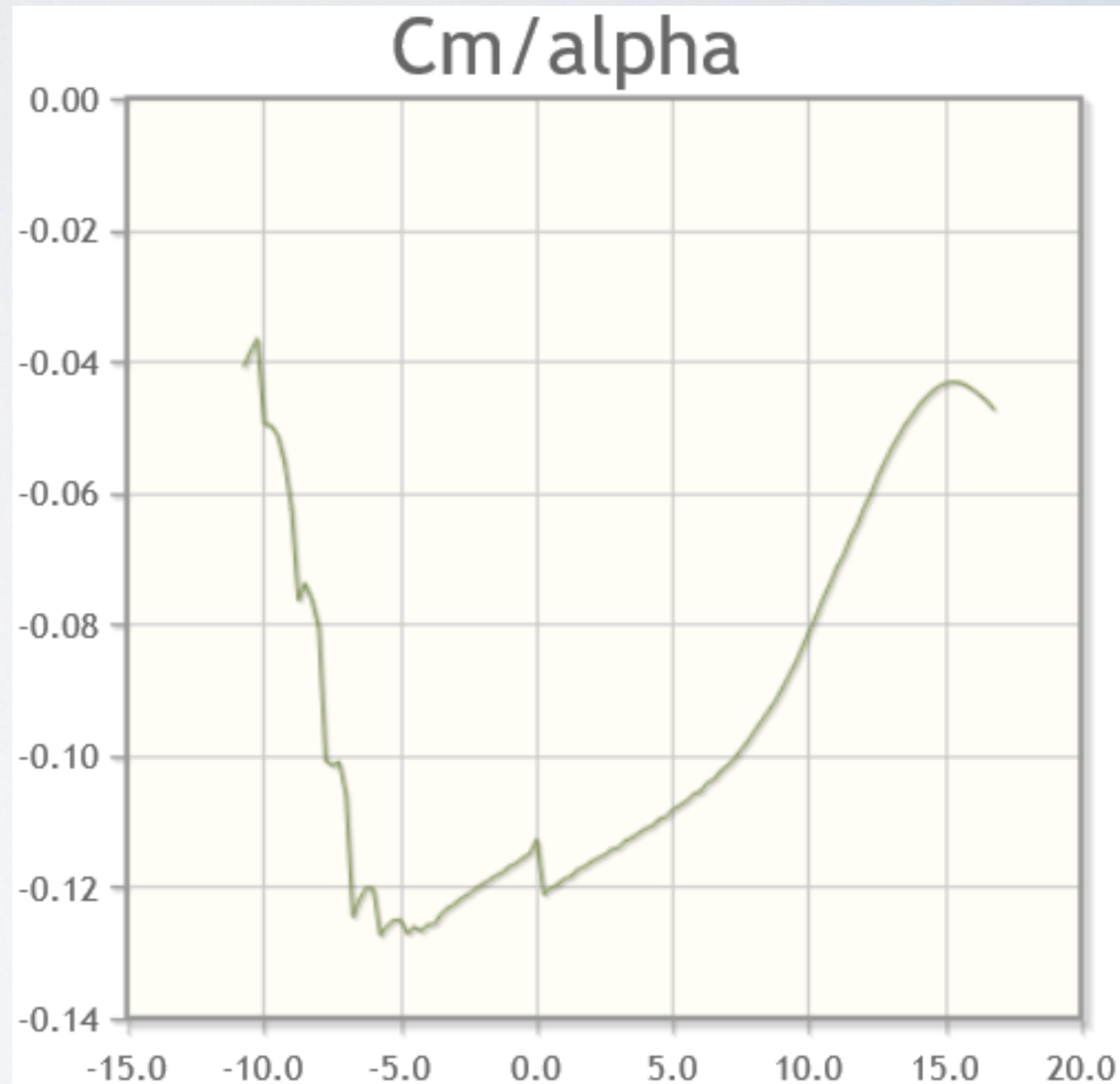
- Max Thickness: 12.5%
- No Thin Leading Edge
    - Easy to Manufacture
    - Durable
- Higher Power Requirement
    - Higher CM
    - Less stability

PARAMETERS

GOE 528



- Lift Advantage
- Minimal Flow Separation
- Linear curve



- Moment
- Fairly Linear curve in Operating α
- Slightly Higher CM

AIRFOIL SELECTION

MANUFACTURING AIRCRAFT

Requires Thick Airfoil
at Root

High C_L

Low C_M

High Lift-to-Drag

TOP AIRFOILS

MANUFACTURING AIRCRAFT

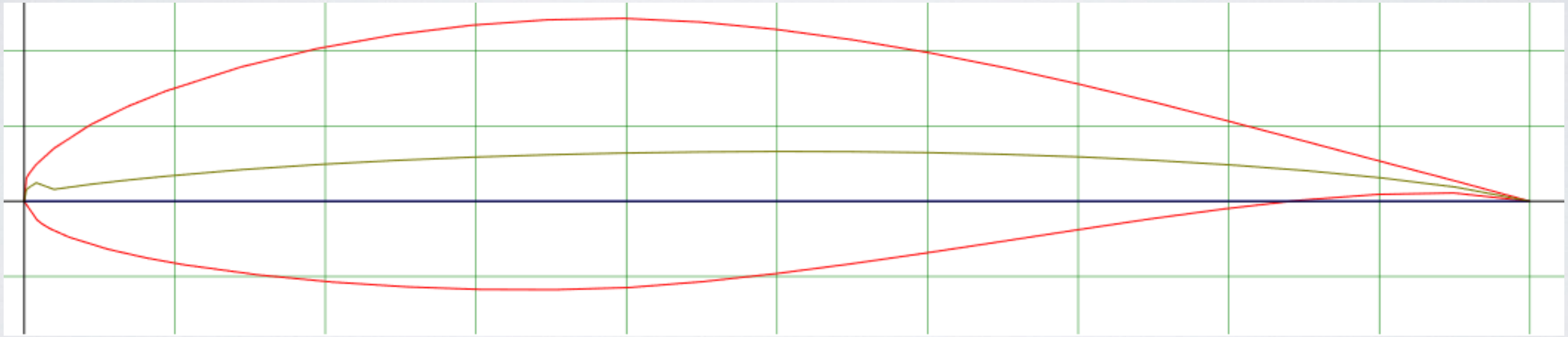
AR = 8

Airfoil	$C_{L, MAX}$	$C_{M\,\alpha = 0}$	Power Required [W]
naca 2414	1.54	-0.05	220
naca643618	1.40	-0.11	220
e560	1.72	-0.15	215

