Interim Design Review

S.U.A.S.

Student Unmanned Aerial System

Senior Design Team# 14

Team Members

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Introduction

Primary Objectives:

- Systems Engineering approach for the design and manufacture of an Unmanned Aerial System (UAS)
- System must be designed for:
  - Waypoint Navigation
  - Autonomous Area Search for Ground Targets
  - Image Recognition of Ground Targets
- System must comply with the 2012 AUVSI Student UAS Competition requirements.

Introduction

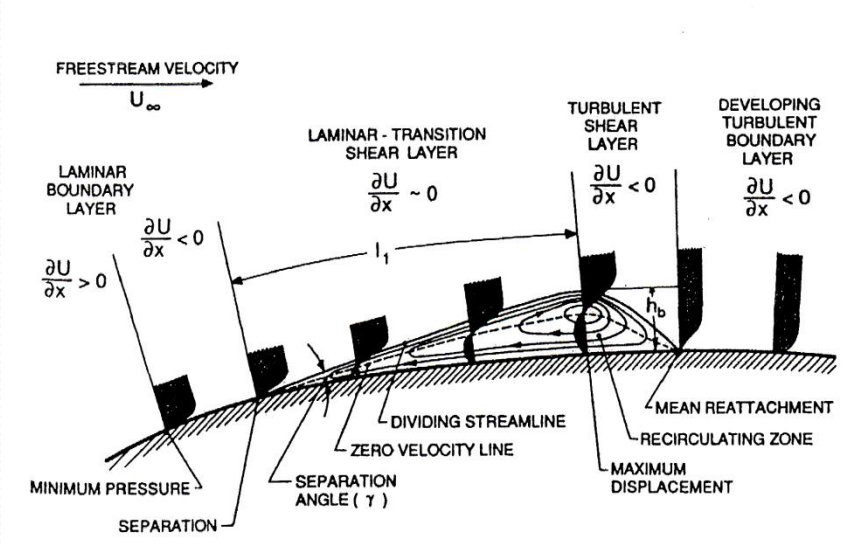
- To accomplish our primary objectives, our UAS must be comprised of several subsystems:
  - Aircraft Subsystem
  - Avionics Subsystem
  - Imagery Subsystem
  - Ground Station Control (GSC) Subsystem

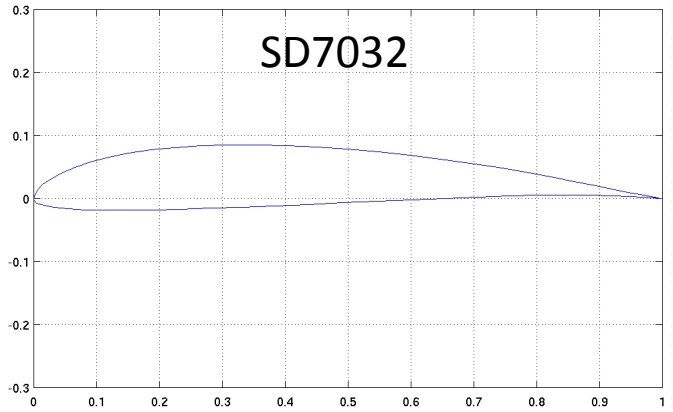
Airframe Design

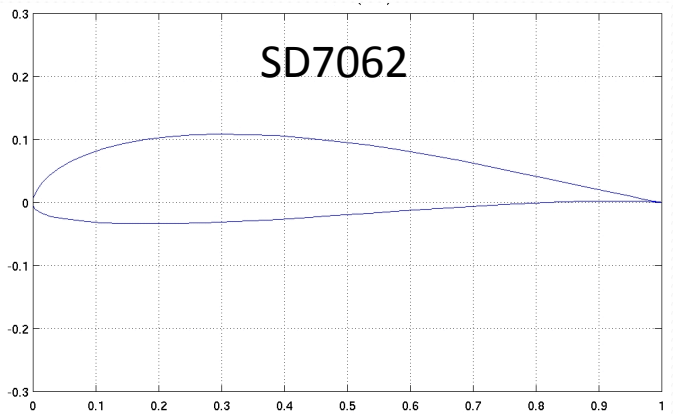
- Conventional Planform
  - High Aspect Ratio
  - Moderate Wing Loading
  - Low Stall Speed
  - Fast Cruise Speed
- Airfoil Selection
  - High C_l
  - Highest Possible L/D
  - Manufacturable

