SAE Aero Regular: Presentation 2

Concept Generation and Evaluation

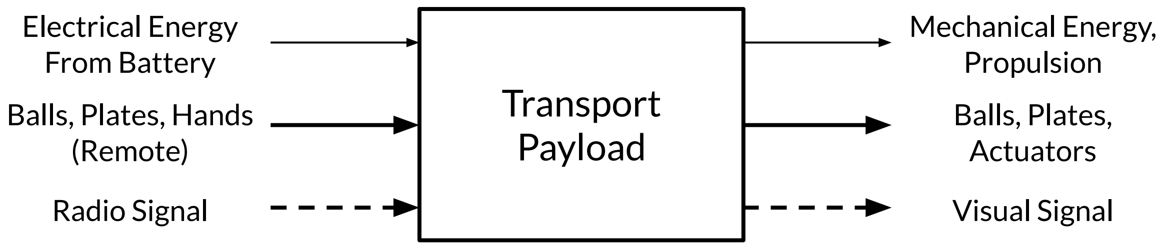
Jacob Cong, Chris Galus, Alex Klausenstock, Nathan Valenzuela

Project Description

Main requirements for regular class:

- Able to carry oversized cargo (soccer balls and steel weights)
- Take off / land on 100 foot runway
- Travel 400 feet from start before turn
- Aircraft must complete a minimum of one 360° circuit
- 120 second time limit
- 10 foot max wingspan
- 1000 Watt power limiter