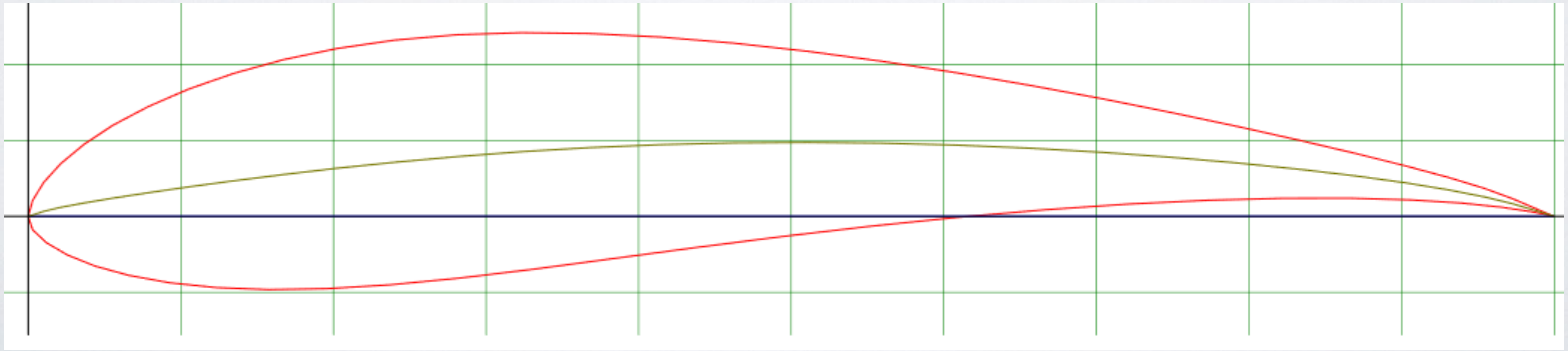
TOP AIRFOILS

MANUFACTURING AIRCRAFT

NACA 643618



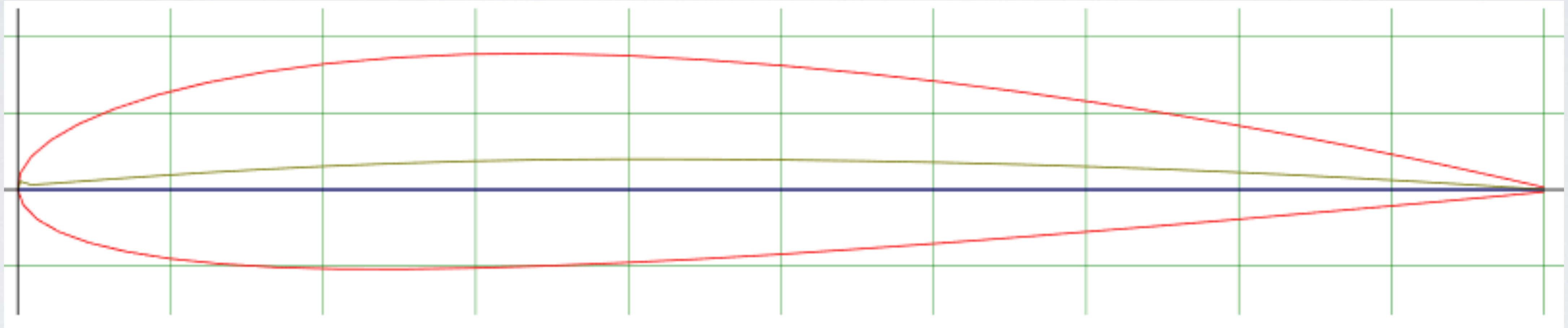
E560



TOP AIRFOILS

MANUFACTURING AIRCRAFT

NACA 2414



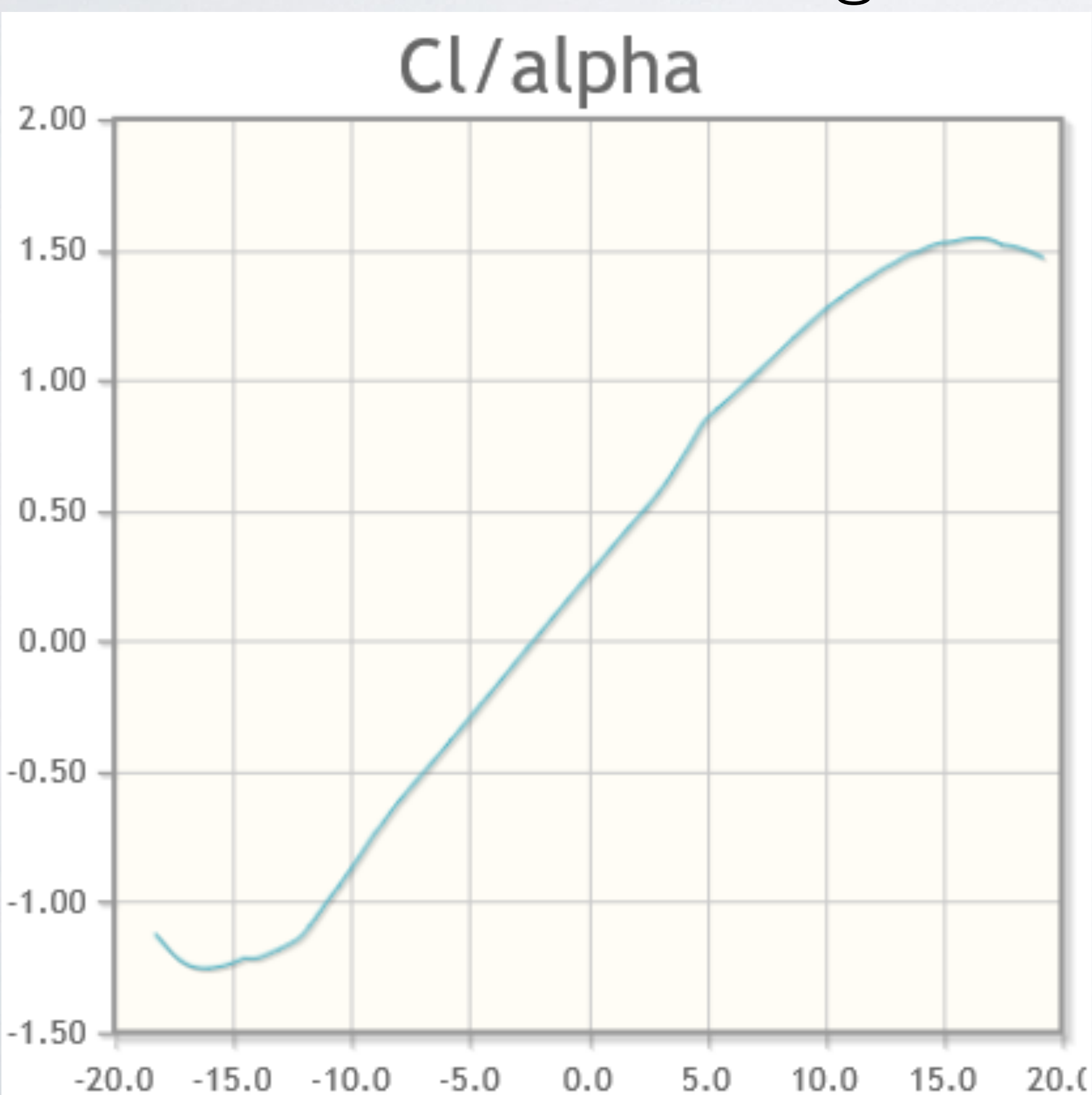
- Small CM
- 14% thickness
- Fairly constant thickness