Low Reynolds Number Airfoils

100,000 < Re < 600,000

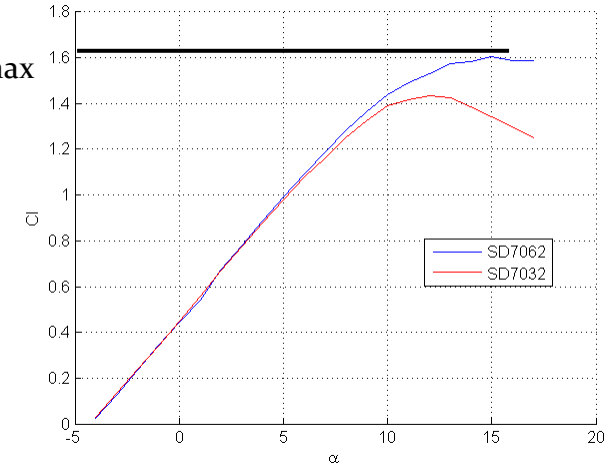


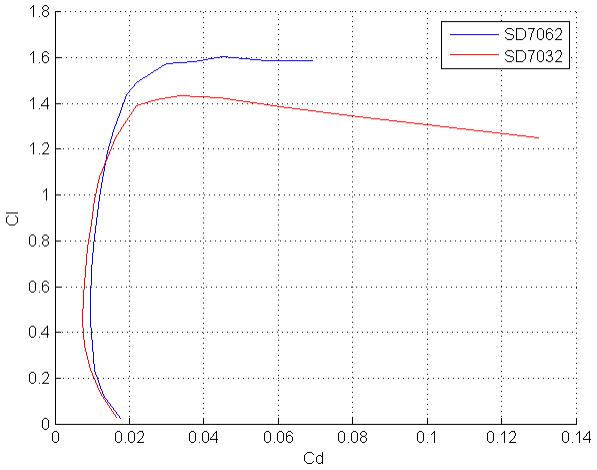


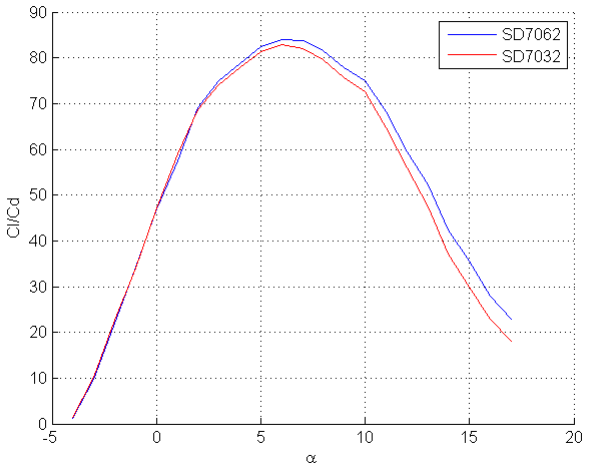


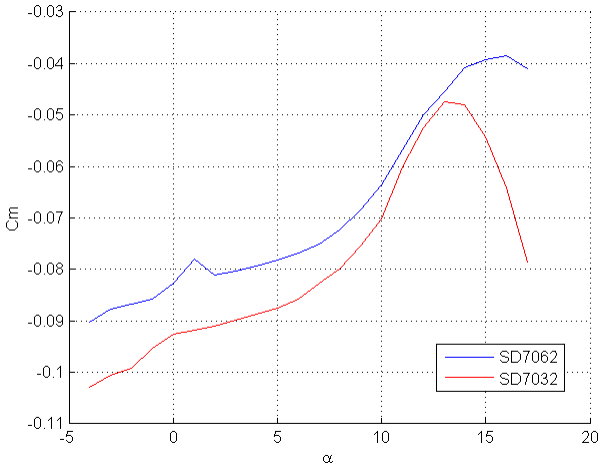
Airfoil Comparison @ Re=3x10^5

C_{lmax}

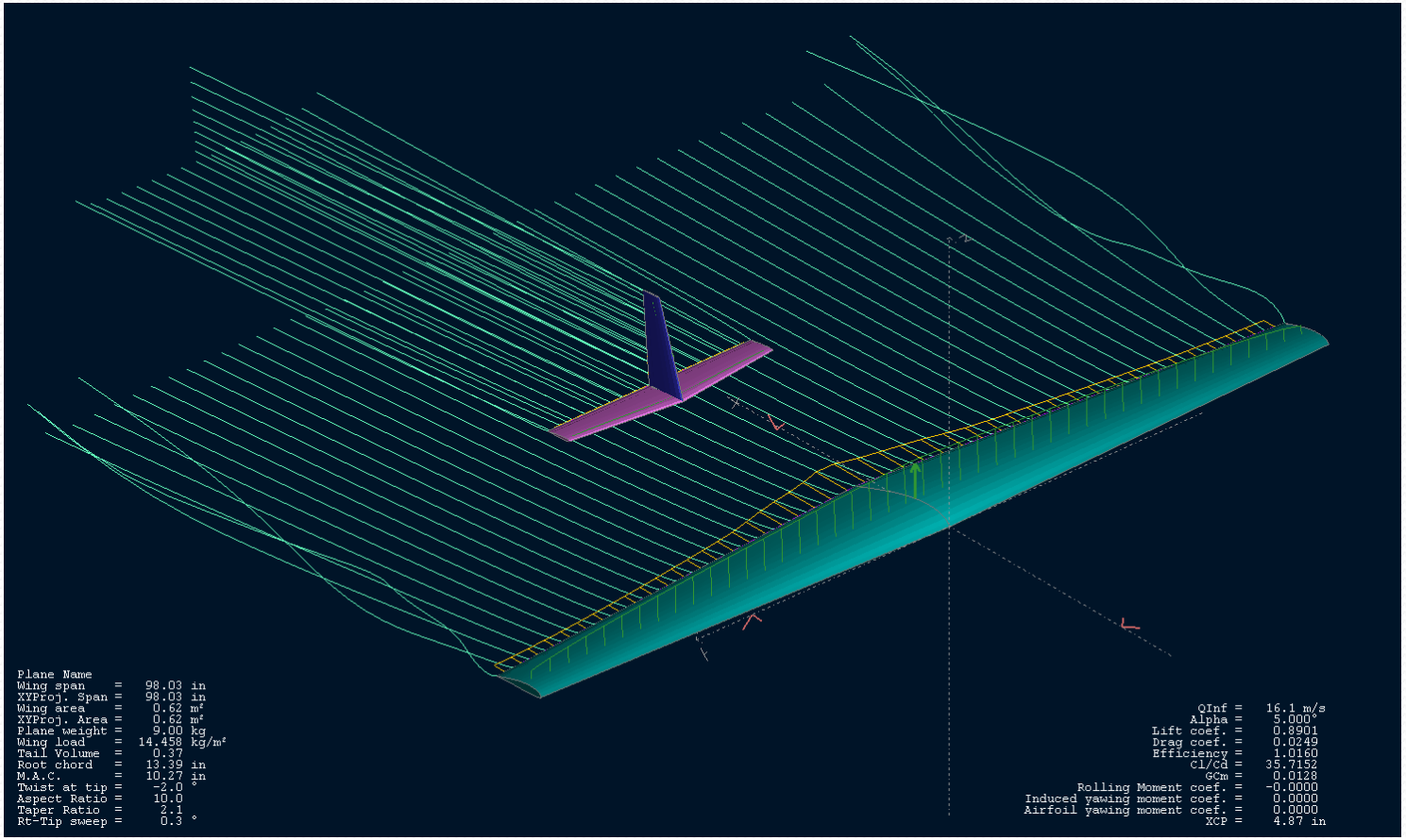




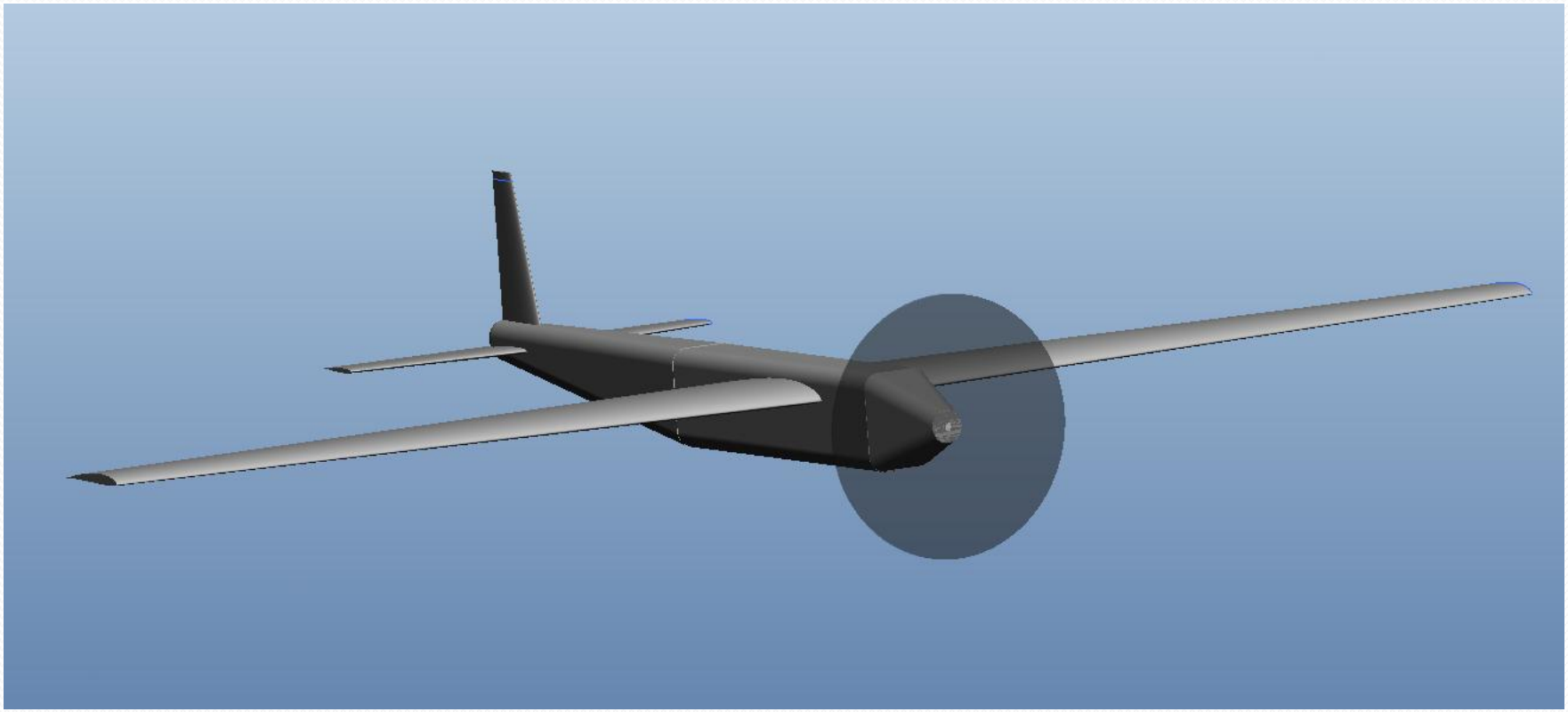




