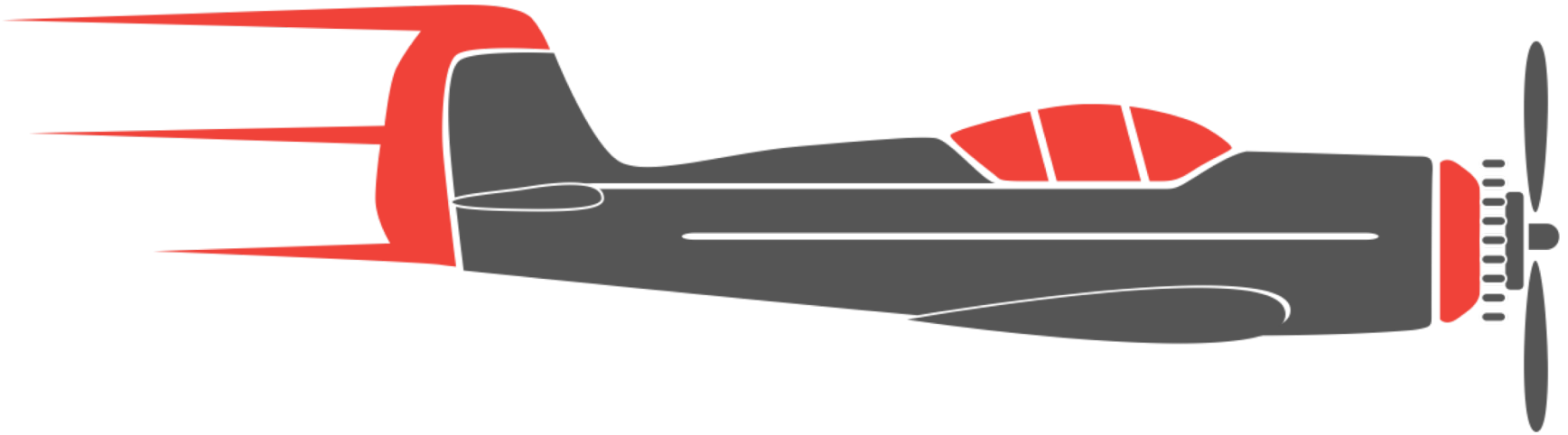


Team 508
SAE Aero Design: Geometric Integration
EML 4551C

Team Members

Jacob Pifer
Project Manager
Materials Engineer
CAD Engineer

Lauren Chin
Controls Engineer
Meeting Coordinator
CAD Engineer

Joseph Figari
Manufacturing Engineer
Financial Coordinator
CAD Engineer

Sponsors

Florida Space Grand Consortium
Financial Sponsor

Seminole RC Club
Equipment Provider

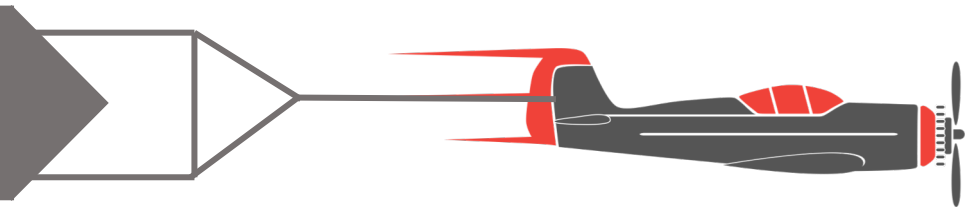
Shayne McConomy, PhD
Faculty Sponsor

Advisors

Simone Hruda, PhD
Faculty Advisor

Eric Adams
Fablab Supervisor

Project Objective



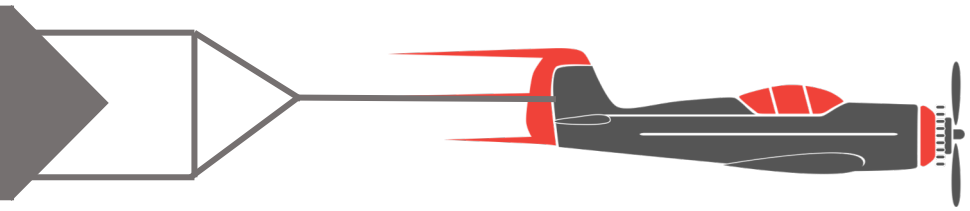
- The objective of this project is to design and manufacture a 3D printed remote control airplane within the rules of the SAE Aero Design Competition

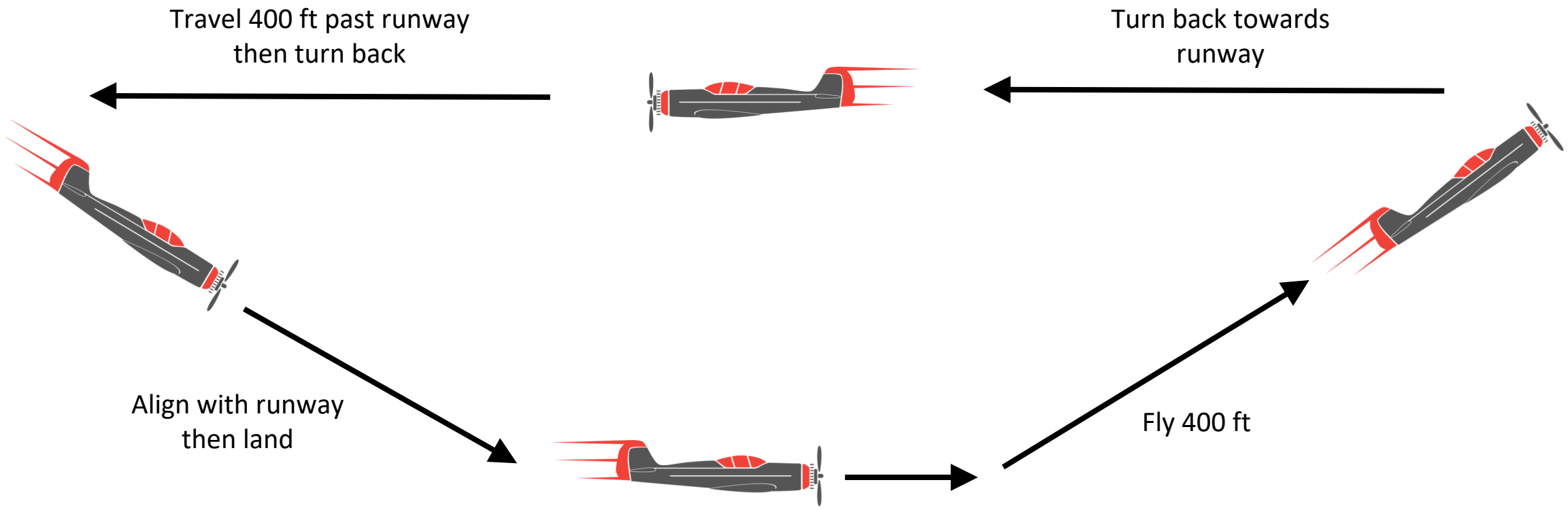
- It will be able to take off, complete the needed flight path, and land while carrying the required cargo

Project Brief Summary

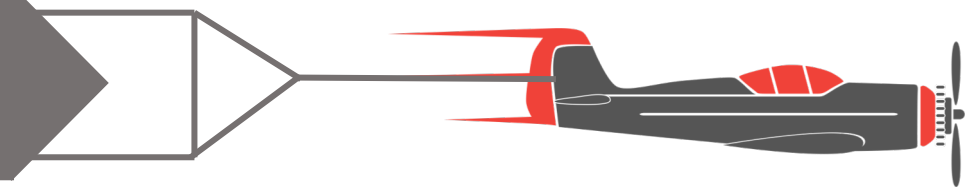
- Competing in the Regular Class SAE Aero Design Competition
- Plane is being built through additive manufacturing
- Team 508 is overseeing the geometric design of the plane

Project Brief Summary





Targets & Metrics

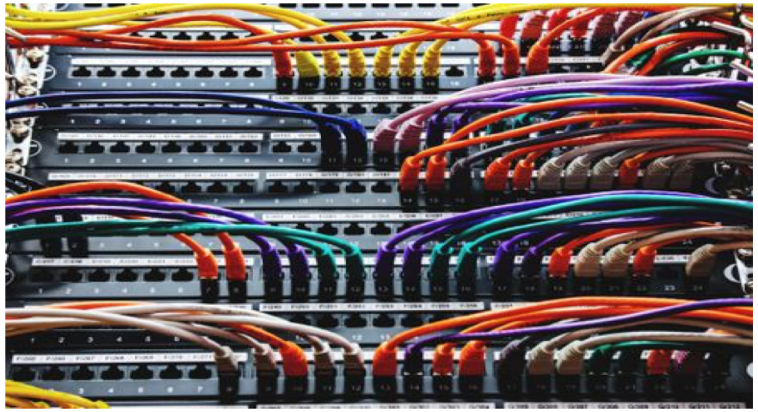


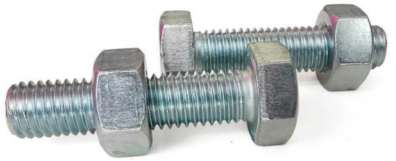
- The SAE Competition Rulebook was used as a minimum guide in creating the targets and metrics
- Suggestions from Dr. McConomy were also used
- Our main goal is to design the most innovative plane at the competition

Joseph Figari

Critical Targets

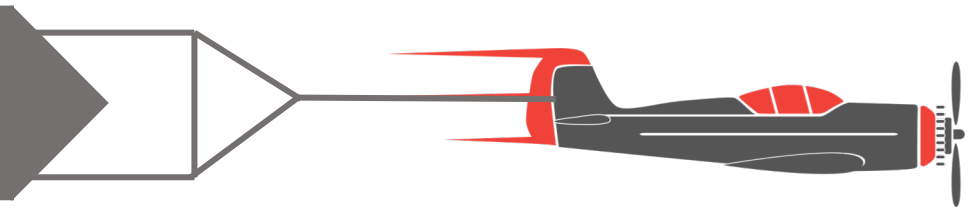
- Plane weighs less than 55 pounds
  - Ue lighter printer filament
  - Reduce amount of wiring in the plane
  - Reduce amount of screws and fasteners used on the plane