PARAMETERS

NACA 2414

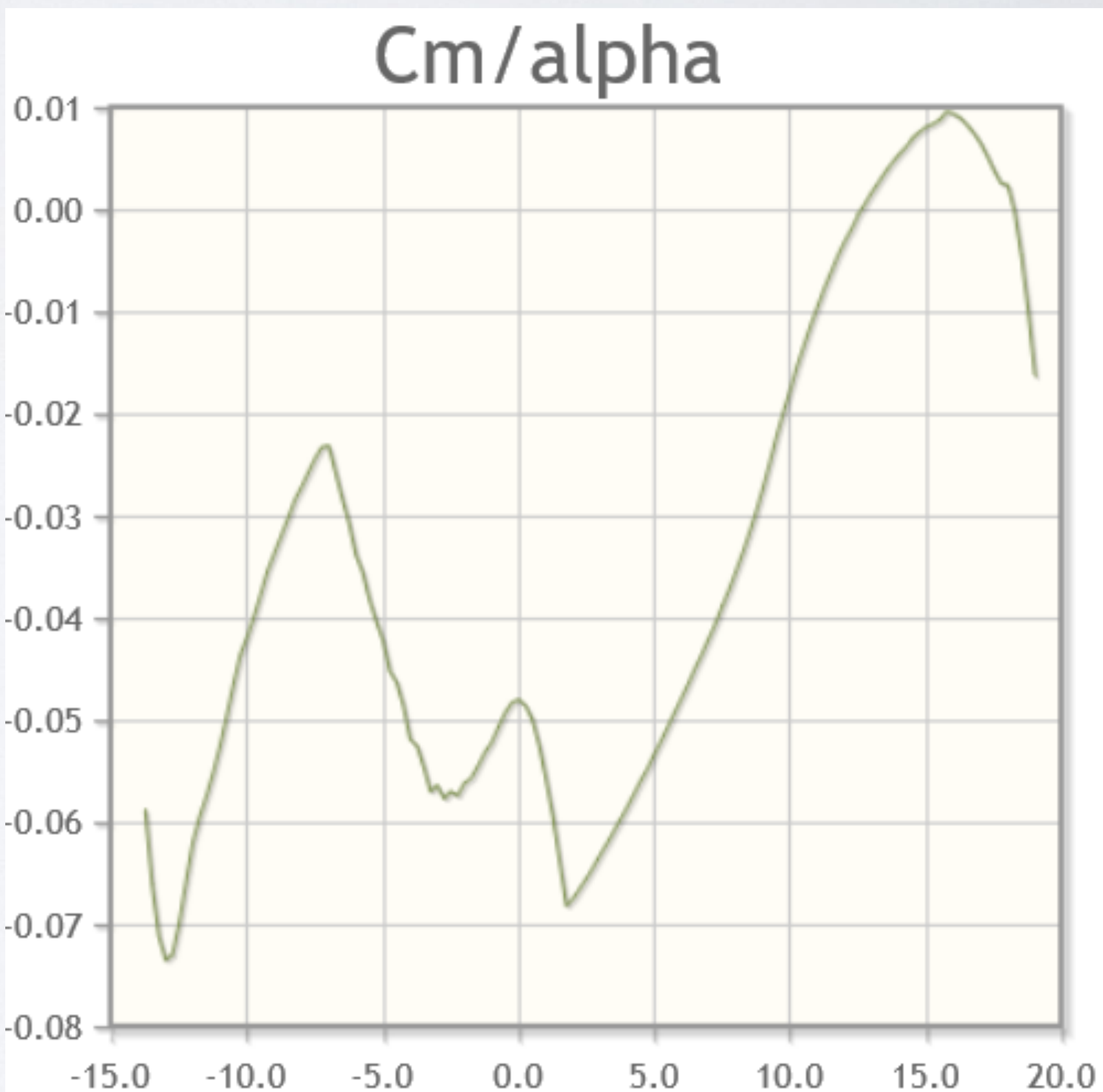
Lift

- Minimal Flow Separation
- Wide α
- Conventional Landing Gear



Moment

- Linear Operational Area
  - Moment Change at α ≅ 2
  - Tail



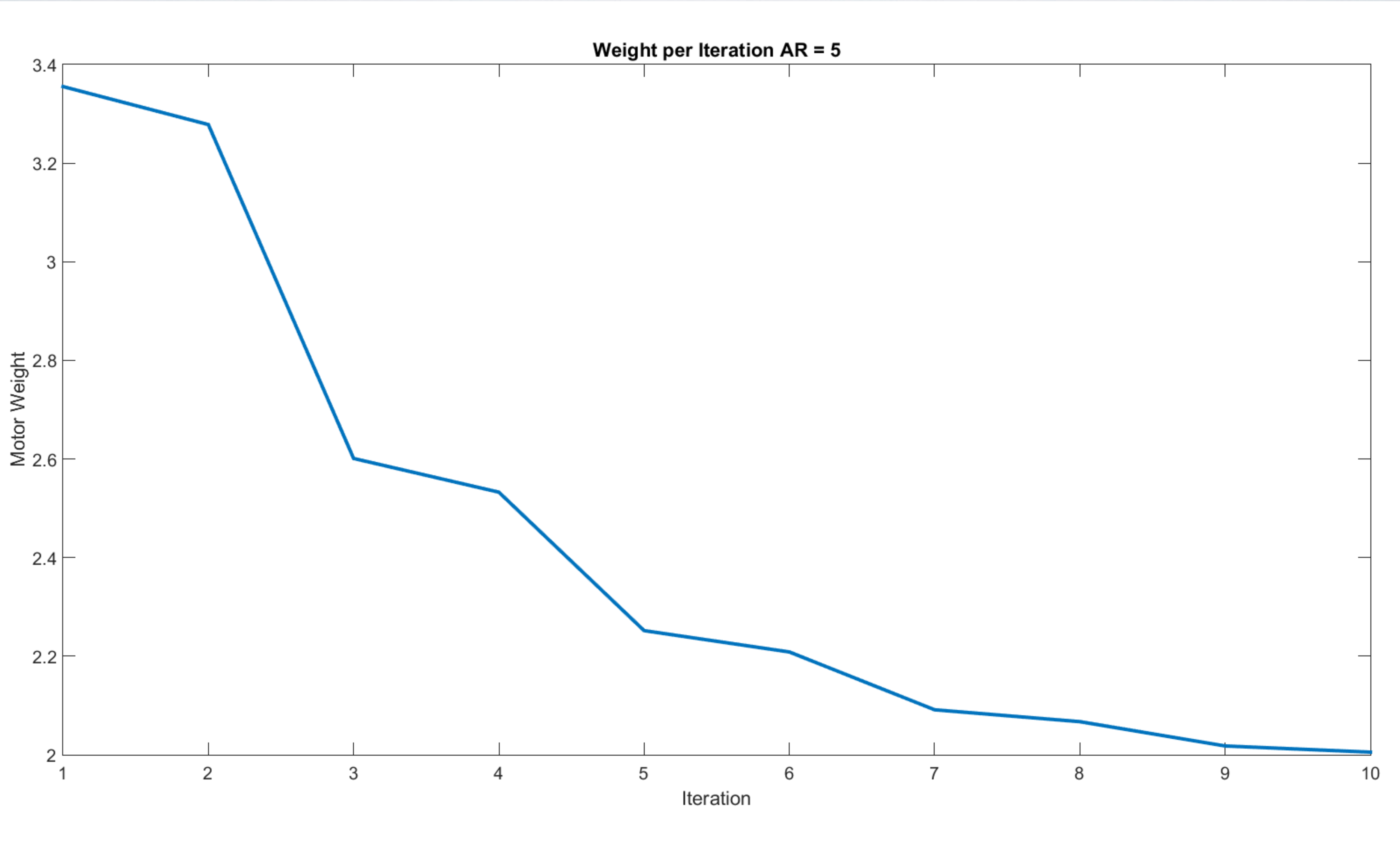
METHODOLOGY

EMPTY WEIGHT

- Picked an Aspect Ratio from older DBF Planes
- Picked an initial empty weight
- Iterated through to determine planform area $\Rightarrow$ PReq
- Iterated through to determine weight of Propulsion
  - Relative Error $\leq$ 1%