SD7062 L.R.N. Airfoil

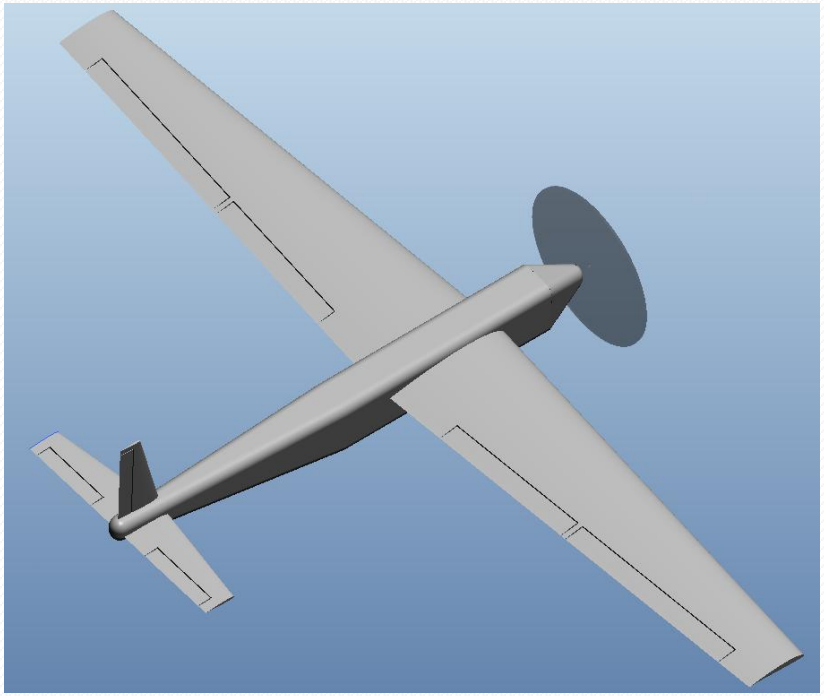


Initial Configuration

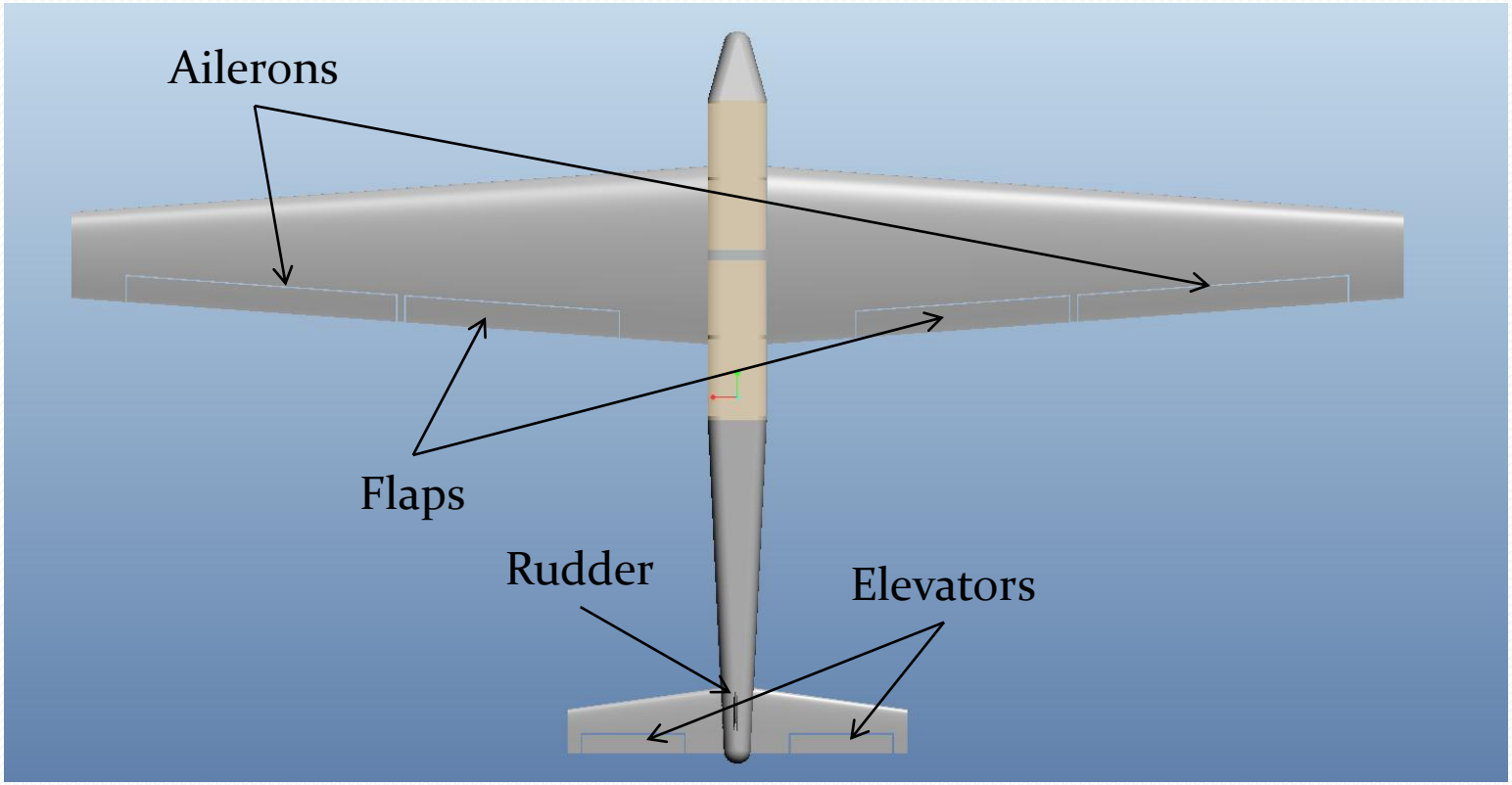


Initial Configuration

- Wing Span: 98 in
- Length: 55 in
- Fuselage Volume: 648 in^3
- Aspect Ratio: 10
- T. O. Weight: 19.8 lbs
- Wing Loading: 3 lb/ft^2
- Stall Speed: 28 mph
- Cruise Speed: 45 mph