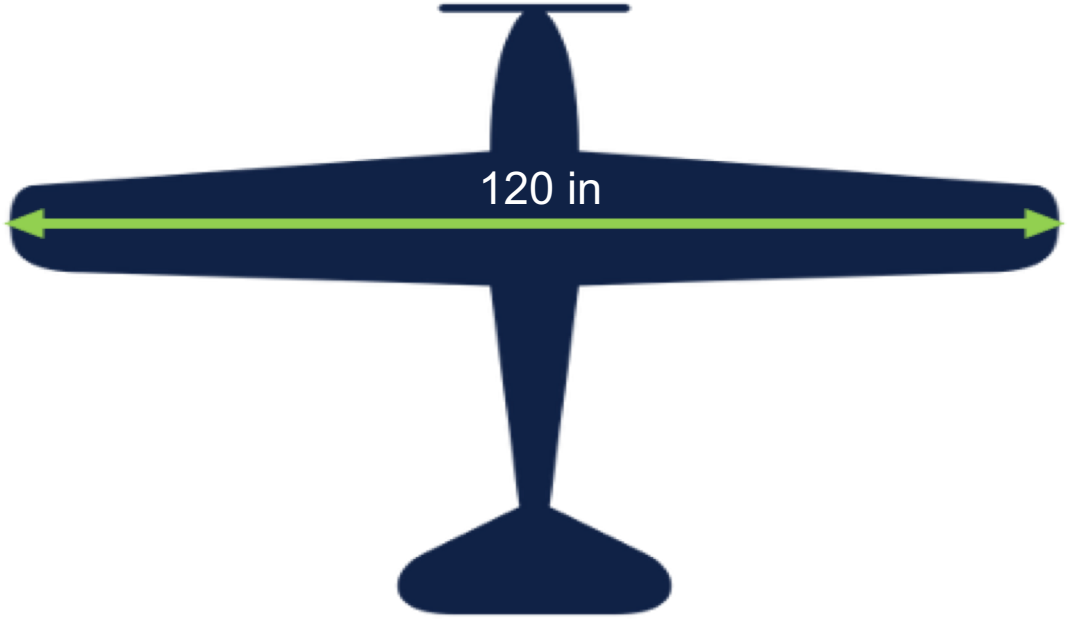


Joseph Figari

Critical Targets



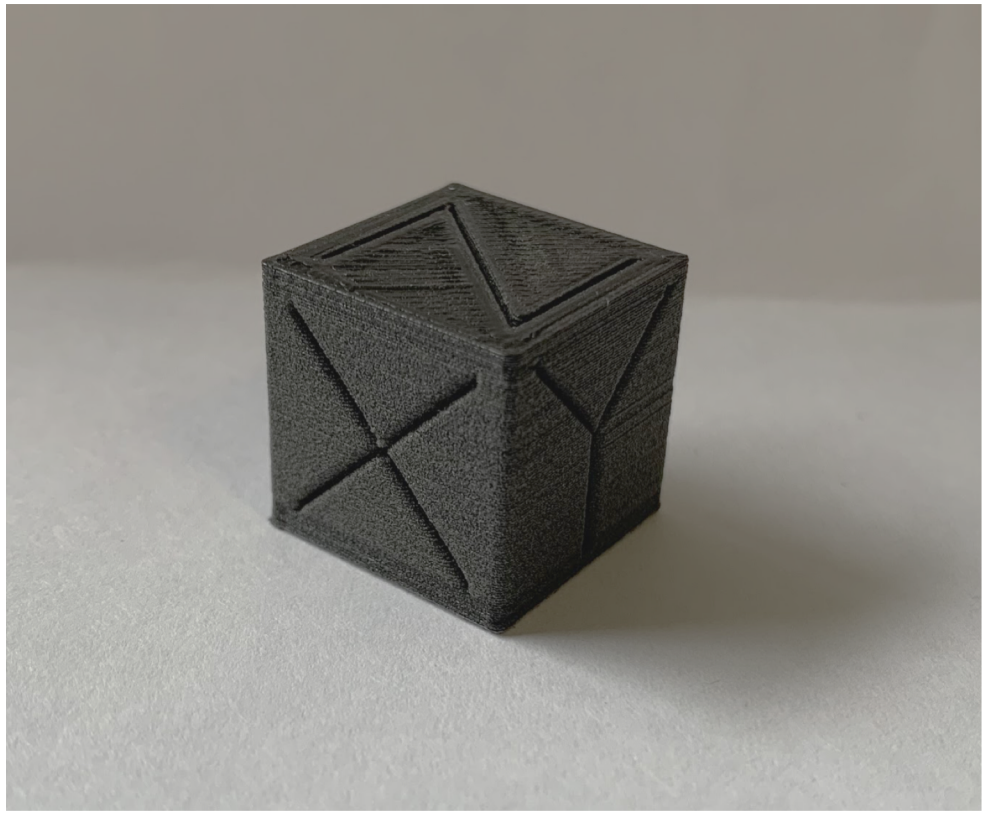
- The wingspan can not be greater than 120 inches
  - Limited chord length
  - Aiming for 80 inch wingspan



Joseph Figari

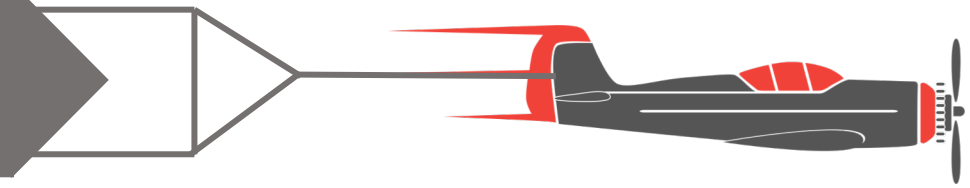
Critical Targets

- The printing error will be ± 0.02 inches
  - Printing error can be measured using calibration cube

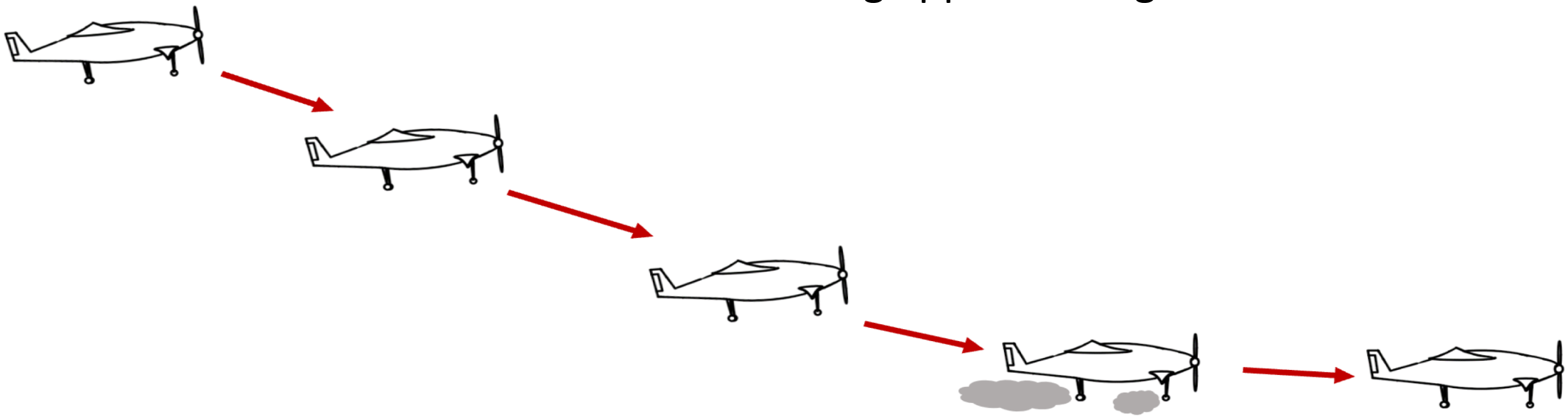


Joseph Figari

Critical Targets

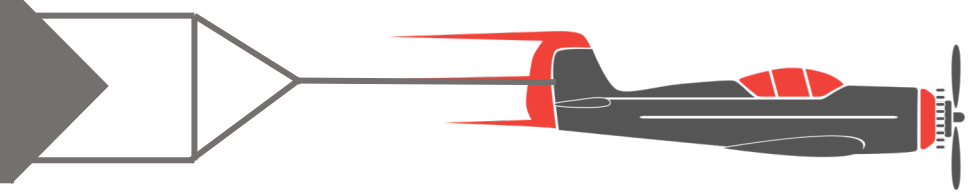


- Landing gear can absorb a force of at least 22.8 lbf
  - Landing speed must be 1.3x the stall speed
  - Landing approach angle must be 15°