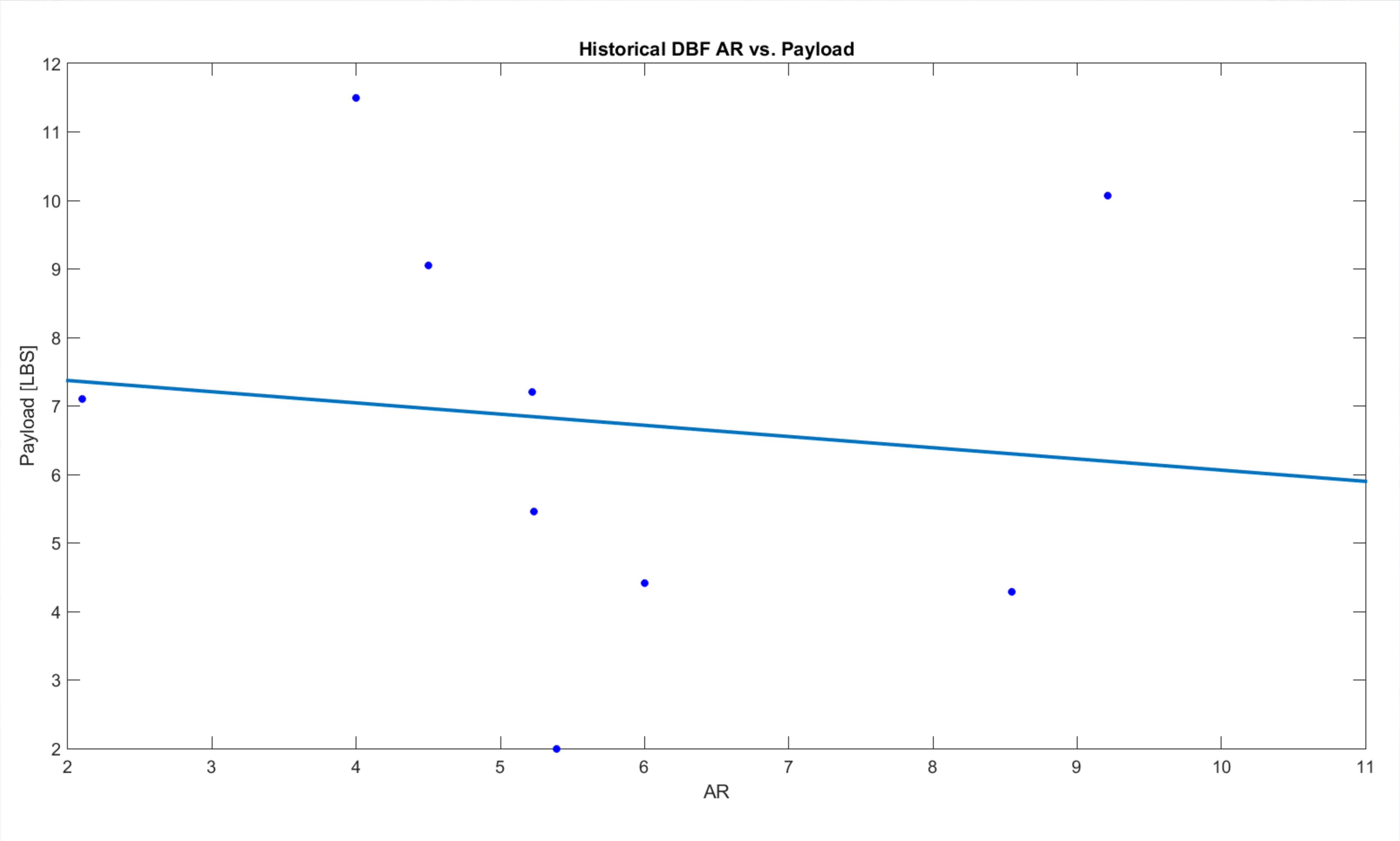
METHODOLOGY

RELATIVE ERROR



PLANFORM

DETERMINATION



PRODUCTION AIRCRAFT

ASSUMPTIONS

Use 3K Carbon Fiber for Fuselage

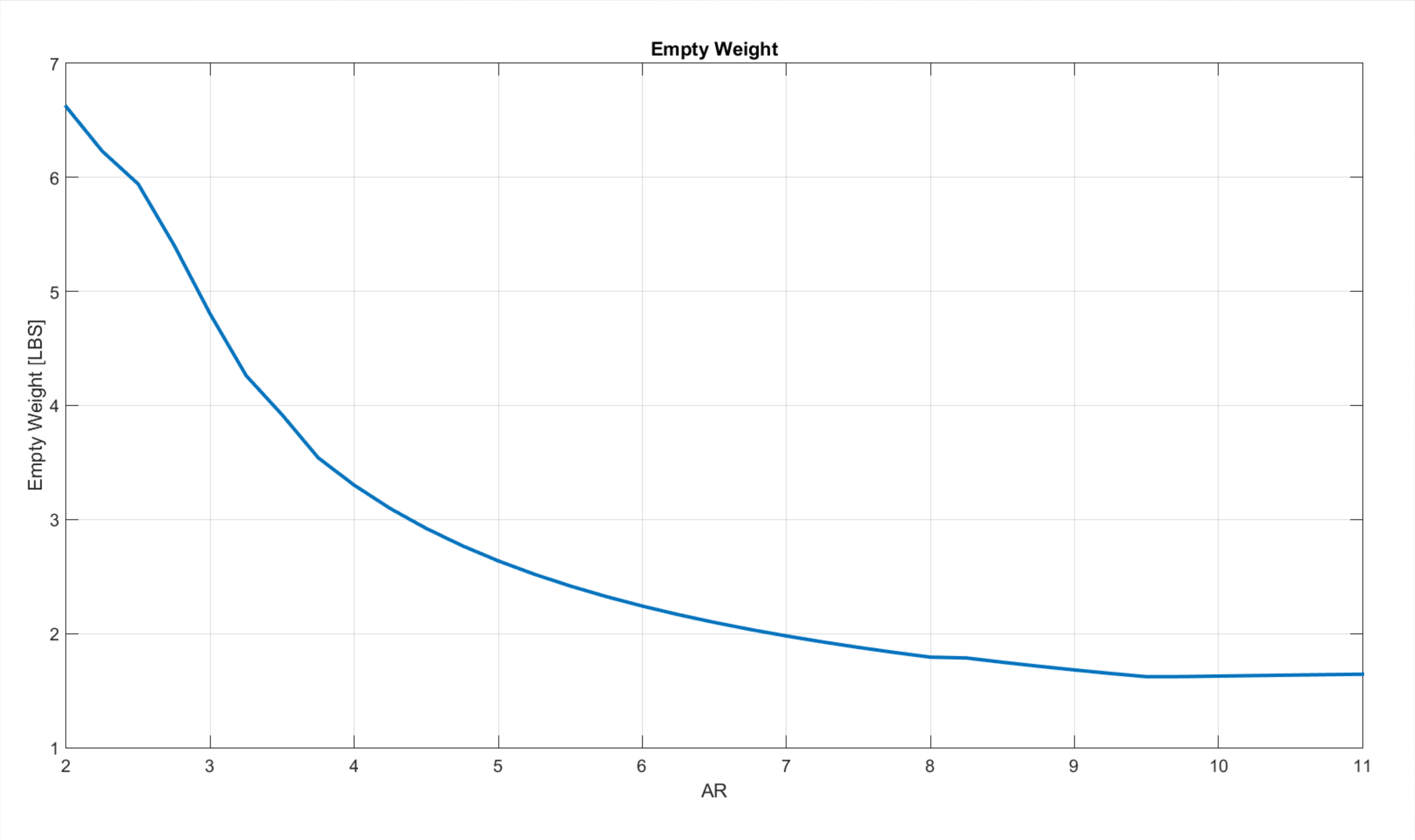
Wing Weight Function of S_{REQ}

$$W_{PROPULSION} = P_{REQ} \times 3 \frac{\text{grams}}{\text{Watt}}$$

Cruise Velocity 50 ft/sec

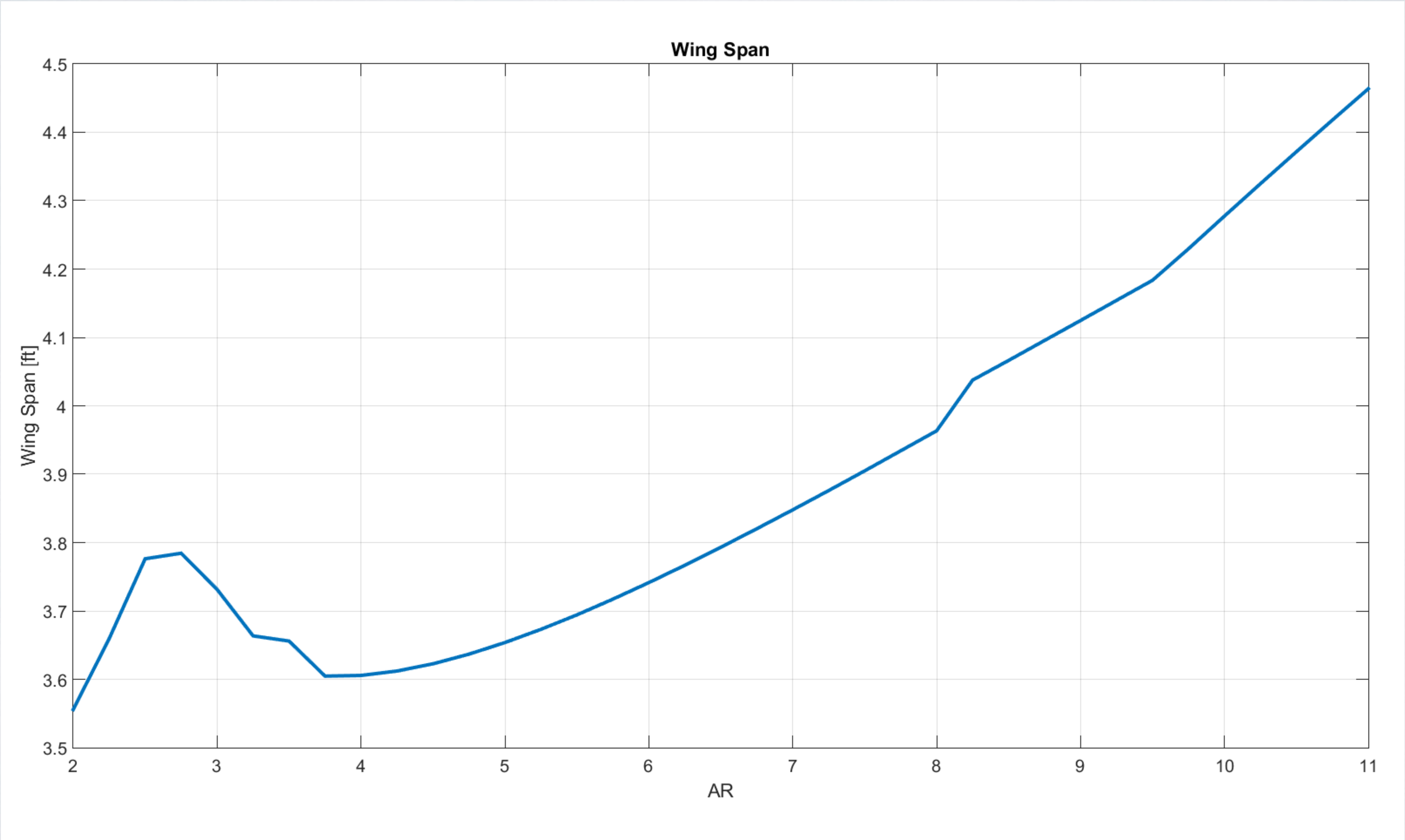