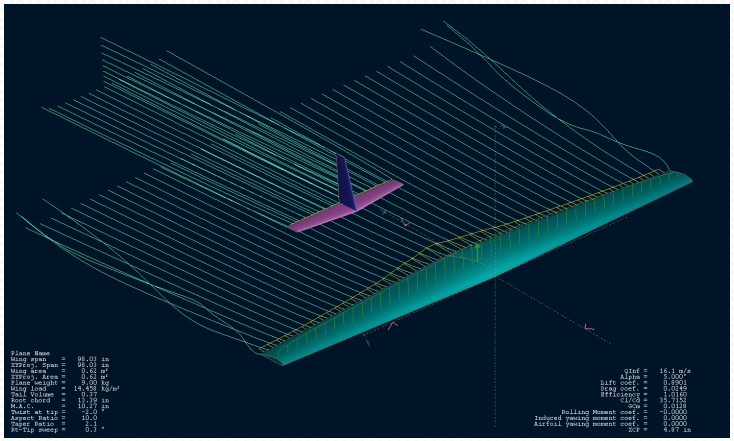


Control Surfaces

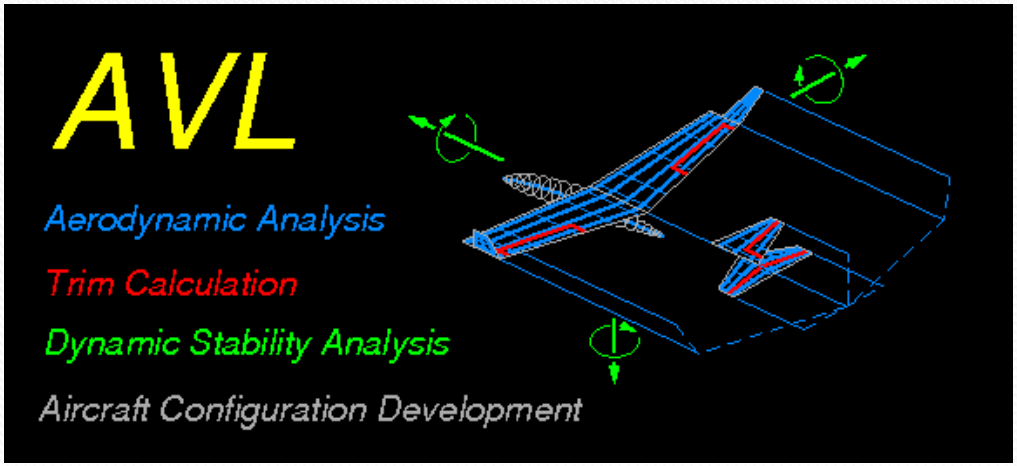


Further Analysis

Further Aerodynamic Analysis



Stability Analysis



Material Decision Matrix

Material Selection Decision Matrix											
Criteria	Weight	Fiberglass and EPS Foam		Fiberglass and Spyder Foam		Carbon Fiber and EPS Foam		Carbon Fiber and Spyder Foam		Hybrid Skin	
Mass	0.35	5	1.75	4	1.4	3	1.05	2	0.7	4	1.4
Strength	0.3	1	0.3	2	0.6	4	1.2	5	1.5	4	1.2
Cost	0.25	5	1.25	4	1	2	0.5	1	0.25	3	0.75
Workability	0.1	5	0.5	5	0.5	5	0.5	5	0.5	5	0.5
Total	1		**3.8**		3.5		3.25		2.95		**3.85**

Weight of air frame:

1. 10.75lb
2. 11.67lb
3. 11.73lb
4. 12.83lb
5. 11.61lb

Cost of material:

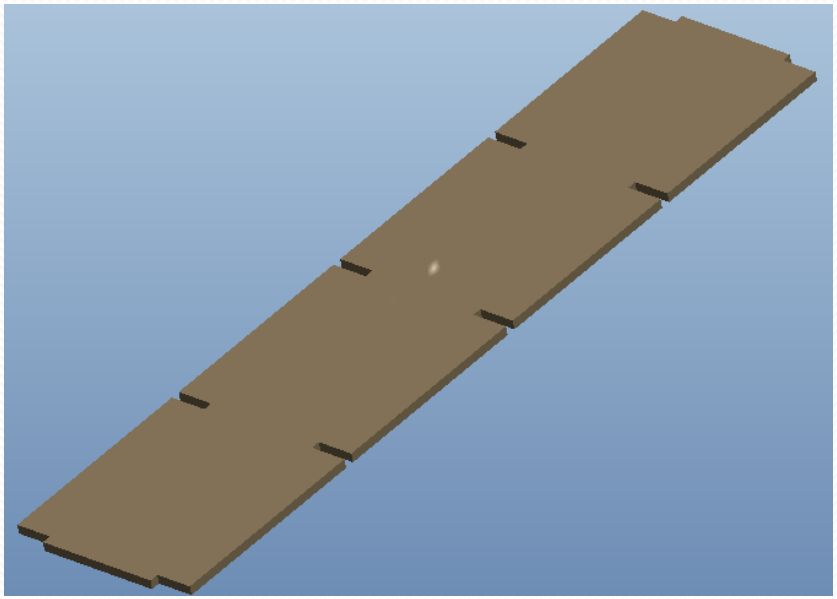
1. $11.45/yd + $8.77 for 5.5”x12”x24”
2. $11.45/yd + $30 for 5.5”x12”x24”
3. $44.95/yd + $8.77 for 5.5”x12”x24”
4. $44.95/yd + $30 for 5.5”x12”x24”

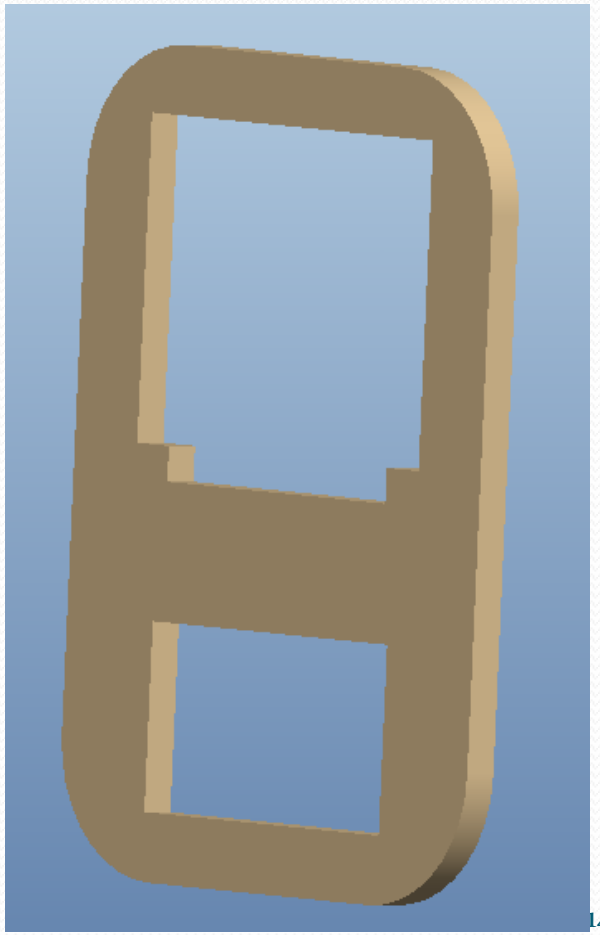
Strength:

1. 45.2kpsi + 25psi
2. 45.2kpsi + 60psi
3. 75.6kpsi + 25psi
4. 75.6kpsi + 60psi

Strength for composite matrices from evaluation using 10 ply layer and identical resin