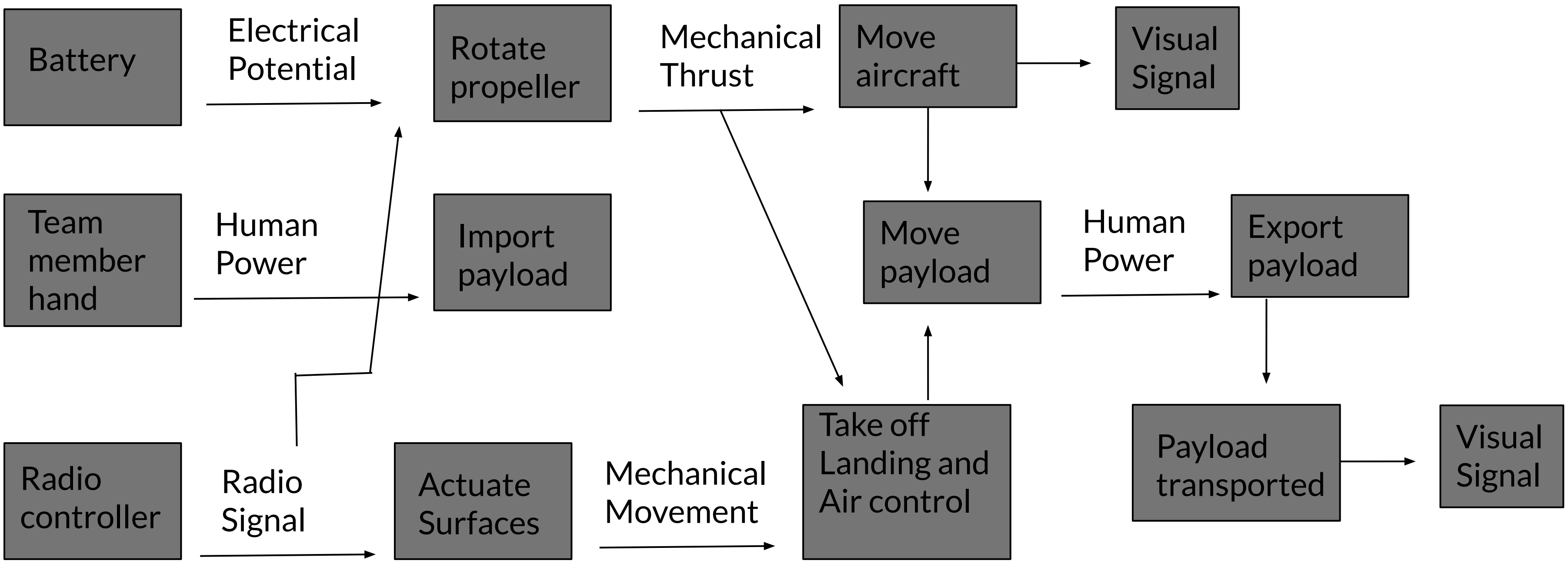
Figure 1: SAE logo



“Black Box” Model

Nathan Valenzuela

Functional Model



Chris Galus

Concept Generation: Airfoil

Need short take off/high lift capabilities. Short list of best short take off and landing (STOL) aircraft and the airfoil they used. Continuing to look at gliding ratio and high available angle of attack before stall utilizing all airfoils on aifoiltool.com.

- USA 35B
  - Used on multiple STOL bush planes
- NACA 2412
  - Used on Cessna bush planes
- Eppler 61
  - Best performance to this point

	Take off distance	Airfoil	Wingspan (ft)	Wing Area (ft)	Payload (lb)
Bounsall Super Prospector	300	proprietary	29.66	120.8	360
Conroy Stolifter	450	proprietary			
Dornier Do 27	558	NACA 23018	39.33	209	585
Fieseler Fi 156 Storch	350	proprietary			
Javelin V6 STOL	150	USA 35B	32	168	1000
Maule M-5	550	USA 35B	30.8333	157.9	900
Scottish Aviation Pioneer	555	proprietary	49.75	390	1965
Slepcev Storch	126	proprietary			
Zenith STOL CH 801	400	proprietary	27	167	1050
piper j3 cub	-	USA35B	35.25	178.5	455
cessna 180/185	-	NACA 2412	35.8333	174	1100

Concept Evaluation: Airfoil

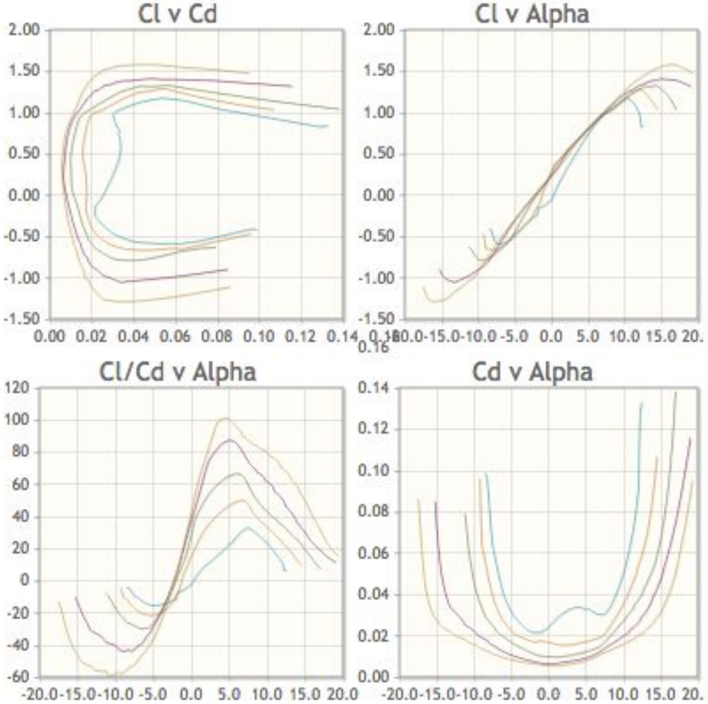


Figure 1: NACA 2412 Aerodynamic Graphs [H]