RESULTS

EMPTY WEIGHT



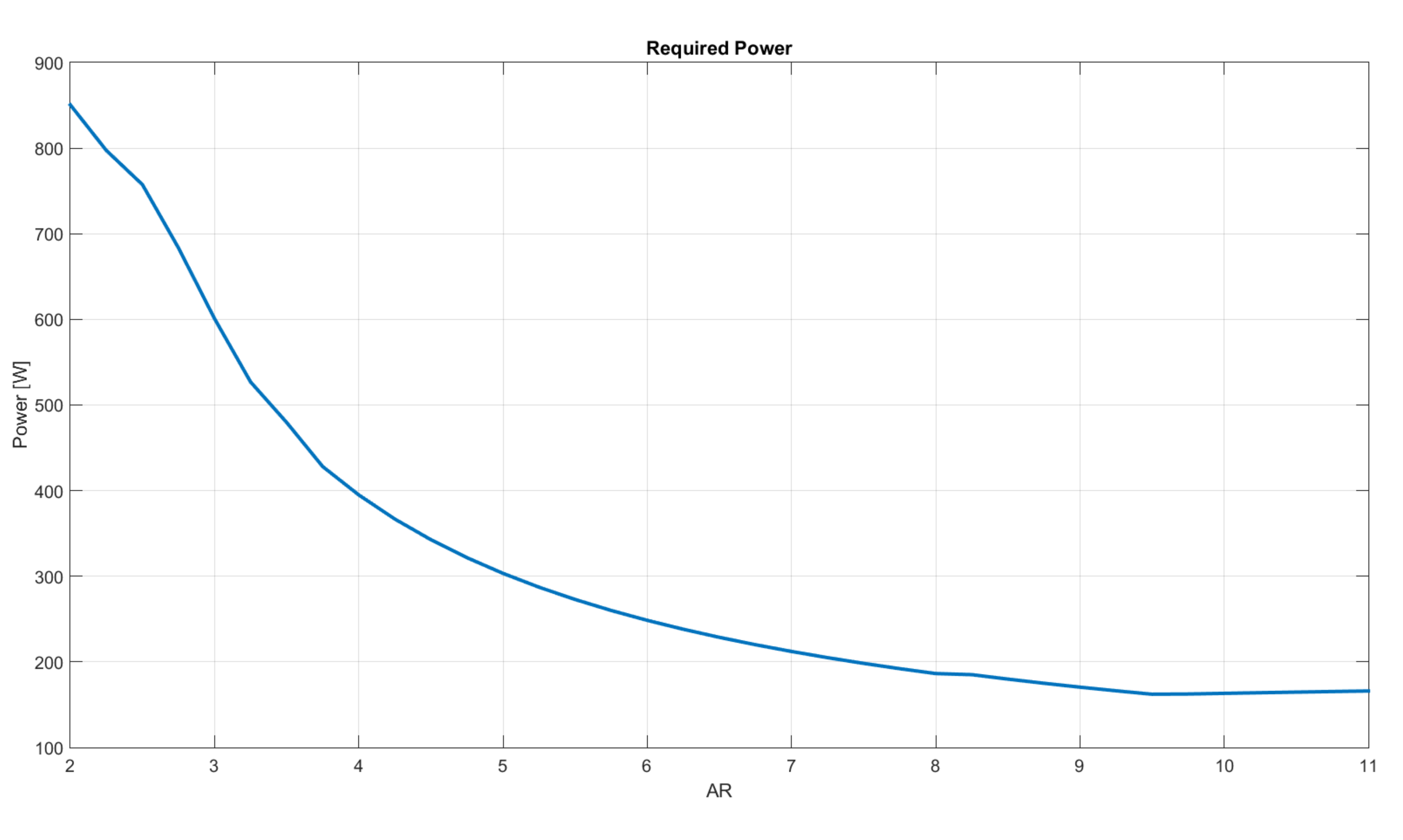
RESULTS

WING SPAN



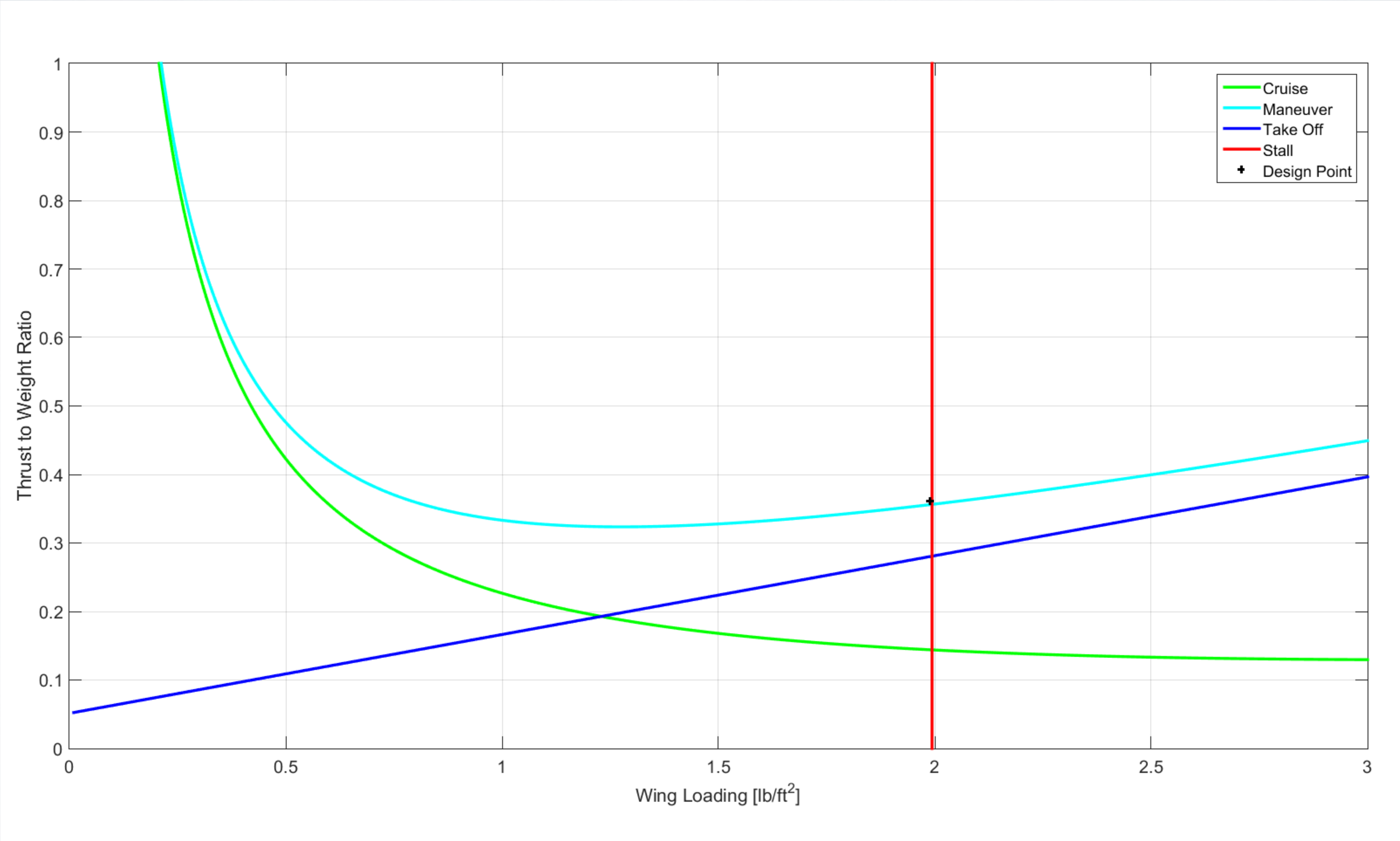
RESULTS

REQUIRED POWER



RESULTS

PERFORMANCE CONSTRAINT



SIZING

PRODUCTION AIRCRAFT

Empty Weight	1.979 [LBS]
Payload	2.2 [LBS]
Power Required	212.18 [W]
Planform Area	2.115 [ft^2]
Wing Span	3.848 [ft]
Propulsion Weight	1.4 [LBS]