Internal Structures

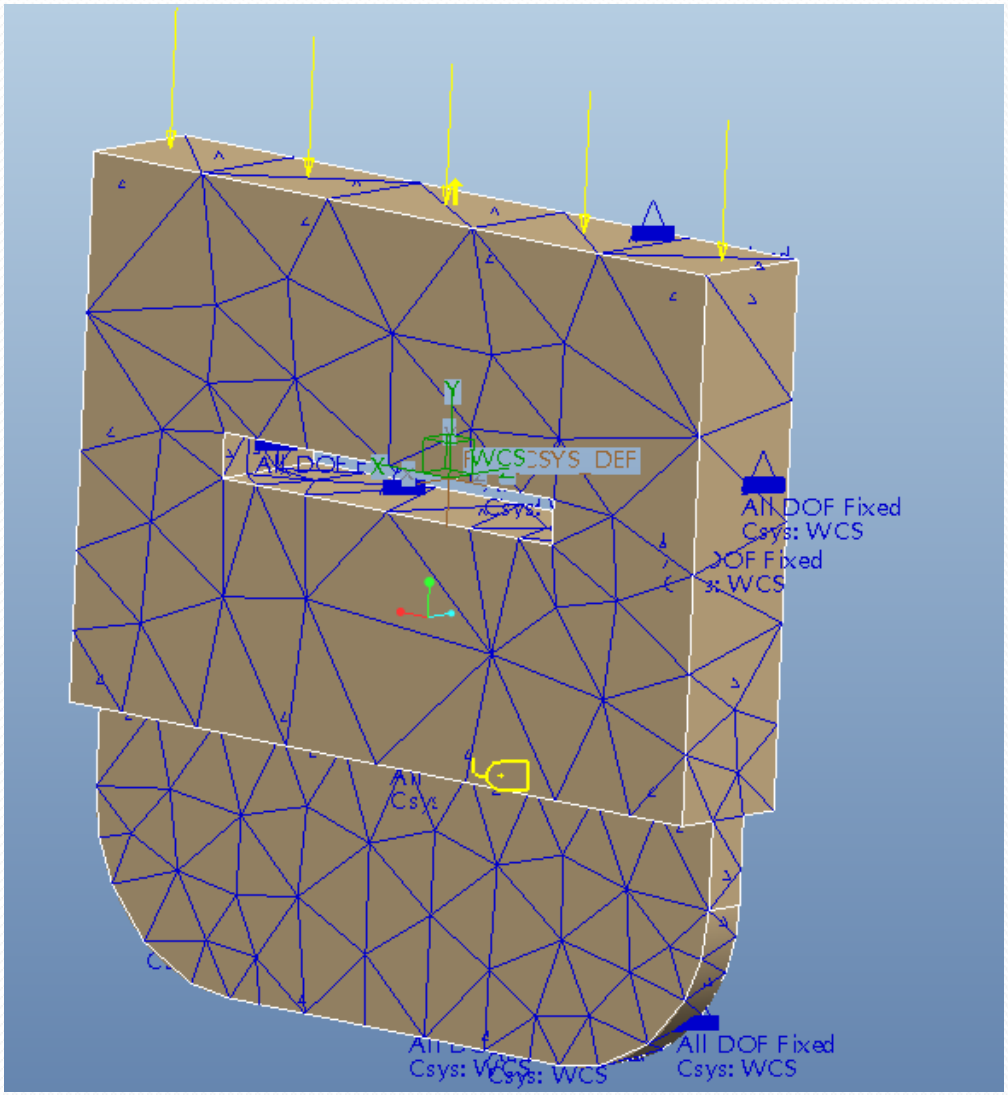




Constructed of light weight spruce or carbon fiber reinforced balsa.

Weight of all internal components is supported by base plate while ribs provide structural stiffness and support for the wings.

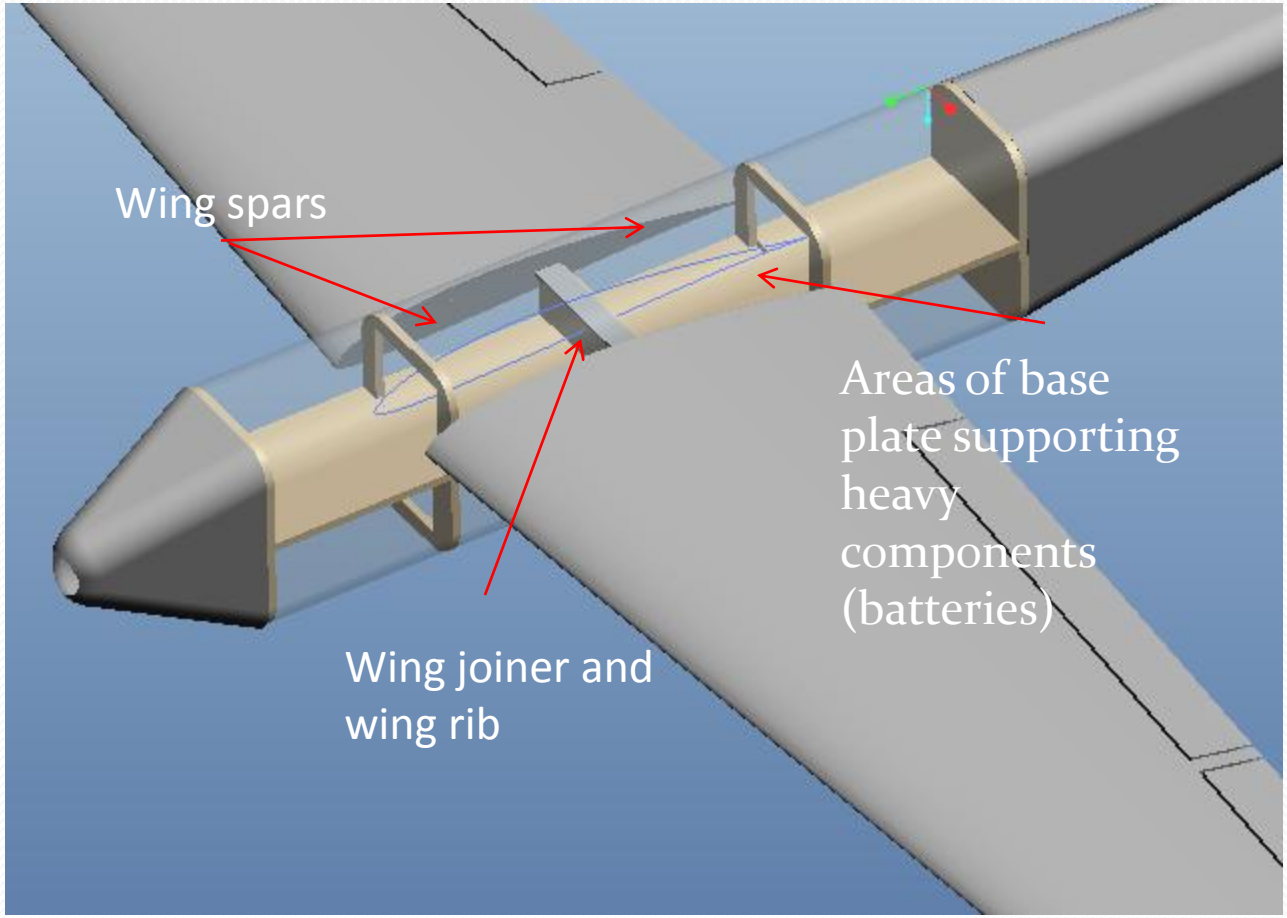
Wing Rib Analysis



- Loads from the wing will be transferred from the spar and wing joiners to the internal structure.

- Known max wing load will be used to determine if extra wood is needed or carbon fiber reinforcement is required.

Carbon Fiber Placement



Motor Type

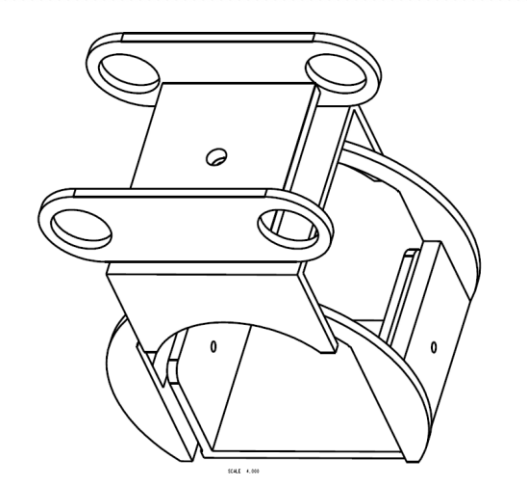
- Decision Matrix
- Motor Type
- Decision Matrix Criteria:
- Cost (30%)
- Power Output (25%)
- Maintenance (20%)
- Ease of operation (15%)
- Weight (10%)

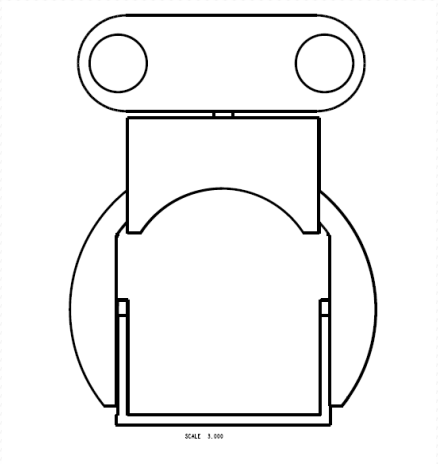
Motor Type

	4-Stroke	2-Stroke	Brushless	Brushed	Pulsejet
Cost	.9	1.2	1.3	0.8	0.5
Maintenance	.6	.7	0.9	0.6	0.5
Power Output	1.2	1.0	1.1	0.6	1.2
Ease of operation	0.5	0.6	.7	0.6	0.5
Weight	0.4	0.4	0.4	0.3	0.3
Total	**3.6**	**3.9**	**4.4**	**2.9**	**3**

Gimbal

- The UAV will need to recognize targets.
- The gimbal will be able to rotate about 2 axes.
- The gimbal will contain the camera.
- It will be located at the bottom of the plane.