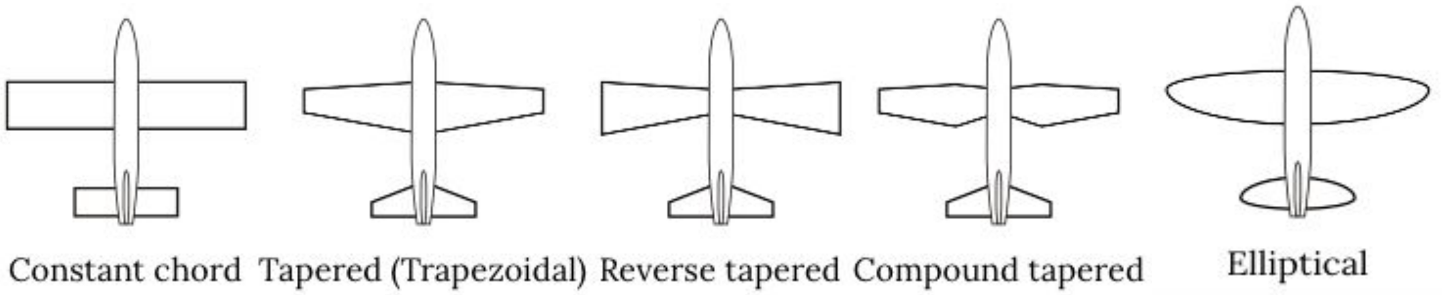
Using the graphs output from airfoiltools.com the team is comparing gliding ratio, angle of stall, how gliding ratio is affected by alpha

USA 35B best Cl/Cd vs alpha

NACA 2412 best Cl vs Cd

E 61 best Cl vs alpha

Concept Generation: Wings



Choosing a straight (constant chord) wing gives:

- Internally supported by whole span spars
- Easiest to manufacture
- Greatest wing area for given span

Choosing a hoerner wing tip gives:

- Helps equalize pressure to reduce drag

Including leading edge slats gives:

- Improved lift and angle of attack

Choosing a top mounted configuration gives:

- Easier to remove and swap if needed, can be additionally supported by struts

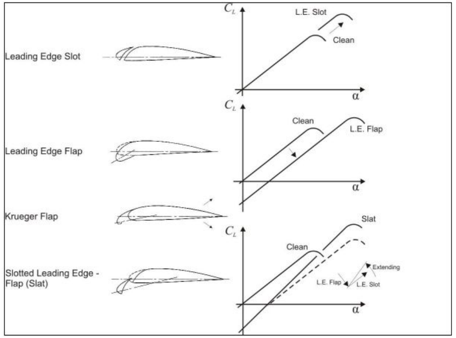


Figure 2: Leading Edge Slats [D]

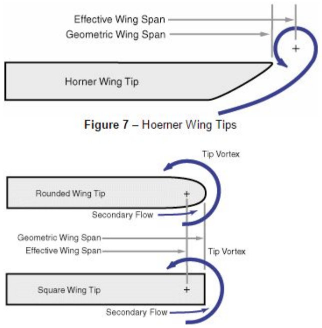


Figure 3: Hoerner tip [G]

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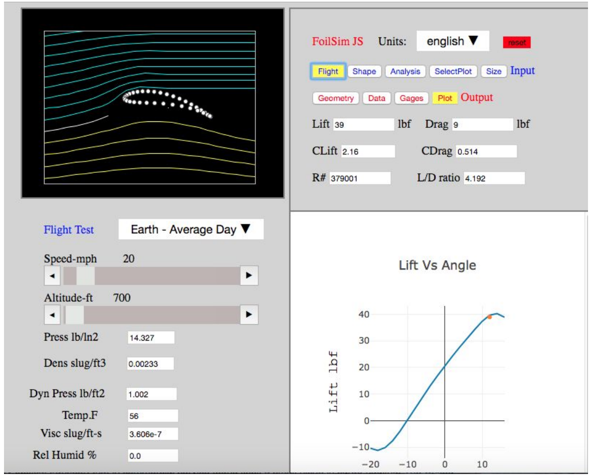
Chris Galus

Concept Evaluation: Wings

- Created an Excel spreadsheet to calculate lift while changing span, chord, angle of attack, and Reynold's number
- Used FoilSim from NASA to confirm calculations for each airfoil and given geometry