MANUFACTURE AIRCRAFT

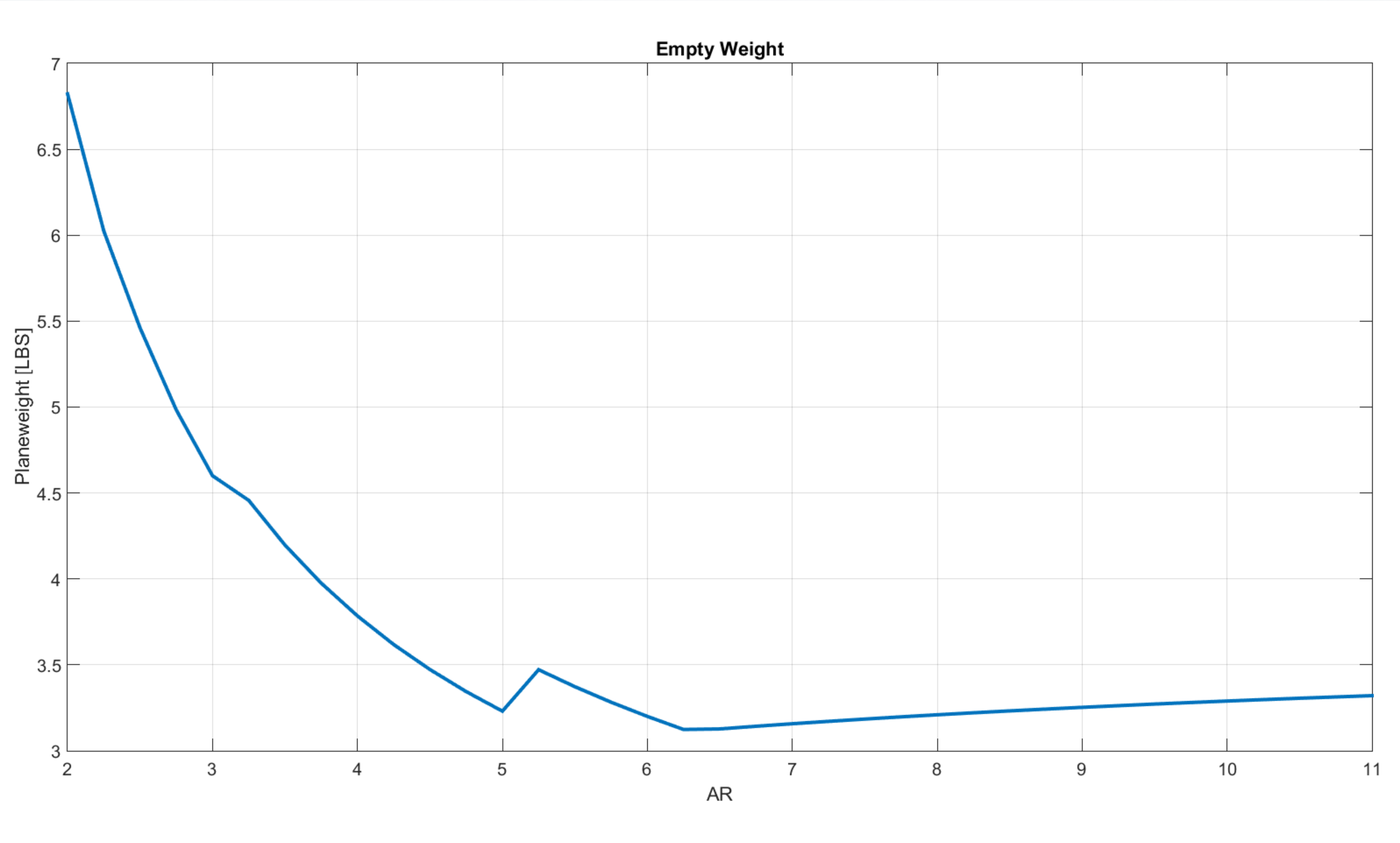
ASSUMPTIONS

3K Carbon Fiber for fuselage

4 layers 3k Carbon Fiber

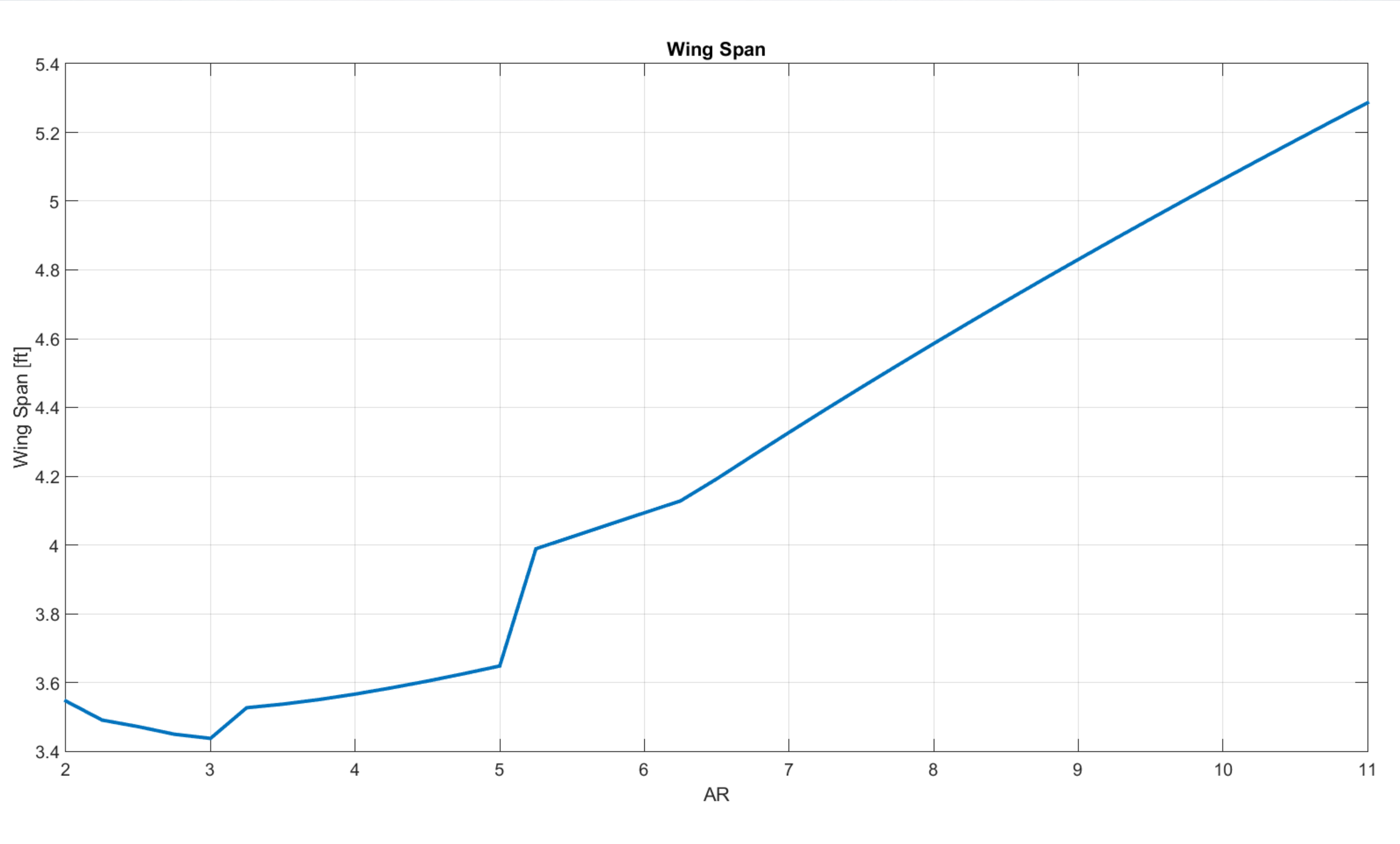
RESULTS

EMPTY WEIGHT



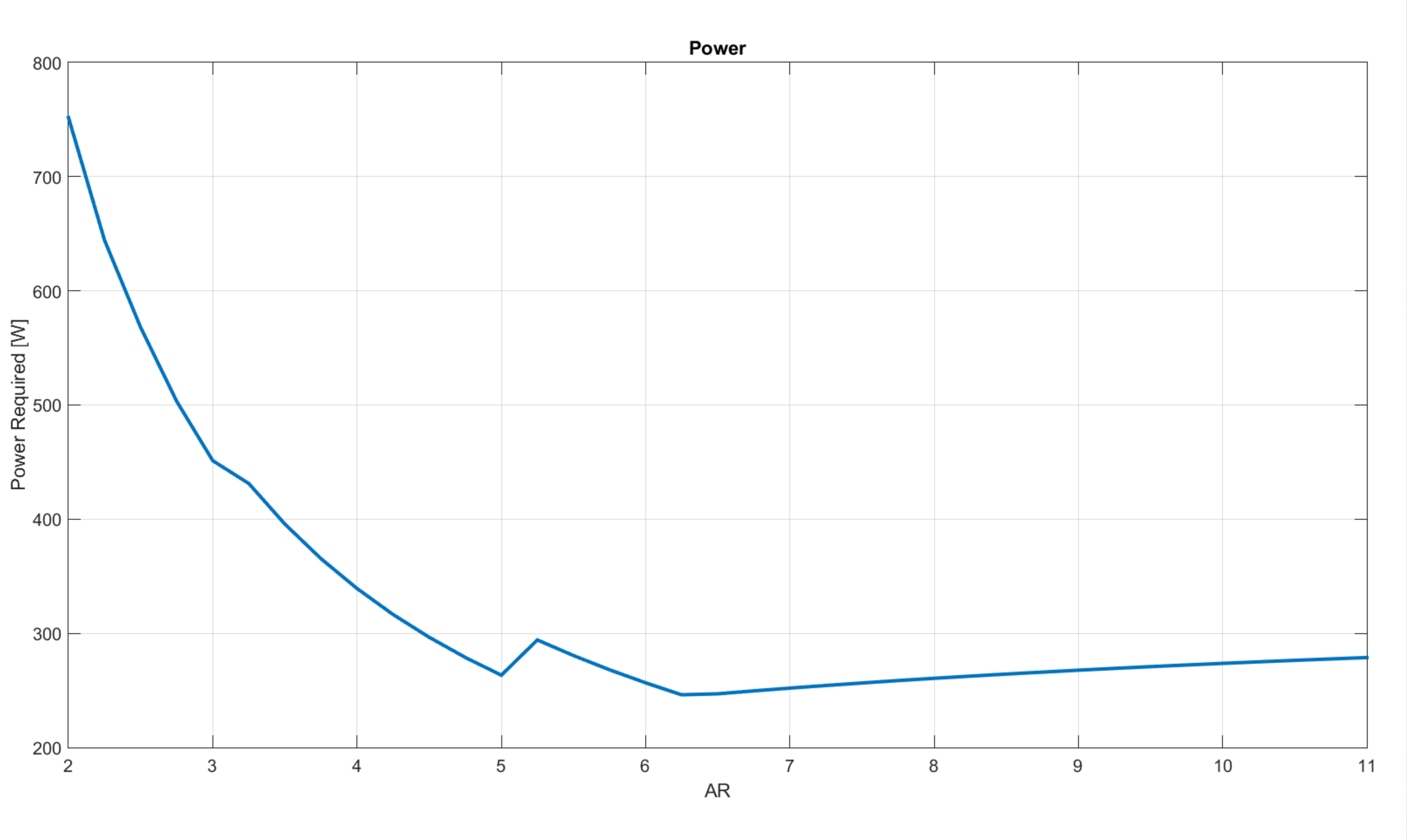
RESULTS

WING SPAN



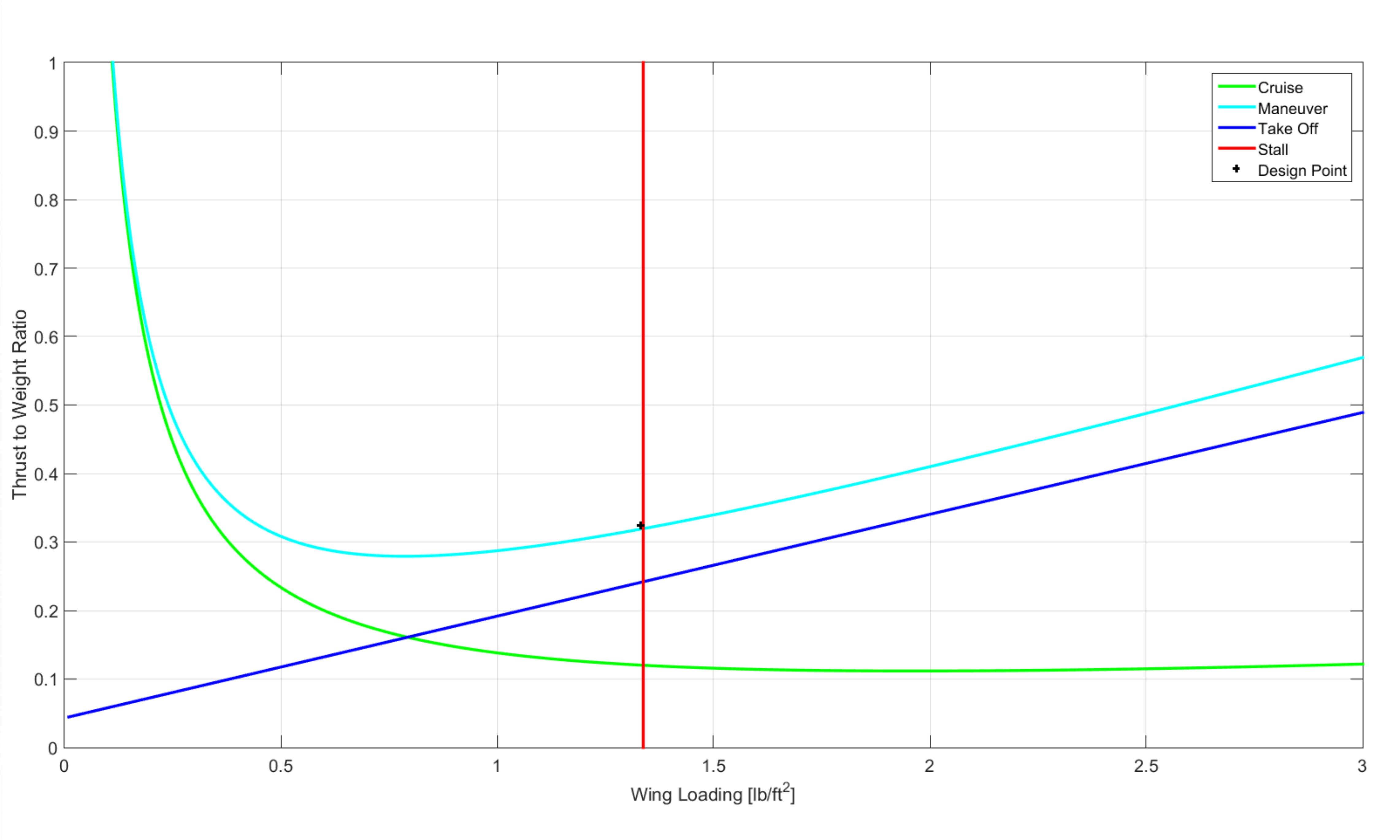
RESULTS

REQUIRED POWER



RESULTS

PERFORMANCE CONSTRAINT



SIZING

MANUFACTURING AIRCRAFT

Empty Weight	3.200 [LBS]
Payload Weight	1.319 [LBS]
Power Required	256.70 [W]
Planform Area	2.79 [ft^2]
Wing Span	4.09 [ft]
Propulsion Weight	1.70 [LBS]

PROPULSIONS

OVERVIEW

Responsibilities:

- Propeller
  - Can create enough thrust (high d), to complete the mission, while also creating enough speed (high pitch) to get off the ground in 100ft and complete the missions in time
- Motor
  - Provide the power required while also minimizing weight
- Electronic Speed Controller
  - Able to handle the amperage draw from the batteries
- Batteries configuration
  - Provide necessary voltage, while minimizing weight
- Optimize design such that weight is minimized
- Test and implement the best design

CONFIGURATION

PRODUCTION AIRCRAFT

Single, two bladed, pull prop

Mission Driver	Weight	Tractor	2 Prop	Pusher
Weight	.4	5	1	5
Effect on landing gear	.3	4	3	2
Effective Thrust	.3	4	5	3
Total	1	4.4	2.8	3.5

PROPELLER SIZING

PRODUCTION AIRCRAFT

MISSION 3: Production aircraft flies 3 laps with a 32 oz Gatorade bottle in under 5 mins

Design drivers and ranges of solutions provided at right