Power Supply Analysis

Engineering Analysis:

1. Estimate total Aircraft Power requirements
   - General components
   - General specifications

2. Select Appropriate Battery models for requirements
   - NiMH
   - LiPO

3. Analyze Battery Concepts
   - Simulink
   - Decision Matrix

Cruise speed and level flight = 12.5 watts per pound

=> 20 lb plane needs 250 watts for cruise

Battery Data

Battery Voltage (V)	29.6

Motor Data

Motor type/name	motor1
Kv (rpm/volt)	225
Rm (Ohms)	.027
Io1 (A) @ V1 (V)	0 @ 0
Io2 (A) @ V2 (V)	2.6 @ 30
Max motor current (A)	110
Simulate motor heating?	Mild
ESC Resistance (Ohms)	0.005

Gearbox Data

Gearbox Ratio	1.0 :1
Gearbox Efficiency (%)	100

Propeller Data

Prop type	APC E
Prop diameter (inches)	20
Prop pitch (inches)	13

Calculate | Help | About

Motor/Propeller Results

Motor Current (A)	71
Motor Input Power (W)	2087.0
Motor Output Power (W)	1873.8
Motor Heating (W)	213.2
Motor Efficiency (%)	89.8
Prop Static Thrust (oz)	314.4
Prop Average Thrust (oz) (zero to pitch speed)	209.9456
Prop Dynamic Thrust (oz) (at pitch speed)	88.0
Prop Pitch Speed (mph)	75.2
Prop RPM (revs/sec)	6189

Four Motor Constants

Motor Kv (rpm/V)	225
Motor Io (A) (at zero voltage)	0.0
Motor R_2 (dV/dIo) (Ohms)	11.538
Motor Rm (cold) (Ohms)	0.0270
Motor Rm (hot) (Ohms)	0.0297

Power Supply Analysis (1)

- Estimate total Aircraft Power requirements

Estimated component power consumption		
Component	**Current (mAh)**	**Power (w)**
Motor	10000	296
Autopilot	40	0.26
Camera	308	2.002
Video TX	500	2.5
Autopilot TX	210	0.693
CS Servos	160	0.8
Gimble Servos	50	0.25
Total	11268	302.505

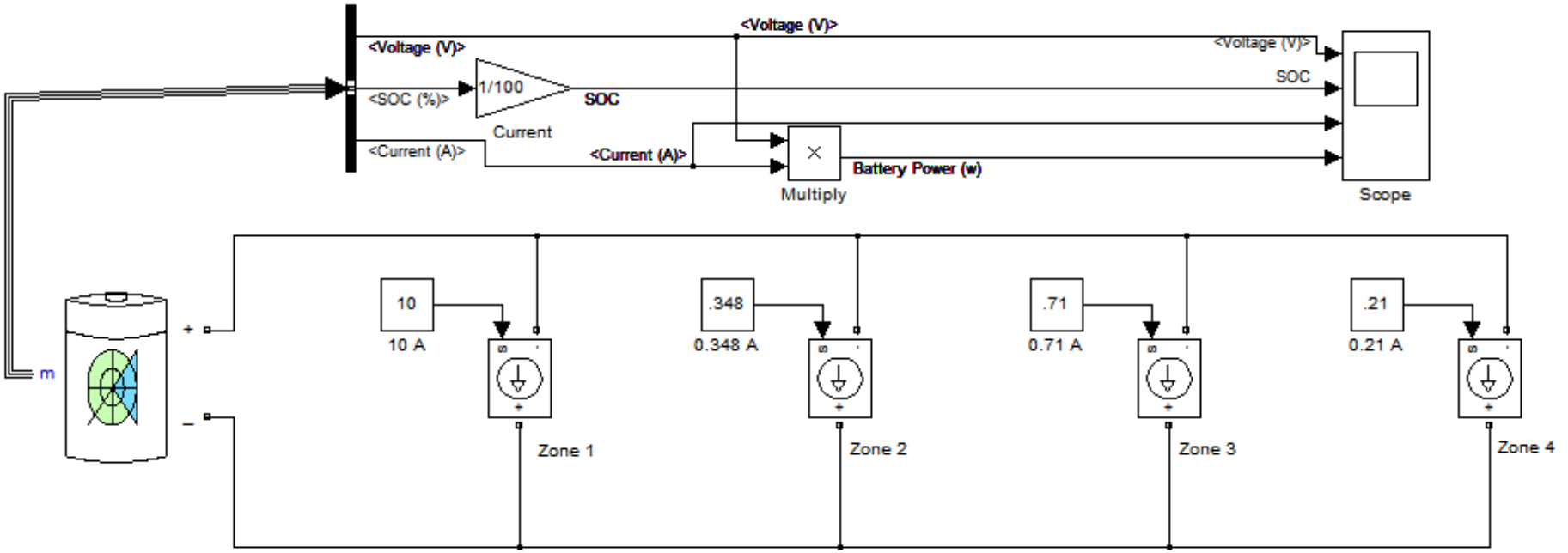
Power Supply Analysis (2)

- Battery Requirements:
  - Capacity > 12000 mAh
  - Cells = Electric motor required cells (Voltage)

- Two Battery Concepts:
  - 3 5000mAh NiMH batteries in parallel
  - 3 5000mAh LiPO batteries in parallel
  - Both provide a capacity of **15000 mAh**
  - NiMH provides (1.2V/cell)(20 cells) = **24 V**
  - LiPO provides (3.7V/cell)(8 cells) = **29.6 V**

Power Supply Analysis (3)