Lift Equation				Calculated Lift		last year 16.4 in chord			
L = Cl * [p*V^2)/2] * Wa				39.67426377					
Weight to carry	15	lb							
Lift Needed	40.25	lb							
				Airfoil	USA35B	NACA2412	E61		@
V	32.81	ft/s		Cl	1.6	1.35	1.6		v = 32.81 ft/s
mu	3.687E-07	lb s/ft^2		AR	4.5454	3.4545	4.3333		
p	0.0021	sl/ft^3		Chord	2.2	2.7	2.25	ft	rho = 21e-4
Wing span	9.75	ft		AOA	12.5	15	8	degrees	
Chord Length	2.25	ft		L	39.79	39.14	39.67	lbf	mu = 3.687e-7
Wa	21.9375	ft^2							
Cl	1.6								
Cd									
AOA	8	degrees							
Aspect Ratio	4.333333333								
Re#	420469.8942								
Rough nose length	1.95	ft							
Rough fuselodge length	7.3125	ft							
Rough tail length	3.9	ft							



Chris Galus

Concept Generation: Empennage

Options: Layout

Pros: Manufacturability

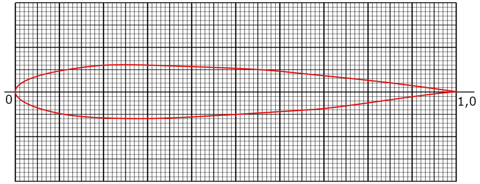
Cons: Size, Placement Concerns

Pros: Size, Placement

Cons: Manufactuability, Weight, Placement

Options: Airfoils

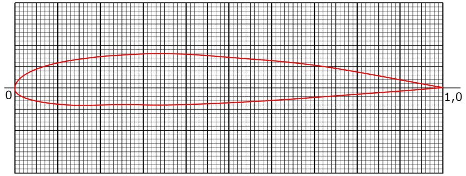
NACA 0012



Pros: Manufacturability, Easy to Modify

Cons: Low Lift

NACA 2412



Pros: High Lift

Cons: Manufactuability, Hard to Modify

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Concept Evaluation: Empennage

Decision: Conventional Tail

CR

- Manufacturability

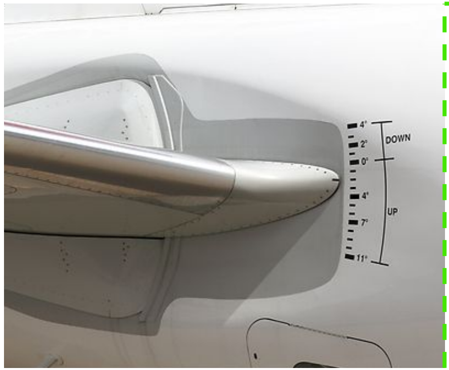
ER

- Weight
- Ease of Assembly
- Turning Capability

Reasons:

- T-Tail not necessary
- Manufacturability/Designability

Decision: Symmetrical Airfoil (NACA 0012)



CR

- Control Authority
- Manufacturability

ER

- Ease of Assembly
- Turning Capability

Reasons:

- Manufacturability
- Can be integrated into “trimmable horiz. stabilizer”

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Concept Generation: Landing Gear, Configuration

Tail-dragger

Pro: Landing capabilities (uneven surfaces)
Con: High angle of attack on take-off

Tricycle ("Nose-Gear")

Pro: Highest stability & control on take-off
Con: Requires smooth runway

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Concept Generation: Landing Gear, Suspension

Suspension

- Aids the absorption and dissipation of kinetic energy experienced on landing impact.
- Reduces the load transmitted to the airframe.

Tail-dragger vs Tricycle suspension

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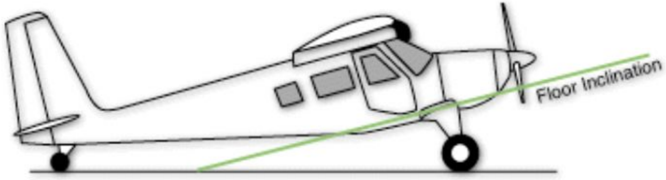
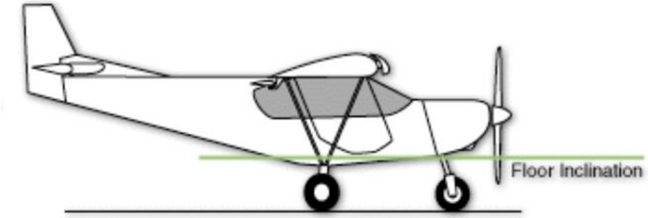
Nathan Valenzuela