Through static testing of various prop and motor configurations it will be possible to determine the optimal propeller size for Mission 3

Parameter	Design Criteria	Range of Choices
Diameter	Larger in order to have enough thrust to lift a heavy payload, but smaller for optimal fitting in manufacturing aircraft	11-14 in
Pitch	Higher in order to meet takeoff field length, but smaller such that there will be sufficient thrust to carry a heavy payload	7-8
Material	Durable, lightweight	Plastic

MOTOR

PRODUCTION AIRCRAFT

Motor Properties	Optimized Mission 3 Values
KV (rpm/min)	Lower, between 500-700
Power Required	155.9 W, 265 used for calculation (SF of 1.7)
Weight	Light as possible (Will depend on brand and appropriate KV value)

Brands: Scorpion, T-Motors, O.S., Hyperion

ecalc.ch: An online calculator that takes (number of motors, weight of the plane, wing area, and flight altitude specs, number of batteries, weight of) as inputs and outputs a list of motors that can meet the mission specs

BATTERIES

PRODUCTION AIRCRAFT

Property	Values
Power	212 W, 360 used for calculation (SF of 1.7)
Number of Cells	10 12
Weight of Cells* (2/3A NiMH)	.55 lb .66 lb
Current Draw	30 A 25 A
Capacity Needed	2505 mAh 2087 mAh

Will test the effectiveness of each battery configuration using static tests. Fewer cells result in less weight which positively affects the score, but the increased current draw may negatively affect the batteries long term.