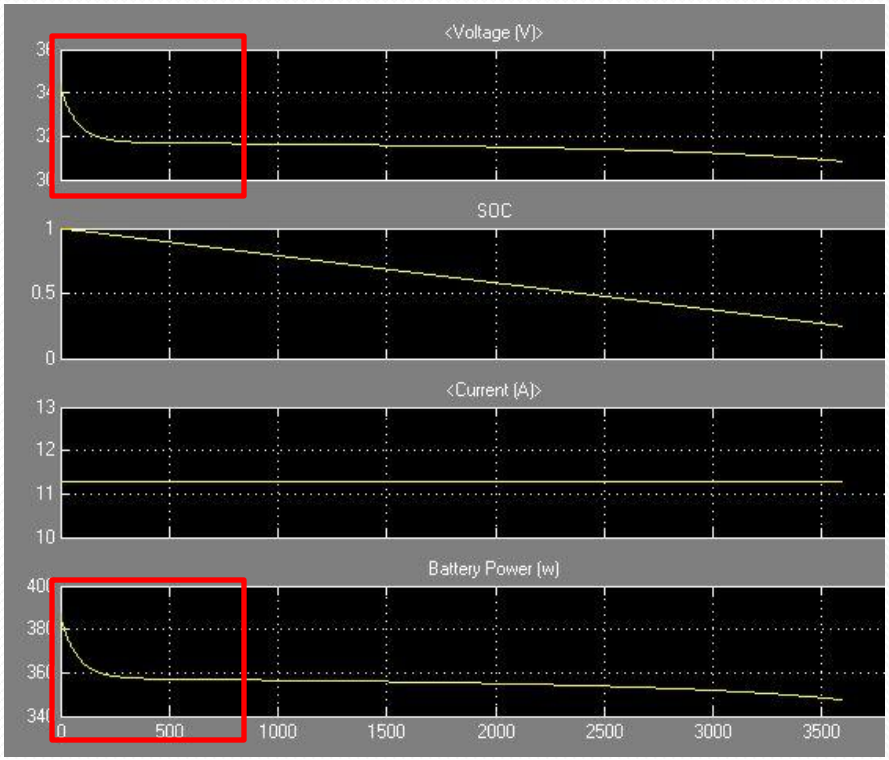
- Simulink



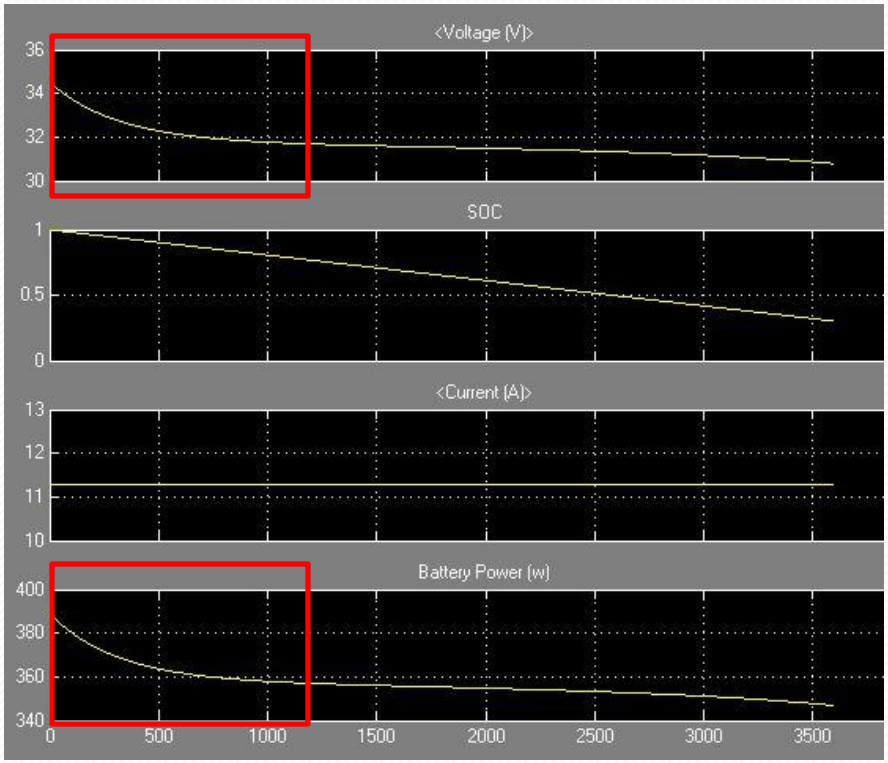
Power Supply Analysis (3)

1 hour flight time

15000 mAh LiPO Battery



15000 mAh NiMH Battery



Power Supply Analysis (3)

- Decision Matrix:
- LiPO Battery Vs. NiMH Battery
- Grade (G):
  - Poor (1)
  - Satisfactory (2)
  - Good (3)
  - Excellent (4)
  - Outstanding (5)

Power Supply Analysis (3)

- Decision Matrix:
- LiPO Battery Vs. NiMH Battery
- Decision Matrix criteria:
  - Performance: 20% weight
  - Weight: 25 % weight
  - Size: 25 % weight
  - Cost: 10 % weight
  - Safety: 20 % weight

Power Supply Analysis (3)

- Decision Matrix:

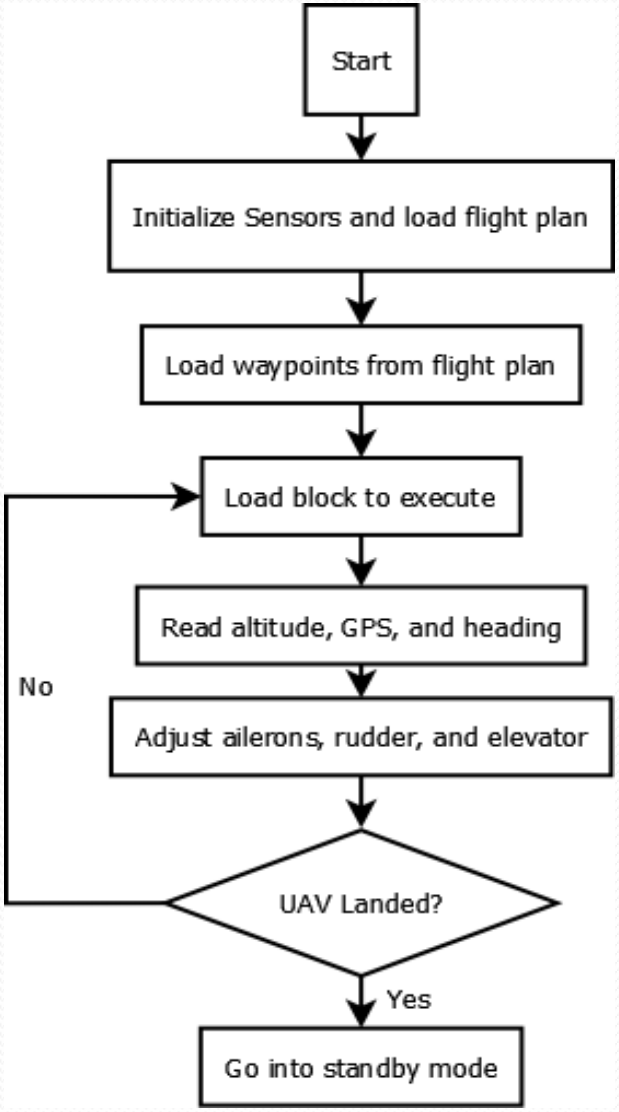
Battery Decision Matrix		NiMH Battery		LiPO Battery	
Criteria	weight	Grade	Weighted G	Grade	Weighted G
Performance	0.2	4	0.8	5	1
Weight	0.25	3	0.75	4	1
Size	0.25	1	0.25	5	1.25
Cost	0.1	5	0.5	1	0.1
Safety	0.2	5	1	3	0.6
Total	1	18	**3.3**	18	**3.95**

Autopilot System Interim Design

- Autopilot Engineering Analysis
- Two Autopilot concepts
  - Ardupilot Mega
  - Paparazzi Tiny v2.11
- Basic Autopilot Flowchart
- Analyze Characteristics of Autopilot
  - Power usage
  - Size & weight
  - Board Layout
  - Ground Control System
  - Flight Simulator

Autopilot System Interim Design

- Autopilot Flow Chart



Autopilot System Interim Design

- Decision Matrix: Grading
  - Poor (1)
  - Satisfactory (2)
  - Good (3)
  - Excellent (4)
  - Outstanding (5)

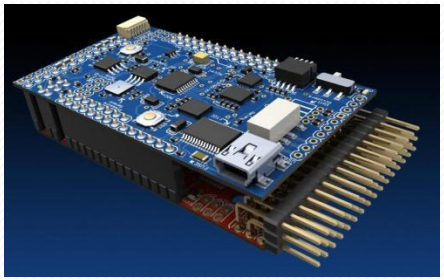
Autopilot System Interim Design

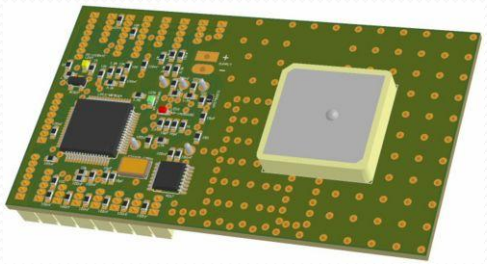
- Decision Matrix: Weight
  - Power Usage – 20%
  - Size – 15%
  - Board Layout – 25%
  - Ground Control System – 30%
  - Flight Simulator – 10%

Autopilot System Interim Design

- Decision Matrix

Autopilot Decision Matrix		Ardupilot Mega		Paparazzi Tiny v2.11	
Criteria	weight	Grade	Weighted G	Grade	Weighted G
Power Usage	0.2	3	0.6	3	0.6
Size & Weight	0.15	2	0.3	4	0.6
Board Layout	0.25	1	0.25	4	1
GCS	0.3	4	1.2	4	1.2
Flight Sim.	0.1	4	0.4	5	0.5
Total	1	14	**2.75**	20	**3.9**





Imagery Equipment Analysis

Engineering Analysis:

1. With UAV Imagery requirements:
   - Review Generated Camera Concepts
   - Insure Camera Concepts can meet requirements

2. Analyze Camera Concepts
   - Calculate Resolution Estimates
   - Create Decision Matrix

Imagery Systems

Imagery Equipment Analysis (2)