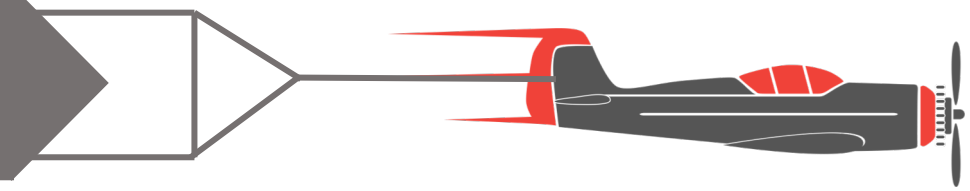
Joseph Figari

Concept Generation



Traditional Tail

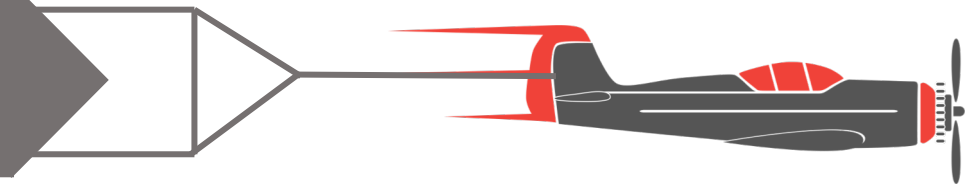
Concept Generation



Traditional Tail

T-Tail

Concept Generation

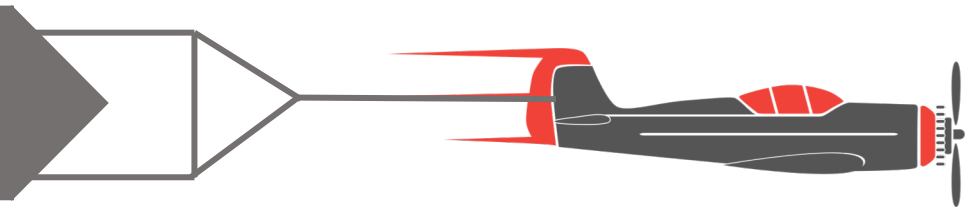


Traditional Tail

T-Tail

Wingless Tail

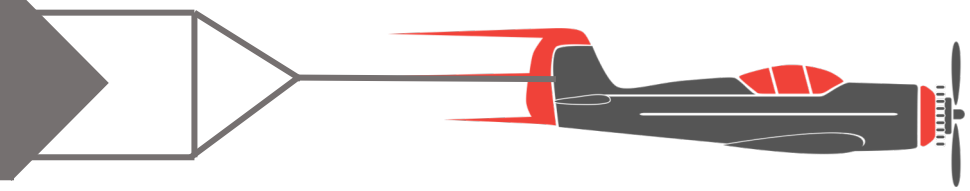
Concept Generation



Pulling Propeller

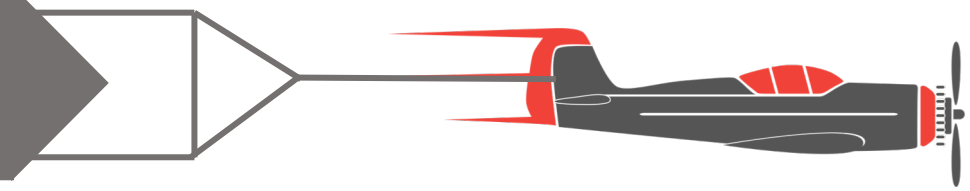
Pushing Propeller

Concept Generation



Rectangular

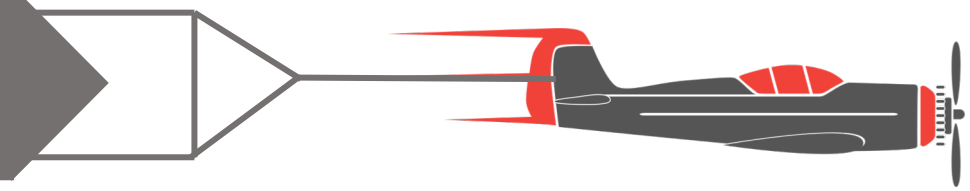
Concept Generation



Rectangular

Elliptical

Concept Generation



Rectangular

Elliptical

Tapered

Concept Generation

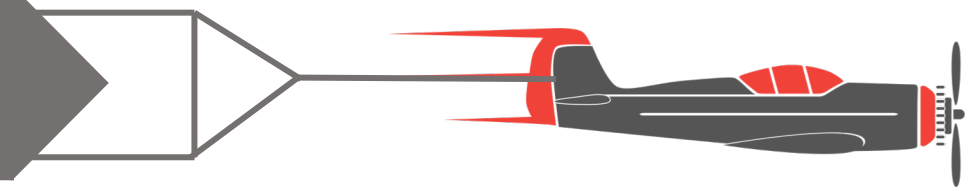
Swept Back

Concept Generation

Swept Back

Delta

Concept Generation



Flying Boat

Concept Generation

Flying Boat

Subsonic

Concept Generation

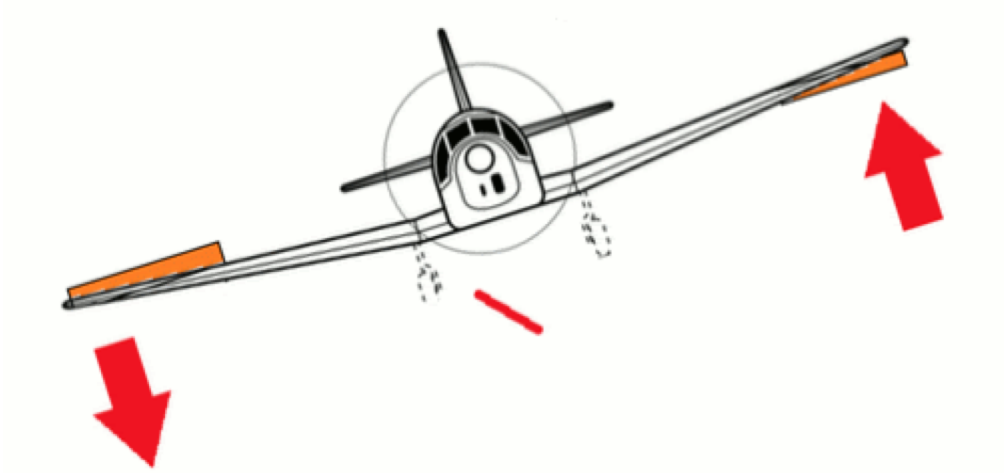
Flying Boat

Subsonic

Boom

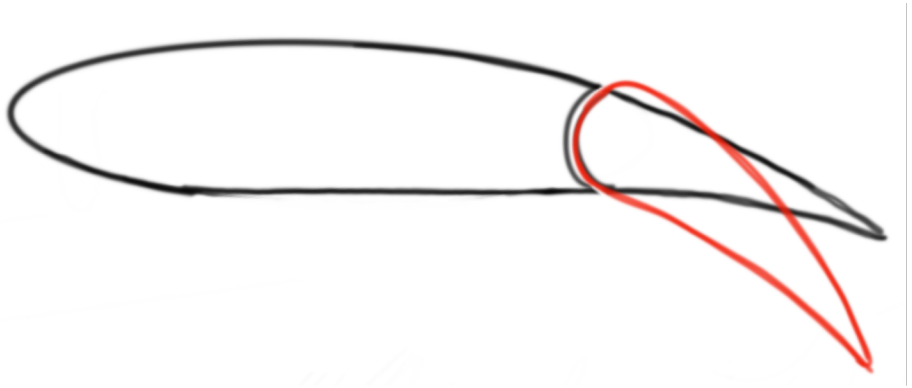
Concept Generation

- Ailerons
  - Controls rotation about roll axis
  - Trailing edge of each wing
  - Typically 15-25% of total wing area



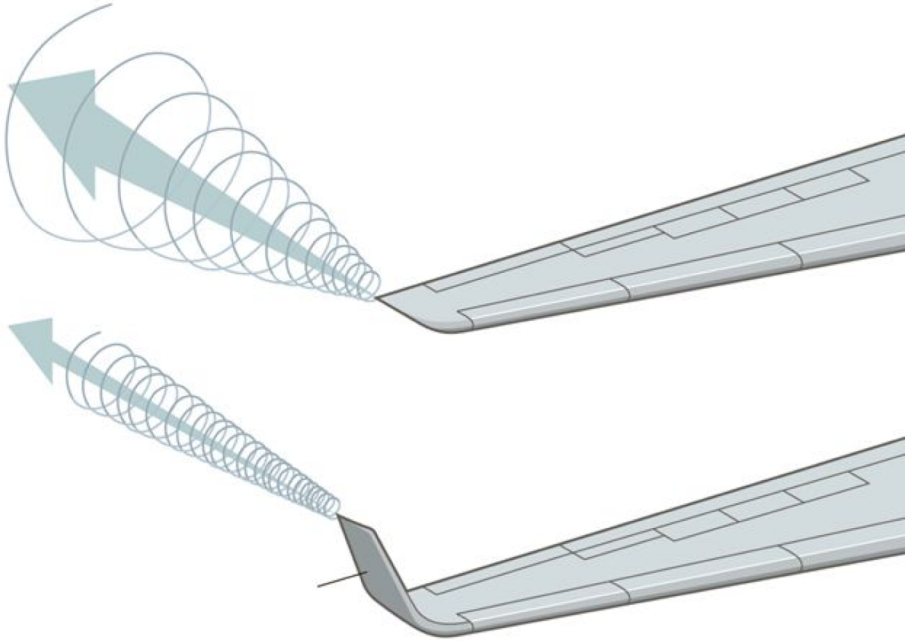
Concept Generation

- Flaps
  - Adjusts lift produced by wings
  - Reduces stall speed
  - Trailing edge of each wing
  - Typically 40% of total wingspan



Concept Generation

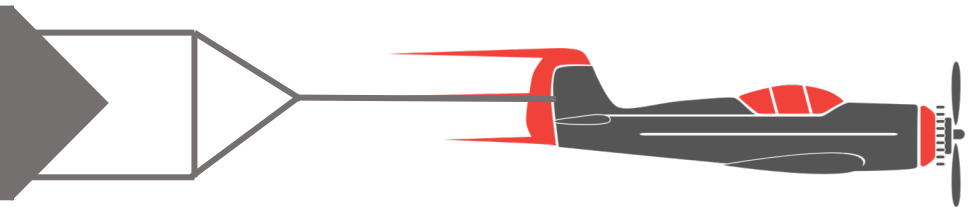
- Grantz Winglets
  - Reduces vortices produced by wings
  - Reduces overall drag of aircraft