*http://www.batteryspace.com/batteryknowledge.aspx

CONFIGURATION

MANUFACTURING AIRCRAFT

Design Driver	Weight	Tractor	Double Prop	Pusher
Effect on landing gear	.2	3	3	3
Propulsion system weight	.4	5	2	5
Effective thrust	.4	3	5	2
Total	1	3.8	3.4	3.4

Double prop seriously considered, however single prop is more efficient as the weight of the entire propulsion system will be less, fewer manufacturing constraints

PROPELLER SIZING

MANUFACTURING AIRCRAFT MISSION 1

Parameter	Design Criteria	Range of Choices
Diameter	Moderately large, will need enough thrust to complete takeoff req, but want more speed efficient to meet 5 min limit	11-13 in
Pitch	Higher in order to complete the mission in the time allotted	8-10
Material	Durable, lightweight	Plastic

MISSION 1: Complete 3 laps with no payload in 5 mins

PROPELLER SIZING

MANUFACTURING AIRCRAFT MISSION II

Parameter	Design Criteria	Range of Choices
Diameter	Large, but able to complete takeoff requirement. Not as concerned with speed this round, 1 subassembly	12-14 in
Pitch	High enough to get off the ground quick enough, but generally lower such that there is enough thrust to carry the payload	7-10
Material	Durable, lightweight	Plastic

MISSION 2: Carry the production aircraft as a payload. 10 minute limit to do one lap with each of the sub-assemblies

MOTOR

MANUFACTURING AIRCRAFT

Motor Properties	Optimized Mission 3 Values
KV (rpm/min)	Low, between 400-700
Power Required	Approximately 436-450 W, used for calculation (SF of 1.7)
Weight	Light as possible (Will depend on brand and appropriate KV value)

Inquiry submitted regarding having two different motors for missions one and two, for now assuming that it must remain the same for both(last year's rules).

Considering brands: Scorpion, T-motors, O.S motors, Hyperion

BATTERIES

MANUFACTURING AIRCRAFT MISSION 1

Do not have a required power for this mission available at this time

Once required power is calculated, will assume that the plane is operating for 5 mins (max time for this mission) and will size batteries accordingly

From here a motor can be selected based on wattage requirements

BATTERIES

MANUFACTURING AIRCRAFT MISSION II

Property	Values
Power	256 W, 436 W used for calculation (SF of 1.7)
Number of Cells	10 12
Weight of Cells* (2/3A NiMH)	.55 lb .66 lb
Current Draw	36.4 A 30.3 A
Capacity Needed	1818 mAh 1515 mAh

ESC

- Will be one of the last considerations in the propulsion system
- Must be able to handle the current drawn from the battery, want to minimize weight as much as possible

NEXT STEPS

PROPULSION

- Motor selection
- Purchasing batteries (unique configurations), motors, and props
- Static tests, determining optimal combination

OUTREACH

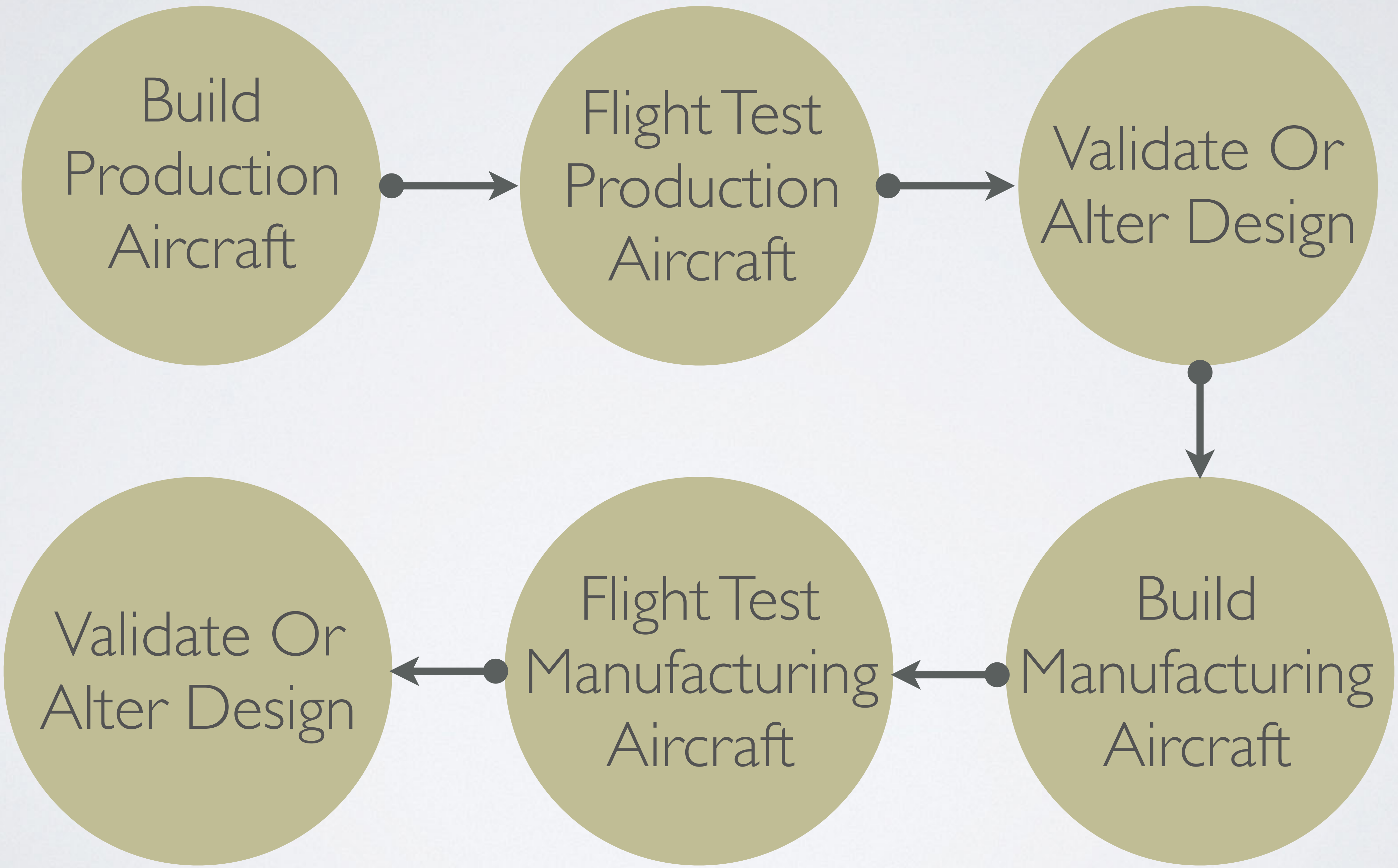
Glider Project

24 Active
General Members

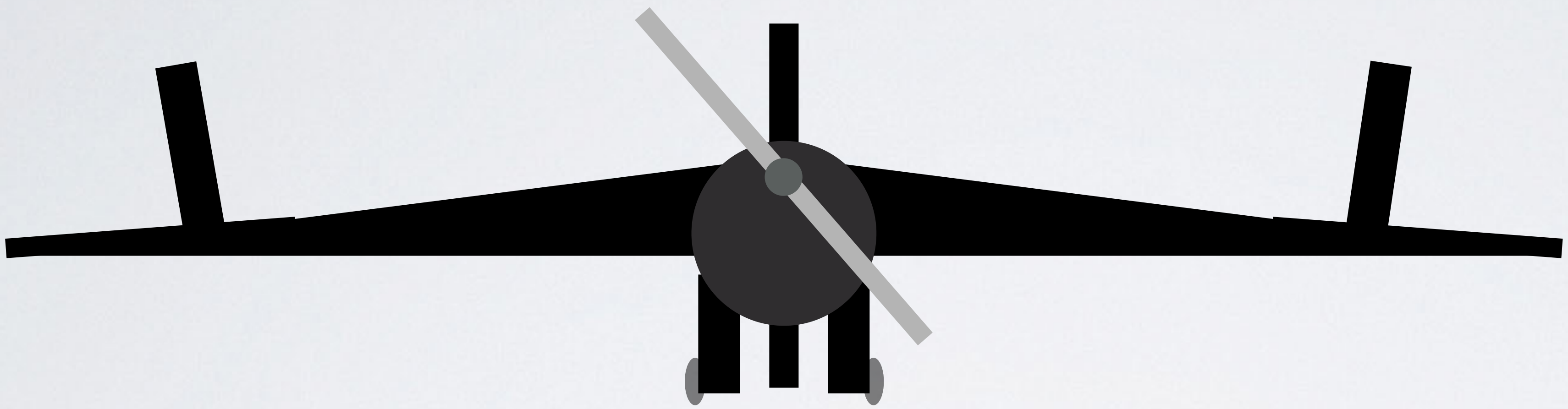
Apprentice
Positions

CONSTRUCTION

APPROACH



THANK YOU



COLORADO
DESIGN - BUILD - FLY