- Decision Matrix:
- Four Camera Concepts
- Grade (G):
  - Poor (1)
  - Satisfactory (2)
  - Good (3)
  - Excellent (4)
  - Outstanding (5)

Imagery Equipment Analysis (2)

- Decision Matrix:
- Four Camera Concepts
- Decision Matrix criteria:
  - Weight: 20 % weight
  - Mounting: 8 % weight
  - Resolution: 15 % weight
  - Zoom: 10 % weight
  - TX Ability: 8 % weight
  - Price: 15 % weight
  - Toughness: 5 % weight
  - Power Requirements: 10% weight
  - Dimensions: 9 % weight

Camera Decision Matrix

Camera Decision Matrix		Nikon D300 DSLR		Sony KX-181 HQ		Sony FCB Block		Axis 212 PTZ	
Criteria	Weight	Grade	Weighted G	Grade	Weighted G	Grade	Weighted G	Grade	Weighted G
Weight	0.2	2	0.4	5	1	4	0.8	3	0.6
Mounting	0.08	3	0.24	3	0.24	4	0.32	5	0.4
Resolution	0.15	5	0.75	3	0.45	3	0.45	3	0.45
Zoom	0.1	5	0.5	0	0	5	0.5	3	0.3
TX Ability	0.08	3	0.24	3	0.24	5	0.4	4	0.32
Price	0.15	1	0.15	5	0.75	3	0.45	2	0.3
Toughness	0.05	4	0.2	1	0.05	2	0.1	5	0.25
Power Req.	0.1	5	0.5	4	0.4	3	0.3	3	0.3
Dimensions	0.09	1	0.09	5	0.45	3	0.27	1	0.09
Total	**1**	30	**3.07**	32	**3.58**	32	**3.59**	29	**3.01**

Imagery Analysis

Focusing on Target
Distance = 425 feet

Target is completely undistinguishable

Imagery Analysis

4.1 Megapixel Camera Test Without Zoom

Target is still undistinguishable at this distance

Imagery Analysis

Fully zoomed (5x optical zoom)

Image is hardly recognizable from this distance

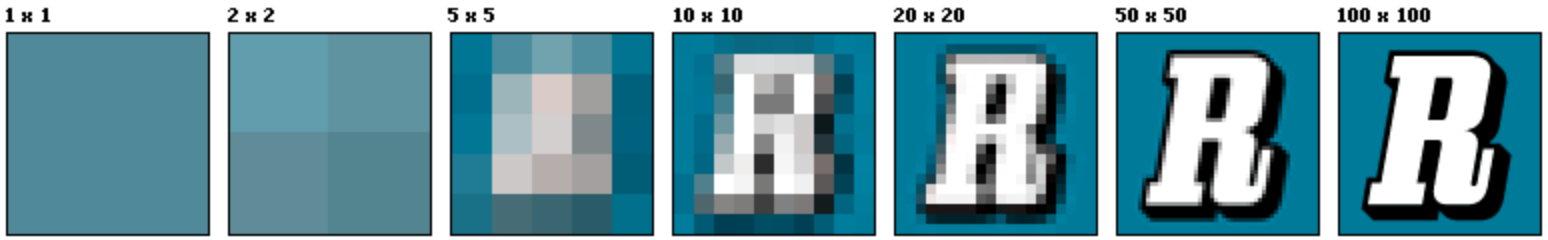
Image Resolution Analysis

$$R = \left(\frac{2h\cos(\theta)r}{\delta}\right)^2 * \frac{3}{4}$$

Flight Target Analysis:

R = Camera Resolution
h = Altitude
θ = Camera Viewing Angle
δ = Target Size
r = Algorithm Mandated Target Resolution

Assuming 3:4 height to width ratio



Imagery Resolution Analysis

- Altitude = 500 ft
- Half-Field of View (FOV) = 30˚
- Minimum Target Size = 2 ft
- 7 Pixel Filter

$$R = \left(\frac{2h\cos(\theta)r}{\delta}\right)^2 * \frac{3}{4}$$

$$R = \left(\frac{2 * 500 * \cos(30) * 7}{2}\right)^2 * \frac{3}{4}$$

$$R = 6.89\ Megapixels$$

- This is a suggested image resolution
- Using a faster algorithm might search an additional pixel, r=8
- Allowing a 9 megapixel resolution

Additional Image Criteria

- Lens Quality
- Distortion
- Image Stabilization
- Computer Controllability

End of Presentation

Imagery Equipment Analysis (1)

- Concept 1 : Still-Image Camera
- Nikon D300 DSLR (Digital Single-Lens Reflex) Camera
- Engineering Analysis:
  - **Weight:** 1.9 lbs
  - **Mounting:** Gimbal
  - **Resolution:** 10.2-Megapixel
  - **Zoom:** 11.1X Optical
  - **Transmission ability:** Still images
  - **Price:** $1400
  - **Toughness:** Magnesium alloy body
  - **Power Requirements:** Dedicated Battery
  - **Dimensions:** 5.8" x 4.5" x 2.9"

Imagery Equipment Analysis (1)

- Concept 2: CCD Color Video Camera
- Sony KX -181 HQ Camera
- Engineering Analysis:
  - **Weight:** 0.055 lbs
  - **Mounting:** Gimbal
  - **Resolution:** 520 TV line
  - **Zoom:** None
  - **Transmission ability:** Video Stream (46 dB)
  - **Price:** $104
  - **Toughness:** Plastic/metal casing
  - **Power Requirements:** 12 V/ 100 mA
  - **Dimensions:** 1" x 1" x 1"

Imagery Equipment Analysis (1)

- Concept 3: CCD Block Camera
- Sony FCB – IX11A Miniature Color Block Camera
- Engineering Analysis:
  - **Weight:** 0.21 lbs
  - **Mounting:** Gimbal
  - **Resolution:** 470 TV line
  - **Zoom:** 10X Optical, 4X Digital
  - **Transmission ability:** 38.4 kbps Serial Stream
  - **Price:** $400
  - **Toughness:** Metal casing
  - **Power Requirements:** 12 V/ 6000 mA
  - **Dimensions:** 1.6" x 1.9" x 2.6"

Imagery Equipment Analysis (1)

- Concept 4: Pan Tilt Zoom Network Camera
- Axis 212 Ptz Network Camera
- Engineering Analysis:
  - **Weight:** 1.1 lbs
  - **Mounting:** Simple attachment
  - **Resolution:** 640 X 480 (3.1 Mega Pixels)
  - **Zoom:** 3X Optical
  - **Transmission ability:** 30 fps VGA with audio
  - **Price:** $630
  - **Toughness:** 2200 lb Impact Resistant casing
  - **Power Requirements:** 5 V/ 1400 mA
  - **Dimensions:** 11" x 10" x 5"

Imagery Equipment Analysis (2)

- Decision Matrix:

Camera Decision Matrix		Nikon D300 DSLR		Sony KX-181 HQ		Sony FCB Block		Axis 212 Ptz	
Criteria	weight	Grade	Weighted G	Grade	Weighted G	Grade	Weighted G	Grade	Weighted G
Weight	0.2	2	0.4	5	1	4	0.8	3	0.6
Mounting	0.15	3	0.45	3	0.45	3	0.45	5	0.75
Resolution	0.08	5	0.4	3	0.24	3	0.24	3	0.24
Zoom	0.08	5	0.4	0	0	4	0.32	3	0.24
TX Ability	0.1	3	0.3	4	0.4	5	0.5	4	0.4
Price	0.15	1	0.15	5	0.75	3	0.45	2	0.3
Toughness	0.05	4	0.2	3	0.15	2	0.1	5	0.25
Power Req.	0.1	5	0.5	4	0.4	2	0.2	3	0.3
Dimensions	0.09	2	0.18	5	0.45	3	0.27	1	0.09
Total	1	30	2.98	32	3.84	29	3.33	29	3.17