Concept Generation

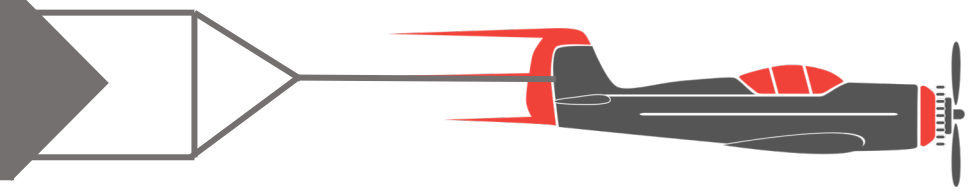
Tail Dragger

Concept Generation

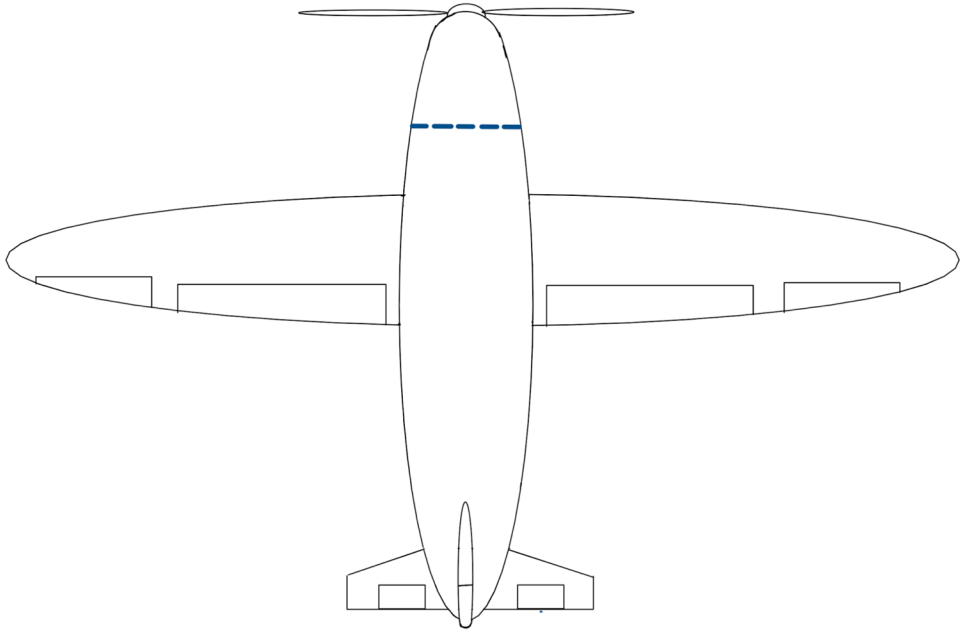


Tricycle

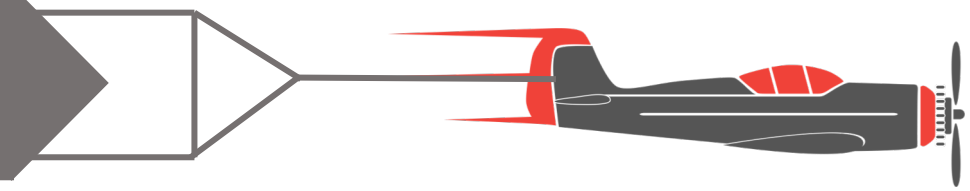
Concept Generation



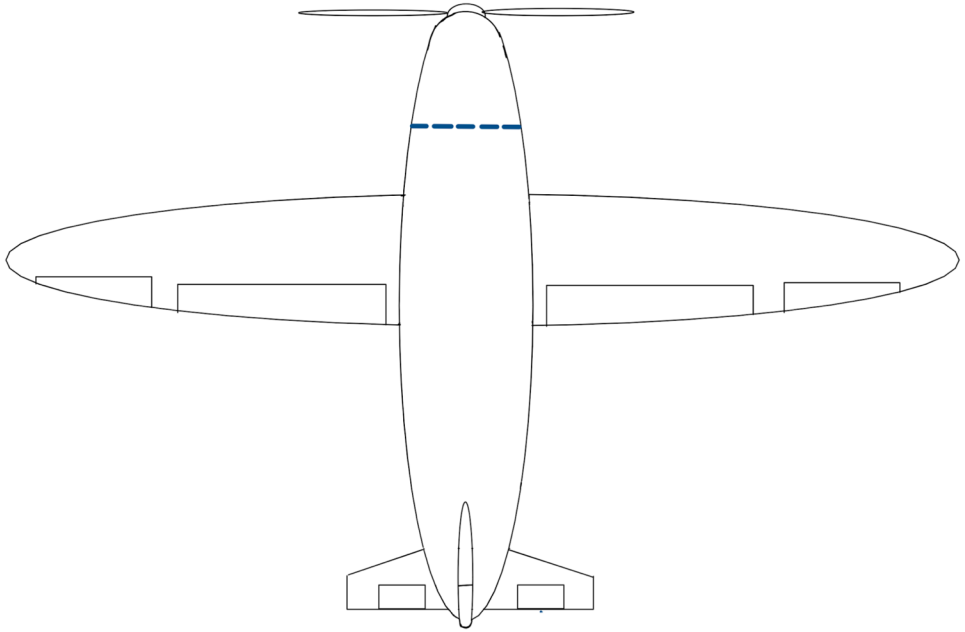
Front Loaded



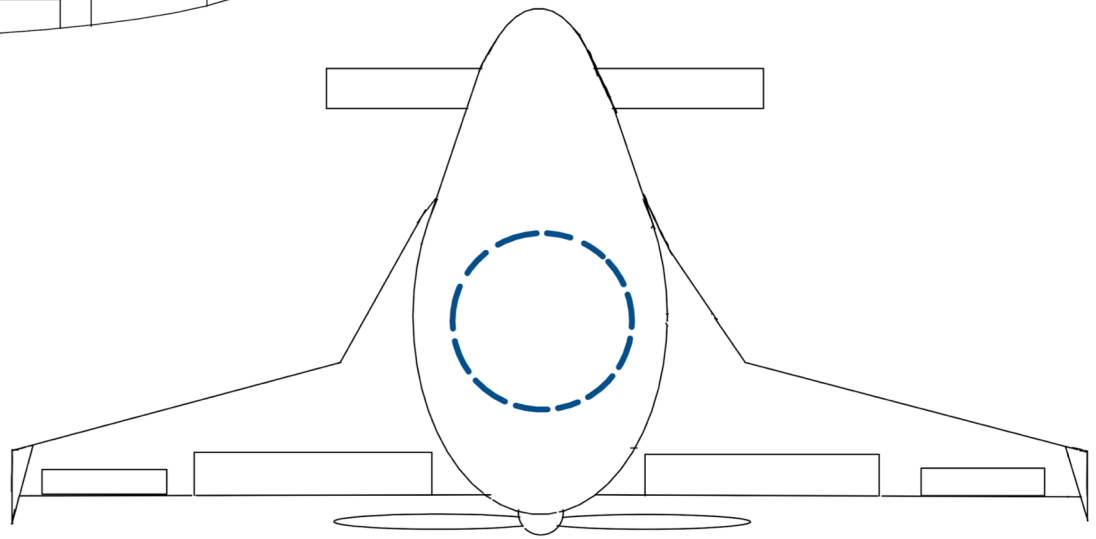
Concept Generation



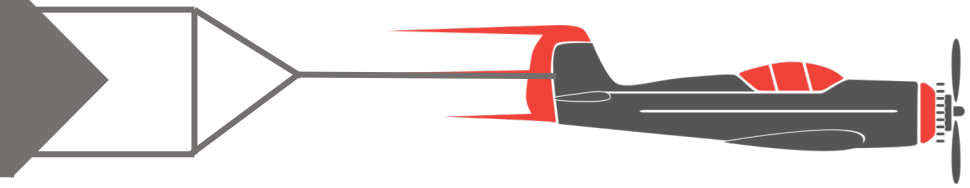
Front Loaded



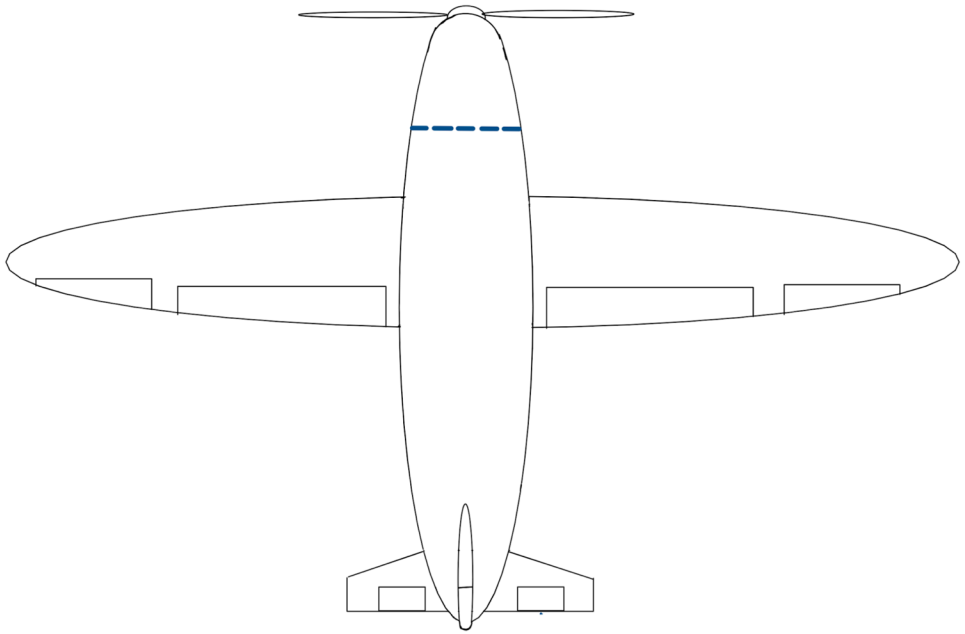
Top Loaded



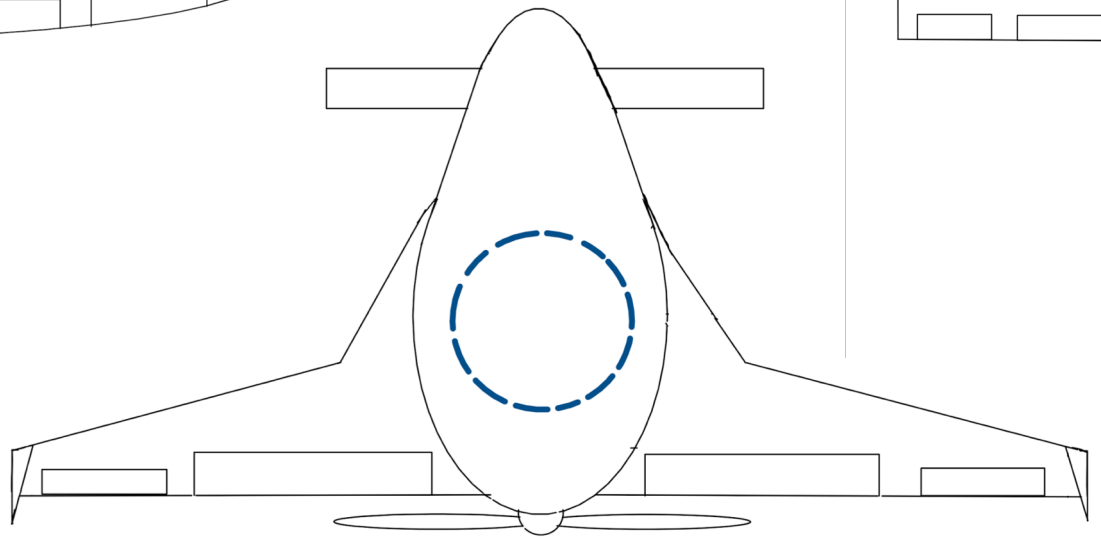
Concept Generation



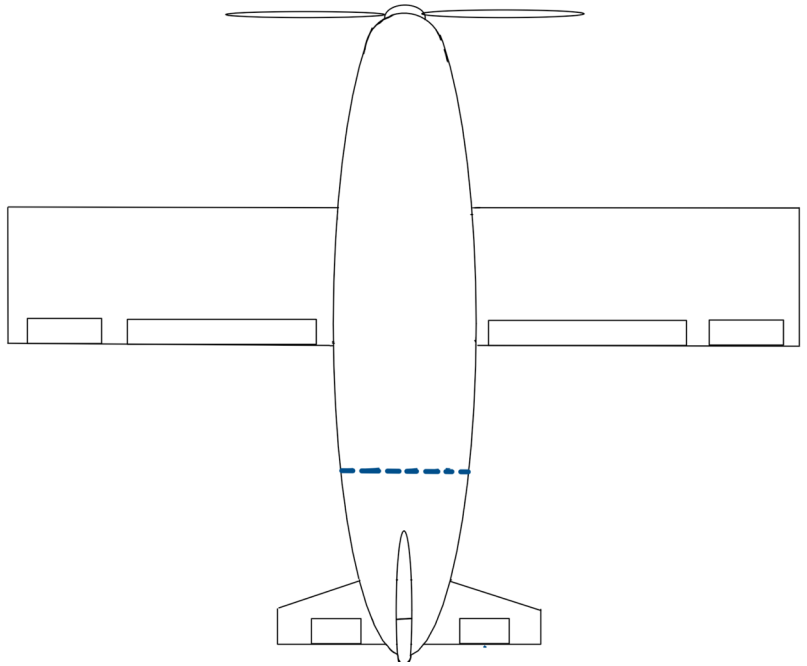
Front Loaded



Top Loaded



Back Loaded



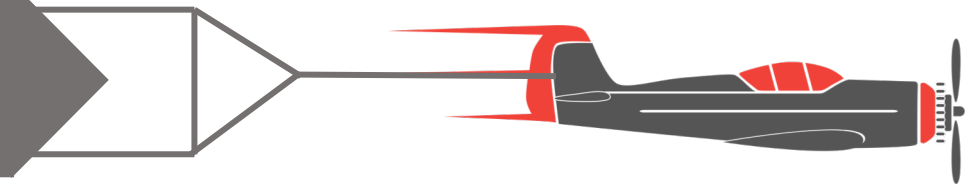
Material Testing

- Two possible printing filaments were chosen

- PLA (Polylactic Acid)
  - Prints accurately
  - Easy to get
  - Heavy in regards to building aircraft

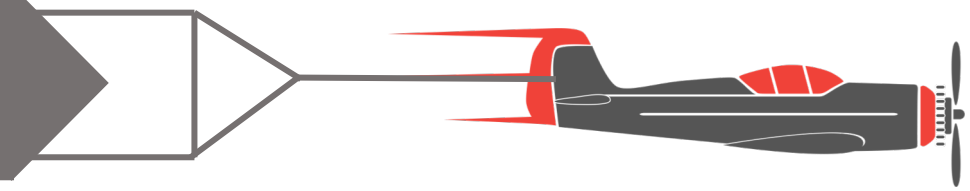
- LW-PLA (Light Weight Polylactic Acid)
  - Foaming action makes reduces density and weight
  - Harder to buy
  - Warping more likely than with normal PLA

Material Testing



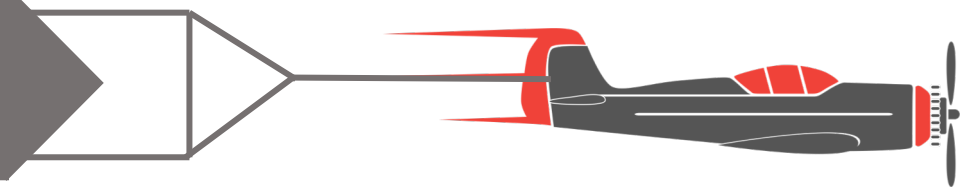
- Two main stresses the plane must endure
  - Flexural stress
  - Torsional stress
- Stresses measured in two ways
  - Three point bending test
  - Tinius-Olsen torsion testing machine
- Specimens of each material needed to be tested to compare their stress behavior