Concept Evaluation: Landing Gear

Relevant Customer Needs	*Customer Weights*	Tail-dragger	Tricycle
Manufactuability	*7*	9	9
Takeoff & Landing Capability	*10*	*	*
*Stability on ground	*10*	7	9
*Takeoff Capability	*10*	6	10
*Landing Capability	*10*	8	8
Flight Capability	*8*	6	7
Lightweight	*7*	6	8
Weighted Score	*86.7*	60.5	74.2



Tail-dragger



Tricycle

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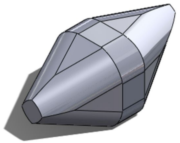
Concept Generation: Payload Configuration

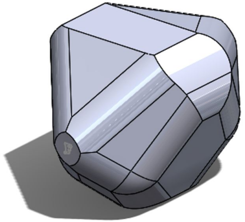
Concept Generation: Simple range of balls vs wt

CR: High Success Rate(Stability), Low Drag, Many Balls

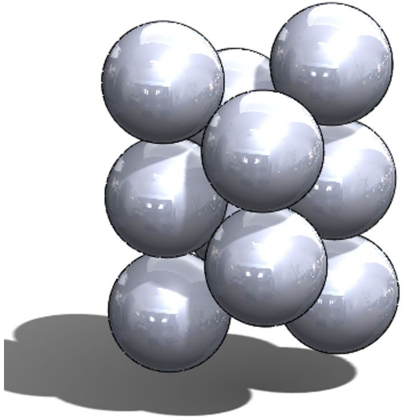
1 Ball



3 Balls



10 Balls



Increasing Drag
Increasing Score
Decreasing Stability

Alex Klausenstock

Concept Evaluation: Payload Configuration

SAE Aero Regular Design Calculation				Flight Score	Payload Prediction	Points
				44.58204334	9.609375	143.355505
Aircraft Wingspan	72	in	b			
Length of Cargo Bay	8.75	in	Lc	Plan for		
Number of soccer balls	10	ball	S	15 lb load		
Number of steel weights	10	lb	Ws	20 lb cabin weight		
Actual Payload	19.375					
Predicted Payload	20					

Scoring:
1 Ball: 103
3 Balls : 112
10 Balls : 143

Must be 5 balls per layer to make depth worth it
4- 9 Balls not worth it

$$FS = Flight\ Score = 120 * \frac{2 * S + W_{steel}}{b\ + L_{cargo}}$$

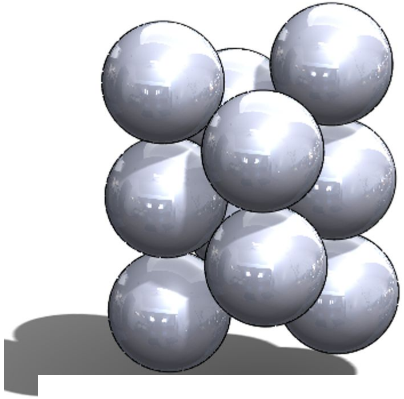
$$S = Number\ of\ Spherical\ Cargo\ Carried\ on\ a\ Flight$$