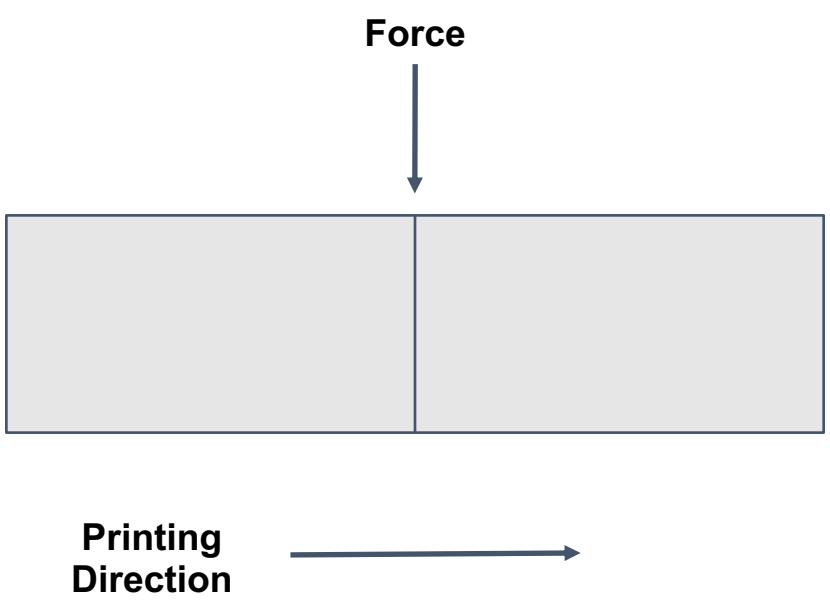
Three Point Bending Test

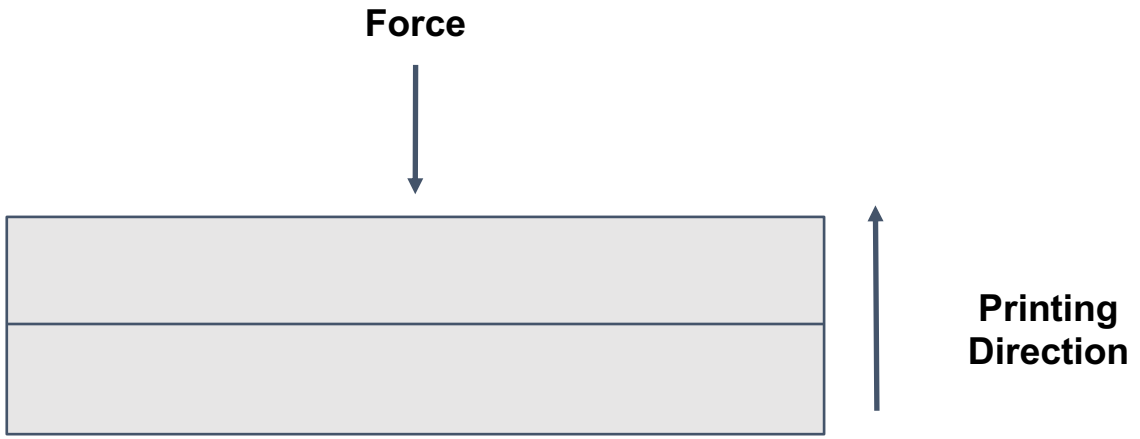


- ASTM D790 is the standard testing procedure
- Requires a ⅛” x ½” x 5” specimen
- Two specimens of each material were used
  - One printed “vertically” and one “horizontally”
  - Same print settings used for all samples
  - Printing direction is crucial when applying stress

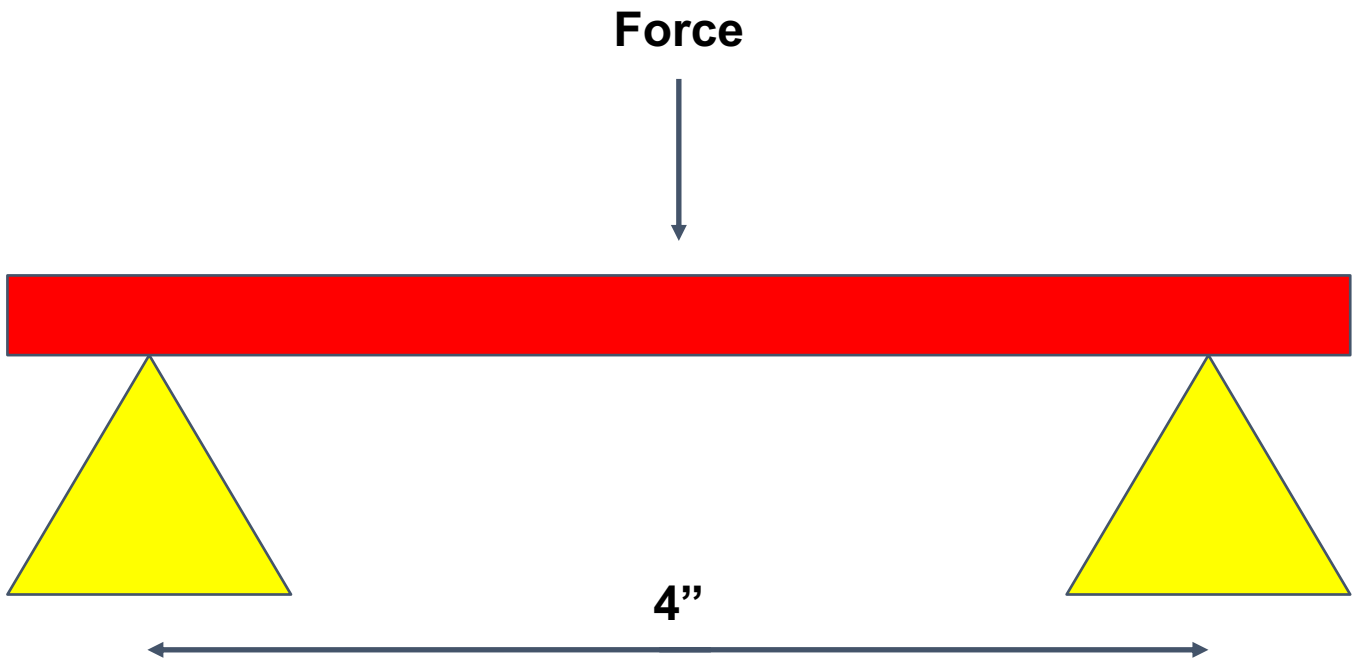
Three Point Bending Test



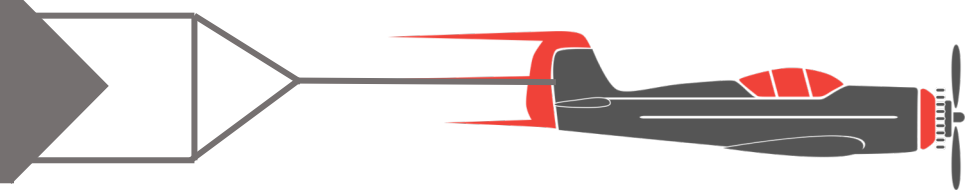




Three Point Bending Test



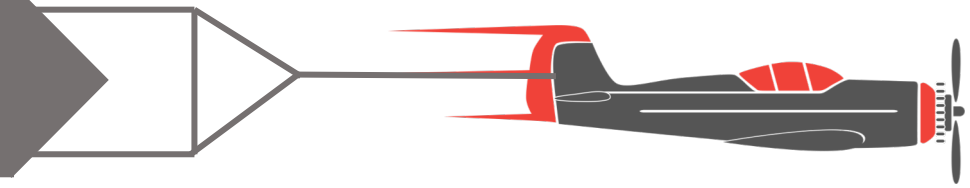
Three Point Bending Test



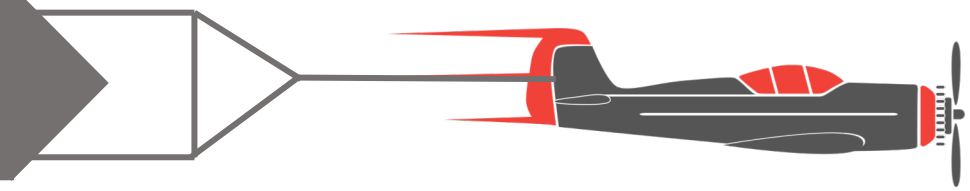
- Force is applied until failure occurs
  - Fracture
  - Enough plastic deformation for specimen to slip from blocks
- Fracture stress is calculated with the formula:

$$\sigma = \frac{3FL}{2wh^2}$$

Three Point Bending Test



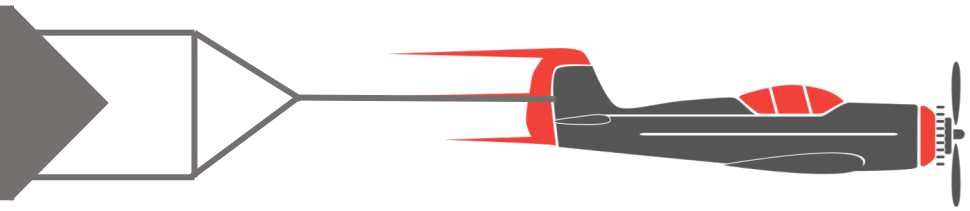
Concept Selection



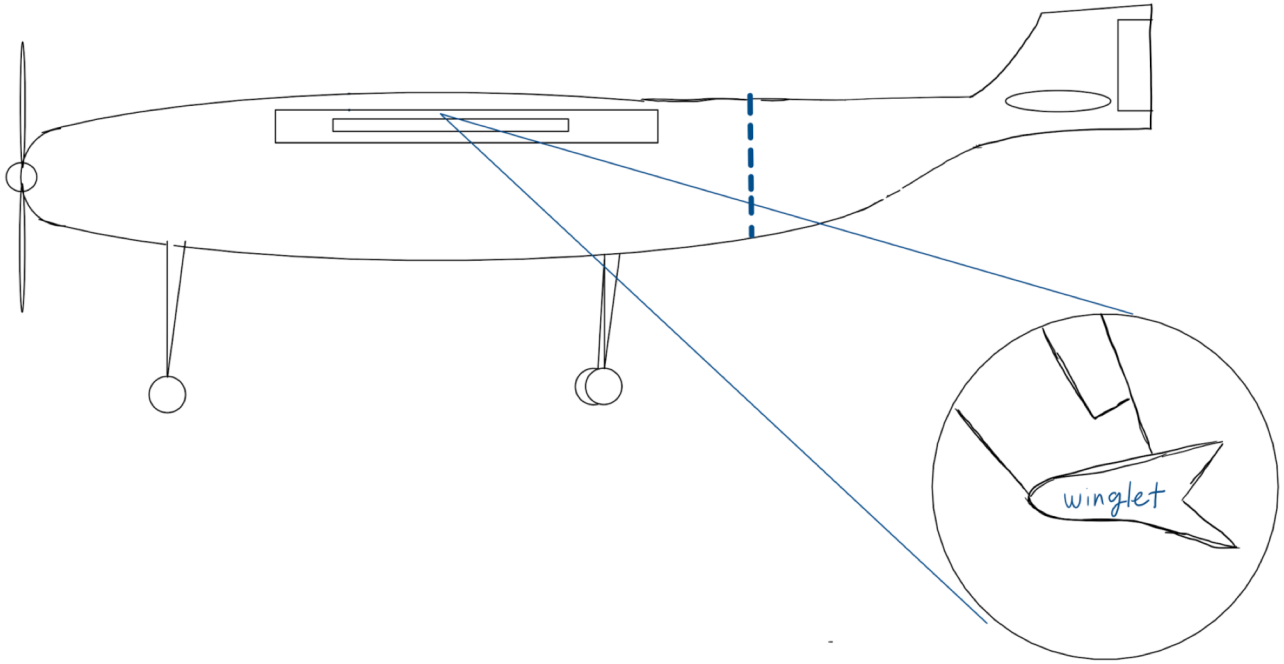
- House of quality chart shows the planes weight is the most important factor to our team
- Came up with 8 concepts for our final design
  - Collaborated with team 507 to come up with concepts

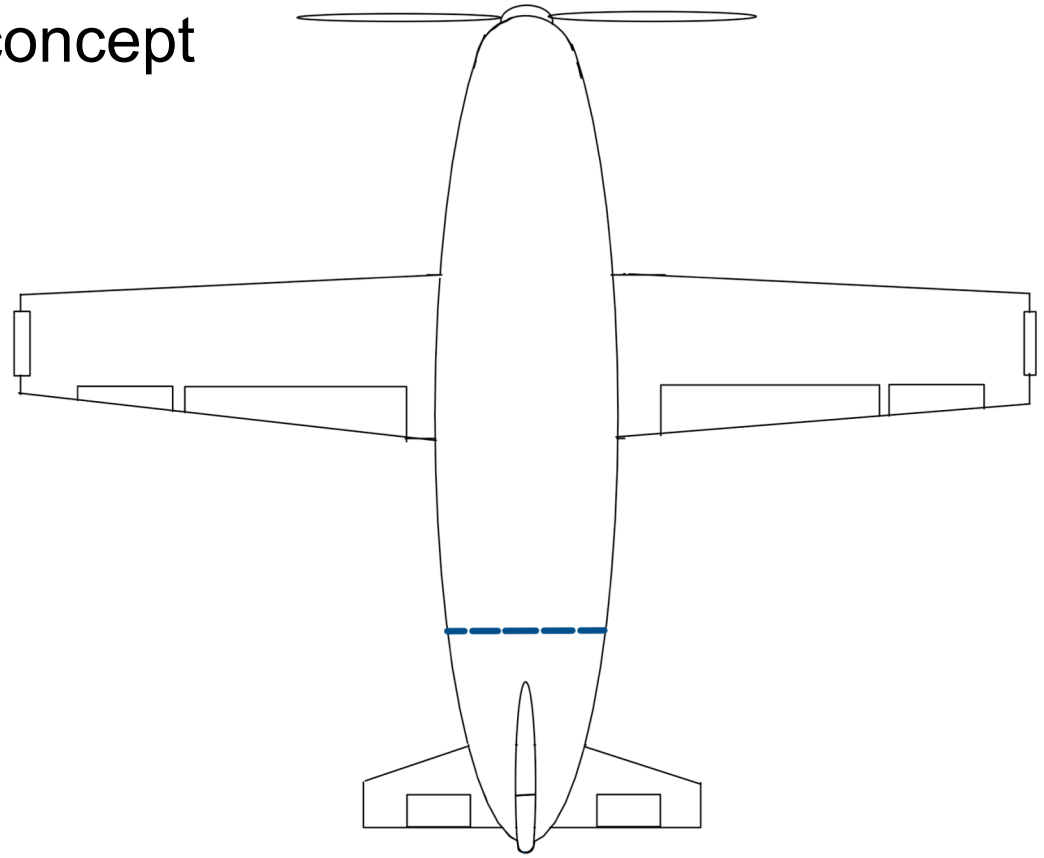
Joseph Figari

Concept Selection



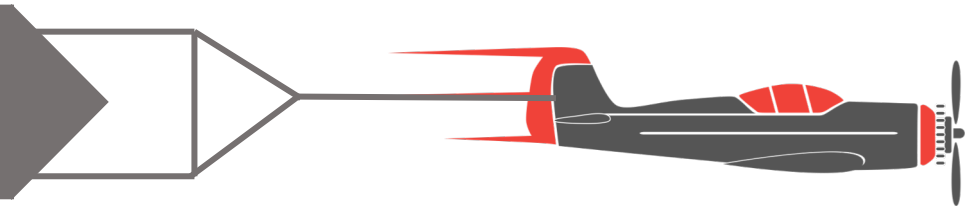
- Concept 1 is our groups first high fidelity concept
  - Includes ailerons and flaps
  - Uses flying boat fuselage



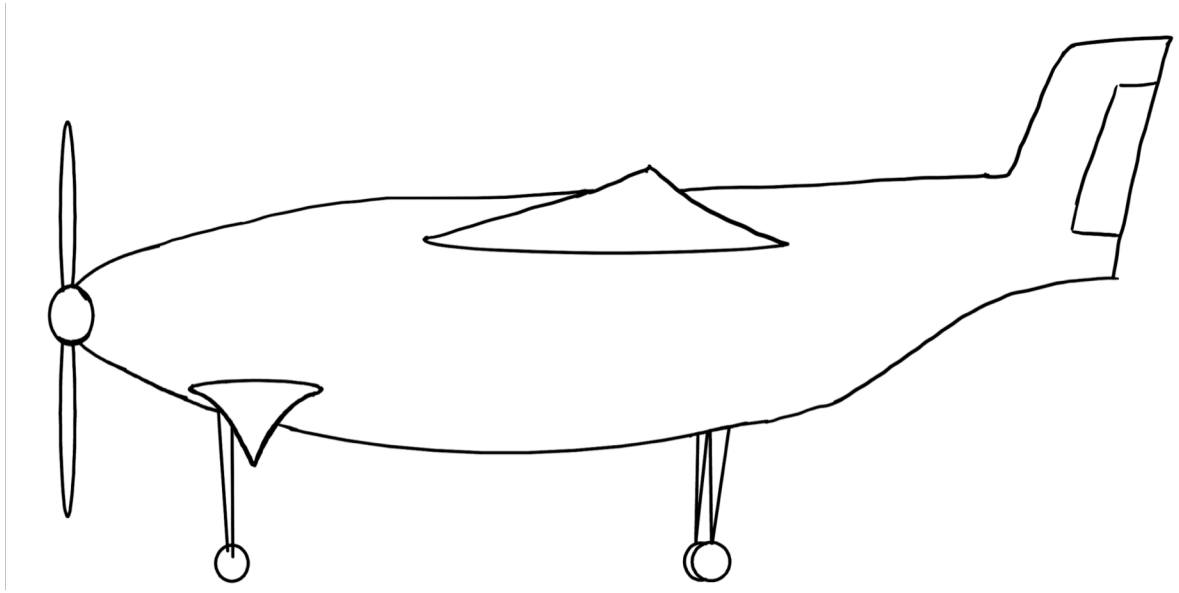


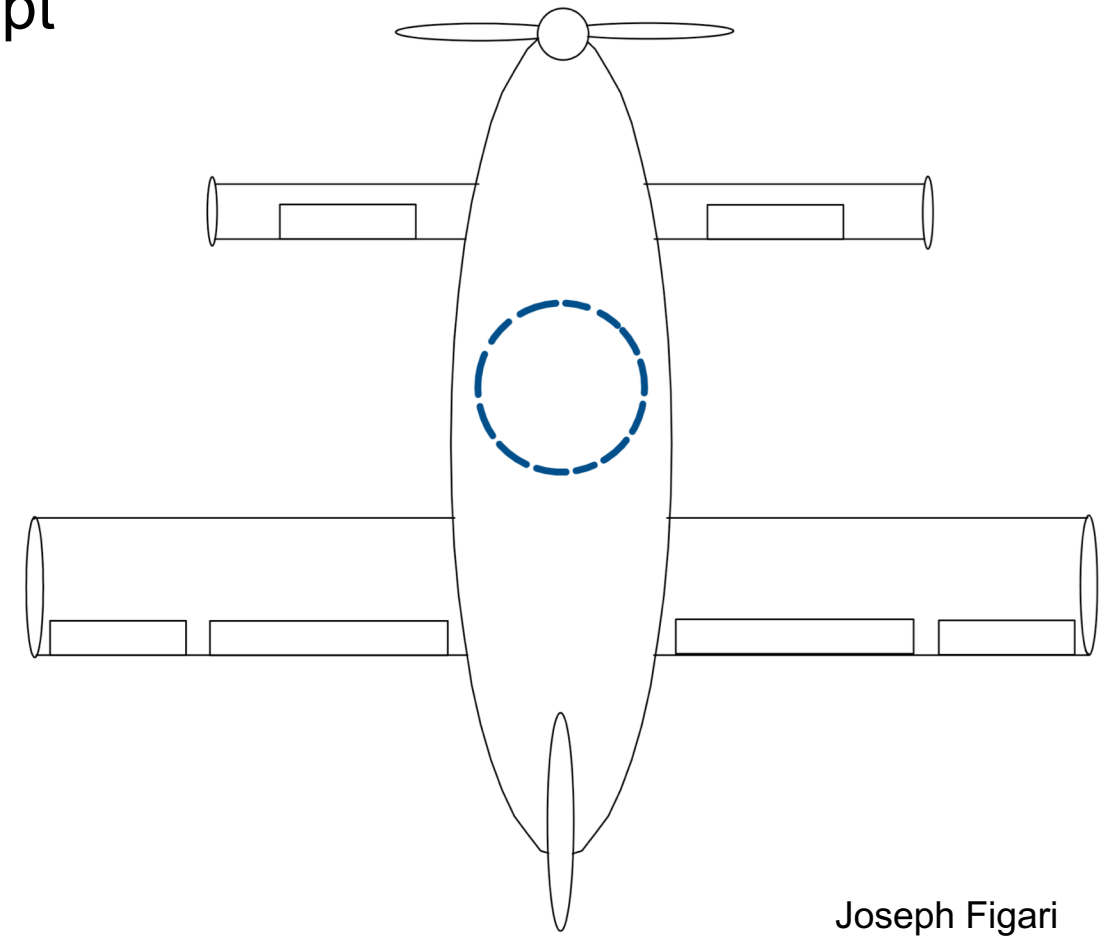
Joseph Figari

Concept Selection



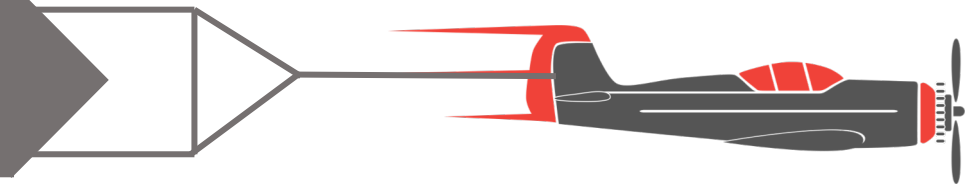
- Concept 3 was the last high fidelity concept
  - Includes flaps and ailerons
  - Uses flying boat fuselage
  - Uses canards