$$W_{steel} = Regular\ Boxed\ Cargo\ Weight\ (lbs)$$

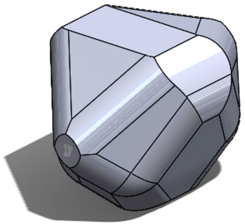
$$b = Aircraft\ Wingspan\ (inches)$$

$$L_{cargo} = Length\ of\ Cargo\ Bay\ (inches)$$

$$A = Actual\ Payload = W_{steel} + 0.9375 * S$$

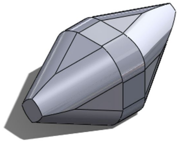


10 Balls



3 Balls

Best Balance ✓



1 Ball

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Alex Klausenstock

Budget

BOM						
	Part	Quantity	Unit	Cost per Unit ($)	Total Cost ($)	Source URL
Electronics	Servos	4	Component	37.73	150.92	https://hitecrcd.c
	ESC	1	Component	124.95	124.95	http://www.castle
	Motor	1	Component	114.05	114.05	https://hobbyking
	Power Limiter	1	Component	75	75	https://neumotors
	Radio receiver	1	Component	64.99	64.99	https://www.horiz
	6S Lipo Battery	1	Battery	63.92	63.92	https://hobbyking
	Soccer Balls	3	Ball	8	24	https://www.adida
Structural	Bass wood	3	15 sheets of 1X24"	22.26	66.78	https://www.dickb
	Balsa wood	6	10 sheets	6.99	41.94	https://www.ama
	Wood Gule	4	Bottle	5.97	23.88	https://www.ama
	Aluminum 6063 T52	4	6 ft beam	35.72	142.88	https://www.meta
	Wheel	3	Wheel	19.94	59.82	https://www.horiz
				Total part value	953.13	
				To purchase	488.21	

	NAU SAE Preliminary Budget	
	Funding	Note
	$3,000.00	Gore Donation
	Costs	Note
Gore Donation Applicable	$1,100.00	SAE Competition Entry Fee
	$488.00	BOM
	$500.00	Operating Redundancies
	$300.00	Manufacturing Equipment
	$400.00	Prototyping
	$100.00	Required Stickers and Gore Branding
Summed	$2,888.00	Gore Funding Usage. For use of plane parts, requirements, and construction only
Gore Donation Non-Applicable	$500.00	2 Nights - Hotel
	$250.00	Gas (1200 miles,17mpg, 3.50$ per gallon)
	$25.00	SAE Membership (4 needed)
	$75.00	Academy of Model Aeronautics License
	$150.00	Team Shirts and Vehicle Markings
Additional Funds Required	$1,075.00	Not deductable from Gore donation, this is our target fund raising goal for memberships and travel expenses
	Leftover	Note
	$112.00	Gore Funding Usage. For use of plane parts, requirements, and construction only
	Fundraising Goal	Note
	$1,200.00	Total fund raising goal. Trip expenses

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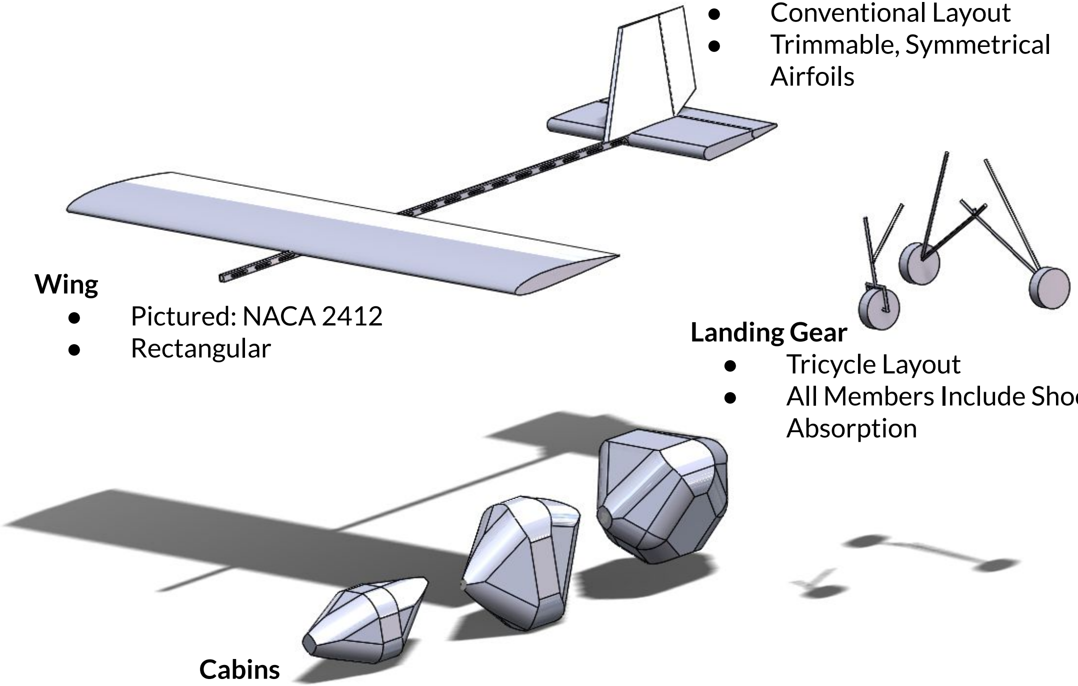
Design Evaluation: Working Design