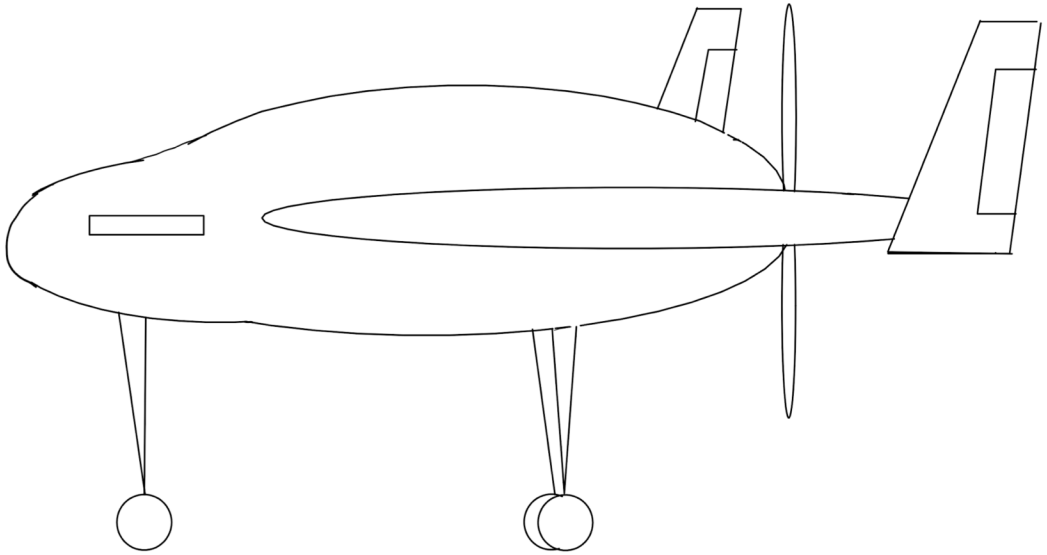


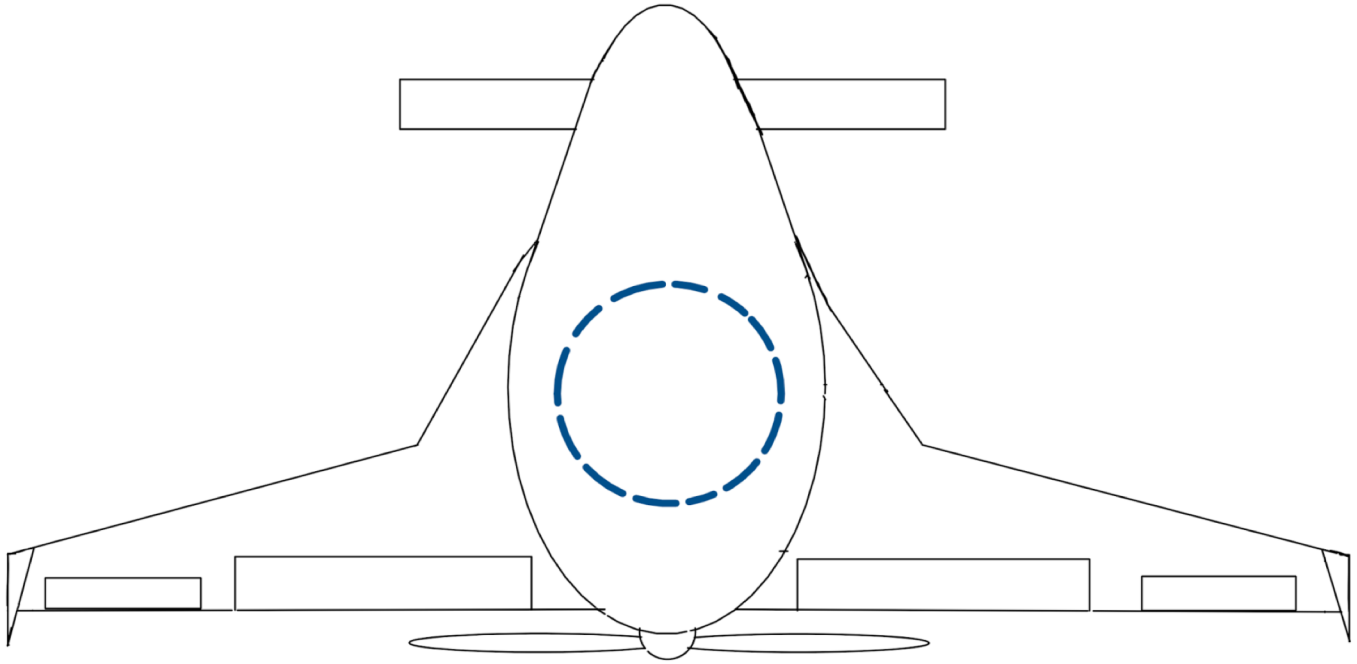
Joseph Figari

Concept Selection



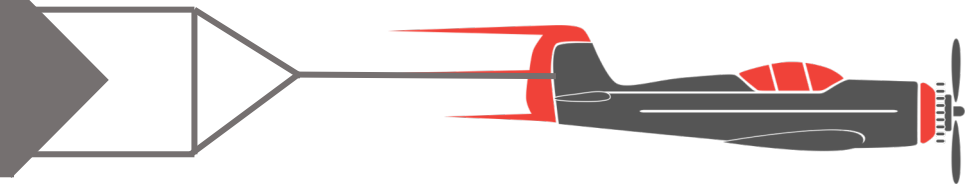
- Concept 6 was our third medium fidelity concept
  - Includes flaps and ailerons
  - Uses subsonic fuselage
  - Uses canards

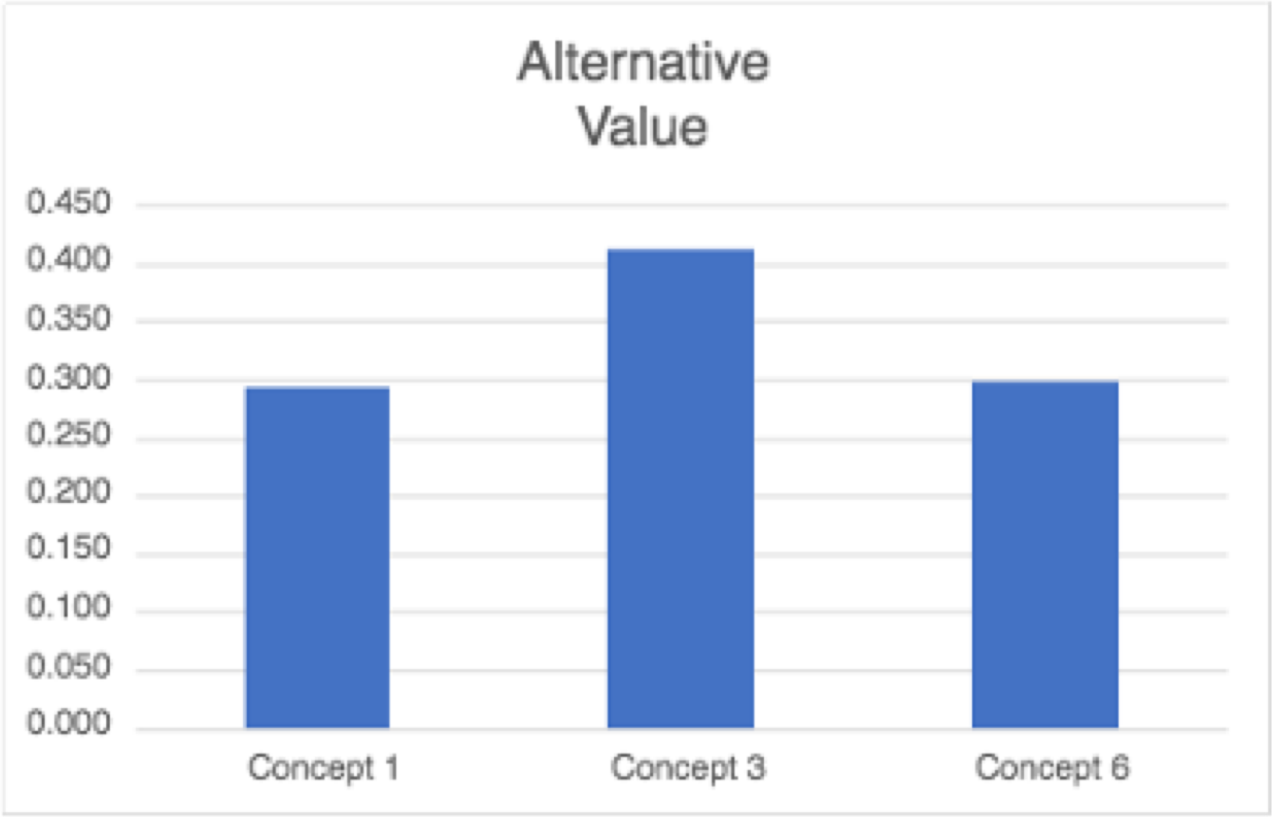




Joseph Figari

Concept Selection

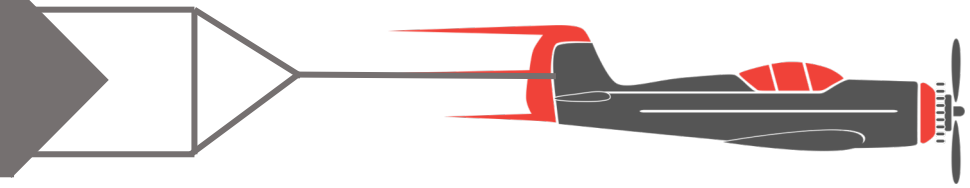




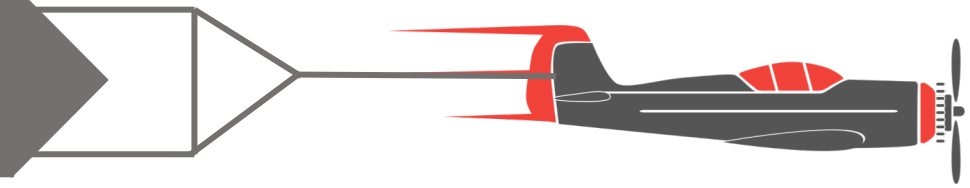
- Group decides concept 3 is the design to go forward with
- Concept 3 meets most of the criteria we deem important

Joseph Figari

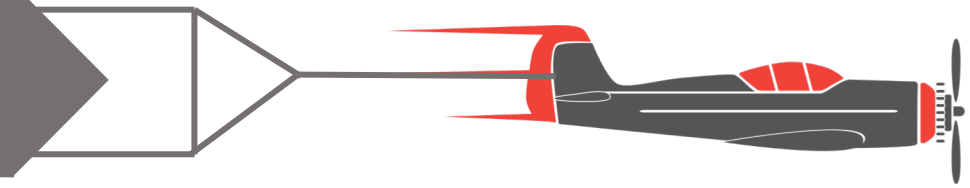
Future Work



Key Takeaways



References



Wing Configuration. (2020, May 28). Retrieved from https://en.wikipedia.org/wiki/Wing_configuration

Tail Design. (n.d.). Retrieved from http://what-when-how.com/flight/tail-designs/

Lennon, A. (1996). *R/C Model Aircraft Design.* Air Age Media Inc.

Aircraft Structure. (n.d.). Retrieved from https://mae.ufl.edu/haftka/structures/FAA.pdf

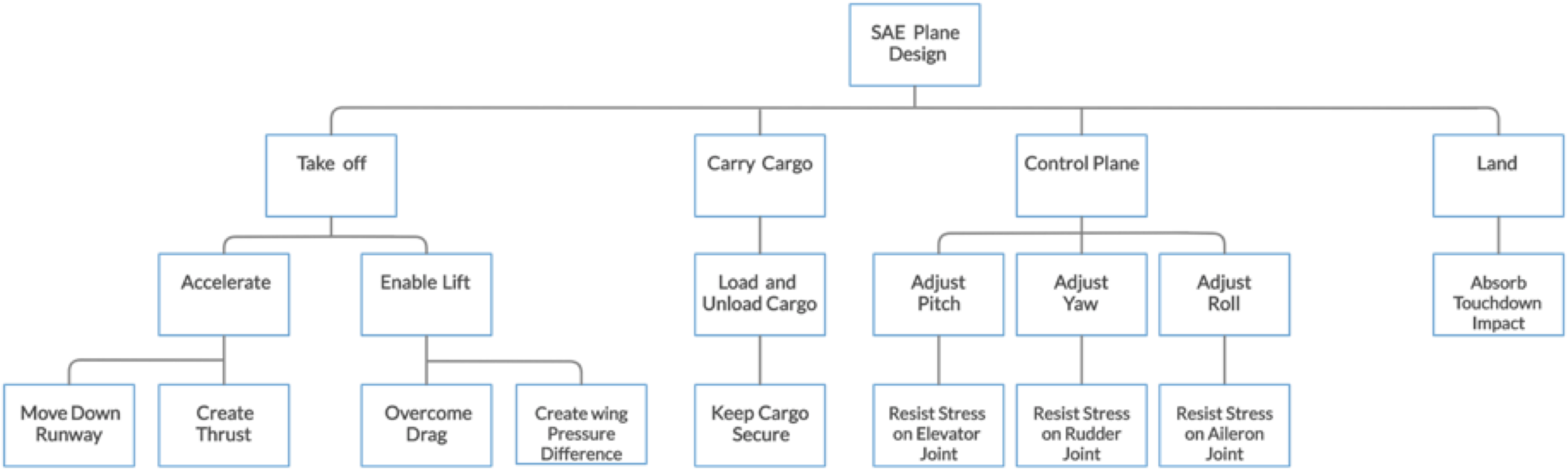
Two Aileron Types. (2014, October, 30). Aviation Safety. Retrieved from https://www.aviationsafetymagazine.com/features/two-aileron-types/

Fuselage. (n.d.). Retrieved from https://studfile.net/preview/5375985/page:2/

Ozgen, S. (2015). *Landing Gear Sizing and Placement.* Middle East Technical University. Retrieved from http://www.ae.metu.edu.tr/~ae451/landing_gear.pdf

Backup Slides

Functional Decomposition



Concept Selection

Pairwise Chart

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1. Material	-	0	0	0	0	0	0	1	0	0	0	0	1
2. Stability	1	-	0	0	0	1	1	1	1	0	0	1	6
3. CG in front of CP	1	1	-	1	1	1	1	1	1	1	1	1	10
4. Meet takeoff/landing requirements	1	1	0	-	1	1	1	0	1	0	0	1	7
5. Wingspan meets restrictions	1	1	0	0	-	1	1	1	1	0	0	1	7
6. Sufficient Power	1	0	0	0	0	-	0	0	1	1	1	1	5
7. Maneuverability	1	0	0	0	0	1	-	0	1	0	0	1	4
8. Light Weight	0	0	0	1	0	1	1	-	1	1	0	1	6
9. Touch-down Impact	1	0	0	0	0	0	0	0	-	0	0	1	2
10. Ground Controls	1	1	0	1	1	0	1	0	1	-	1	1	7
11. Carry the Minimum Cargo Load Required	1	1	0	1	1	0	1	1	1	0	-	1	8
12. Easy to Load/Unload	1	0	0	0	0	0	0	0	0	0	0	-	1
Total	10	5	0	4	4	6	7	5	9	4	3	10	-

Pairwise Chart: Concepts 3 and 12 were chosen as most important

Pugh Chart 1

		Concepts							
		High			Medium				
Selection Criteria	**2020 Competition Entry**	1	2	3	4	5	6	7	8
Lift	DATUM	+	+	+	-	-	+	-	-
Thrust		S	S	S	S	S	S	S	S
Control Surface Movement		+	+	+	+	S	+	S	S
Weight		-	S	-	-	-	S	-	S
Joint Strength		+	+	+	+	+	+	+	+
# of pluses		3	3	3	2	1	3	1	1
# of S's		1	2	1	1	2	2	2	3
# of Minuses		1	0	1	2	2	0	1	1

Pugh Chart 1: Concept 2 was chosen as new datum

Pugh Chart 2

		Concepts		
		High		Medium
Selection Criteria	Concept 2	1	3	6
Lift	Datum	-	+	-
Thrust		S	S	S
Control Surface Movement		+	+	+
Weight		-	-	-
Joint Strength		S	S	S
# of pluses		1	2	1
# of S's		2	2	2
# of Minuses		2	1	2

Pugh Chart 2: Concept 3 chosen as final design

House of Quality

Units		lbf	lbf	lbf	degrees	ft/s	ft/s^2	degrees	seconds	lbs	ft/s^2	psi	psi
Customer Requirements	Importance Weight Factor	Lift	Drag	Thrust	Max Angle of Attack	Stall Speed	Acceleration	Control Surface Movement	Loading/ Unloading Time	Weight	Deceleration	Joint Strength	Material Strength
1. Material	1		1							9		9	9
2. Stability	6	9	3	3				9					
3. CG in front of CP	10	9	3	9	9	9		9		3			
4. Meet takeoff/landing requirements	7	9	3	9			9				9		
5. Wingspan meets restrictions	7	9	3		3	3		1				3	3
6. Sufficient Power	5	1	1	3			3	3		1	1		
7. Maneuverability	4				3	3		9		3		3	1
8. Light Weight	6	3		3			3			9	3		
9. Touch-down Impact	2							3		3	9	9	9
10. Ground Controls	7							1					
11. Carry the Minimum Cargo Load Required	8	9		3			3		9	9	3	9	9
12. Easy to Load/Unload	1								9	3		3	
Raw Score		365	96	228	123	123	120	215	81	191	128	135	124
Relative Weight %		18.92	4.98	11.82	6.38	6.38	6.22	11.15	4.20	9.90	6.64	7.00	6.43
Rank Order		1	11	2	6	6	10	3	12	4	8	5	9

AHP Criteria Weights & Consistency

	Lift	Thrust	Control Surface Movement	Weight	Joint Strength
Lift	1.00	0.33	3.00	9.00	9.00
Thrust	3.00	1.00	3.00	9.00	9.00
Control Surface Movement	0.33	0.33	1.00	5.00	3.00
Weight	0.11	0.11	0.20	1.00	0.11
Joint Strength	0.11	0.11	0.33	9.00	1.00
Sum	4.56	1.89	7.53	33.00	22.11

λ Average Consistency	CI Consistency Index	CR Consistency Ratio
6.053	0.027	0.051

Lift Matrix

{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Con={Ws}/{W} Consistency Vector
0.731	0.243	3.005
2.015	0.669	3.014
0.265	0.088	3.002

λ Average Consistency	CI Consistency Index	CR Consistency Ratio
3.00703	0.00352	0.00676

Thrust Matrix

{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Con={Ws}/{W} Consistency Vector
1.000	0.333	3.000
1.000	0.333	3.000
1.000	0.333	3.000

λ Average Consistency	CI Consistency Index	CR Consistency Ratio
3.00000	0.00000	0.00000

Control Matrix

{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Con={Ws}/{W} Consistency Vector
0.697	0.236	2.959
0.320	0.110	2.898
1.912	0.654	2.924

λ Average Consistency	CI Consistency Index	CR Consistency Ratio
2.92716	-0.03642	-0.07004

Weight Matrix

{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Con={Ws}/{W} Consistency Vector
0.790	0.260	3.033
1.946	0.633	3.072
0.320	0.106	3.011

λ Average Consistency	CI Consistency Index	CR Consistency Ratio
3.03871	0.01936	0.03723

Joint Strength Matrix

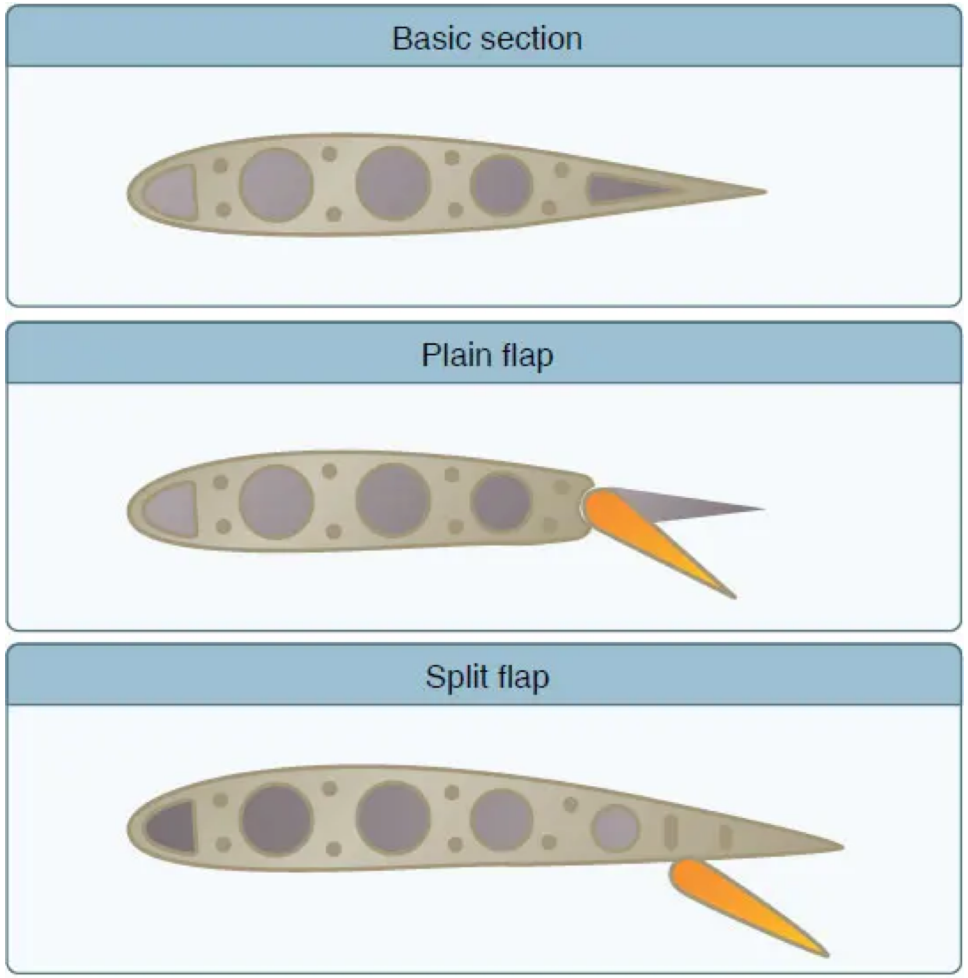
{Ws}=[C]{W} Weighted Sum Vector	{W} Criteria Weights	Con={Ws}/{W} Consistency Vector
1.000	0.333	3.000
1.000	0.333	3.000
1.000	0.333	3.000

λ Average Consistency	CI Consistency Index	CR Consistency Ratio
3.00000	0.00000	0.00000

Final Rating Matrix

Selection Criteria	Concept 1	Concept 3	Concept 6
Lift	0.243	0.669	0.088
Thrust	0.333	0.333	0.333
Control Surface Movement	0.236	0.110	0.654
Weight	0.260	0.633	0.106
Joint Strength	0.333	0.333	0.333

Concept	Alternative Value
Concept 1	0.292
Concept 3	0.411
Concept 6	0.297


Basic section
Plain flap
Split flap
Slotted flap
Fowler flap
Slotted Fowler flap