Empennage
- Conventional Layout
- Trimmable, Symmetrical Airfoils

Wing
- Pictured: NACA 2412
- Rectangular

Landing Gear
- Tricycle Layout
- All Members Include Shock Absorption

Cabins
- Support 1-,2-, and 3-ball configurations
- Short Cabin Length

Satisfied CRs
- Ball/Weight Capacity
- Low Cargo Bay Length
- Inside Budget
- Takeoff and Landing Capability
- Control Authority
- Constructability

Satisfied ERs
- Weight (Est. 35 lbf)
- Power (1000W)
- Cost ($488)
- Lift (39.7 lbf)
- Low Drag (10.6 lbf)
- Ease of Assembly
- Velocity
- Turning
- Cabin Length (22.5”)

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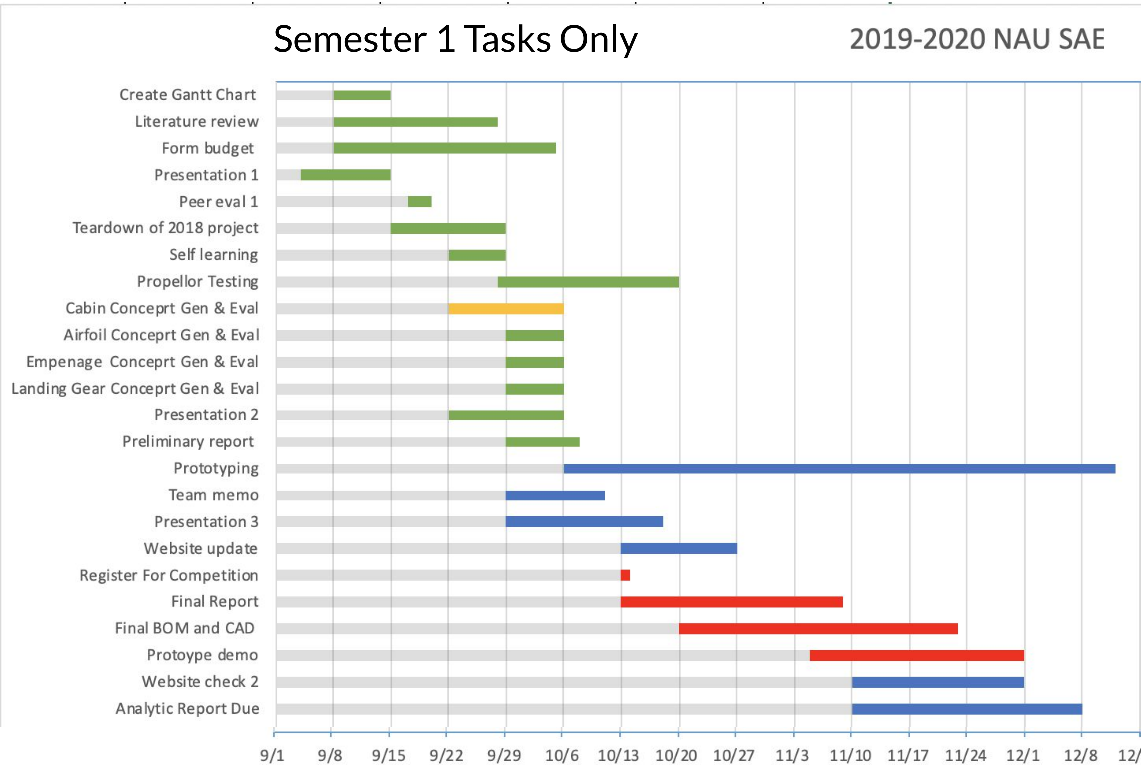
Jacob Cong

Schedule



DESCRIPTION	Team Member
Create Gantt Chart	Chris, Nate
Literature review	All members
Form budget	Nate
Presentation 1	All members
Peer eval 1	All members
Teardown of 2018 project	All members
Register For Competition	All members
Self learning	All members
Presentation 2	All members
Propellor Testing	All members
Cabin Conceprt Gen & Eval	All members
Airfoil Conceprt Gen & Eval	Chris, Alex
Empenage Conceprt Gen & Eval	Jacob
Landing Gear Conceprt Gen & Eval	Nate
Preliminary report	All members
Prototyping	All Members
Team memo	All members
Presentation 3	All members
Website update	Nate,Alex

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Q/A

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Work Cited

[A] AeroToolbox.net. (2019). Horizontal and Vertical Tail Design | AeroToolbox.net. [online] Available at: https://aerotoolbox.net/design-aircraft-tail/ [Accessed 1 Oct. 2019].

[B] Wikimedia Commons contributors (2019). File:NACA 2412.svg - Wikimedia Commons. [online] Commons.wikimedia.org. Available at: https://commons.wikimedia.org/w/index.php?title=File:NACA_2412.svg&oldid=146747312 [Accessed 3 Oct. 2019].

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Work Cited

[H "Airfoil Tools NACA 2412," [Online]. Available: http://airfoiltools.com/airfoil/details?airfoil=naca2412-il. [Accessed 5 October 2019].

[I] C. Heinz, "Zenithair," 2009. [Online]. Available: http://www.zenithair.com/stolch801/design/design.html. [Accessed 5 October 2019].

[J] M. Sadraey, "Chapter 9: Landing Gear Design," Daniel Webster College, pp. 1-61.

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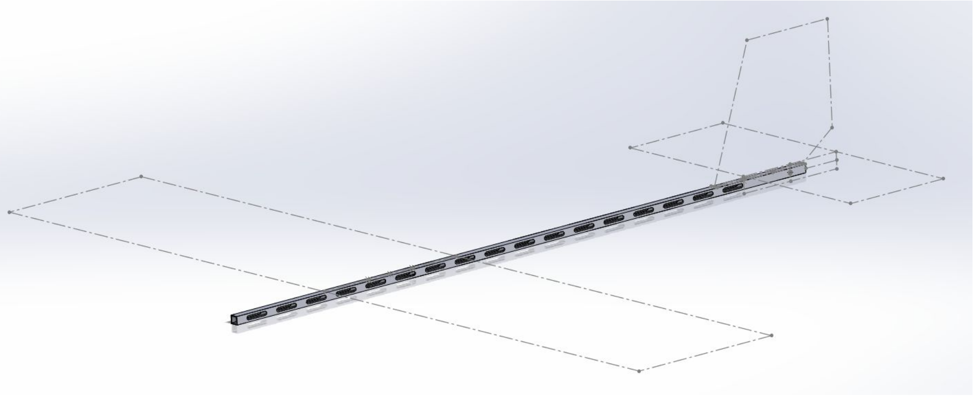
Appendix A: Equations

How the CAD works: Dimensions related by Equations



Name	Value / Equation	Evaluates to
Global Variables		
"Cmac"	= "Cmac@Sketch4"	20.00in
"Wing Span"	= "Wing Span@Sketch4"	108.00in
"HorizTailCord"	= "HorizTailCord@Sketch2"	14.00in
Add global variable		
Features		
Add feature suppression		
Equations		
"WingHoleSpace@Sketch4"	= "Cmac" / 3	6.67in
"WHS@Sketch4"	= "WingHoleSpace@Sketch4"	6.67in
"lever@Sketch4"	= "Cmac" * 3	60.00in
"ElevatorCord@Sketch2"	= "HorizTailCord" / 3	4.67in
"HorizTailSpan@Horiz Tail Line	= "HorizTailCord" * .5 * "Wing Span" /	37.80in
Add equation		

Appendix A: Gantt Chart