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TALON: Tactical Autopilot Long-Term Overwatch Network (HERD-CU)

Testing Readiness Review
14 February 2022

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Presentation Outline

1. Overview
2. Design Solution Updates
3. Schedule
4. Testing Readiness
   a. Avionics/Battery
   b. Structures
   c. Propulsion
   d. Full-System Integration
5. Budget

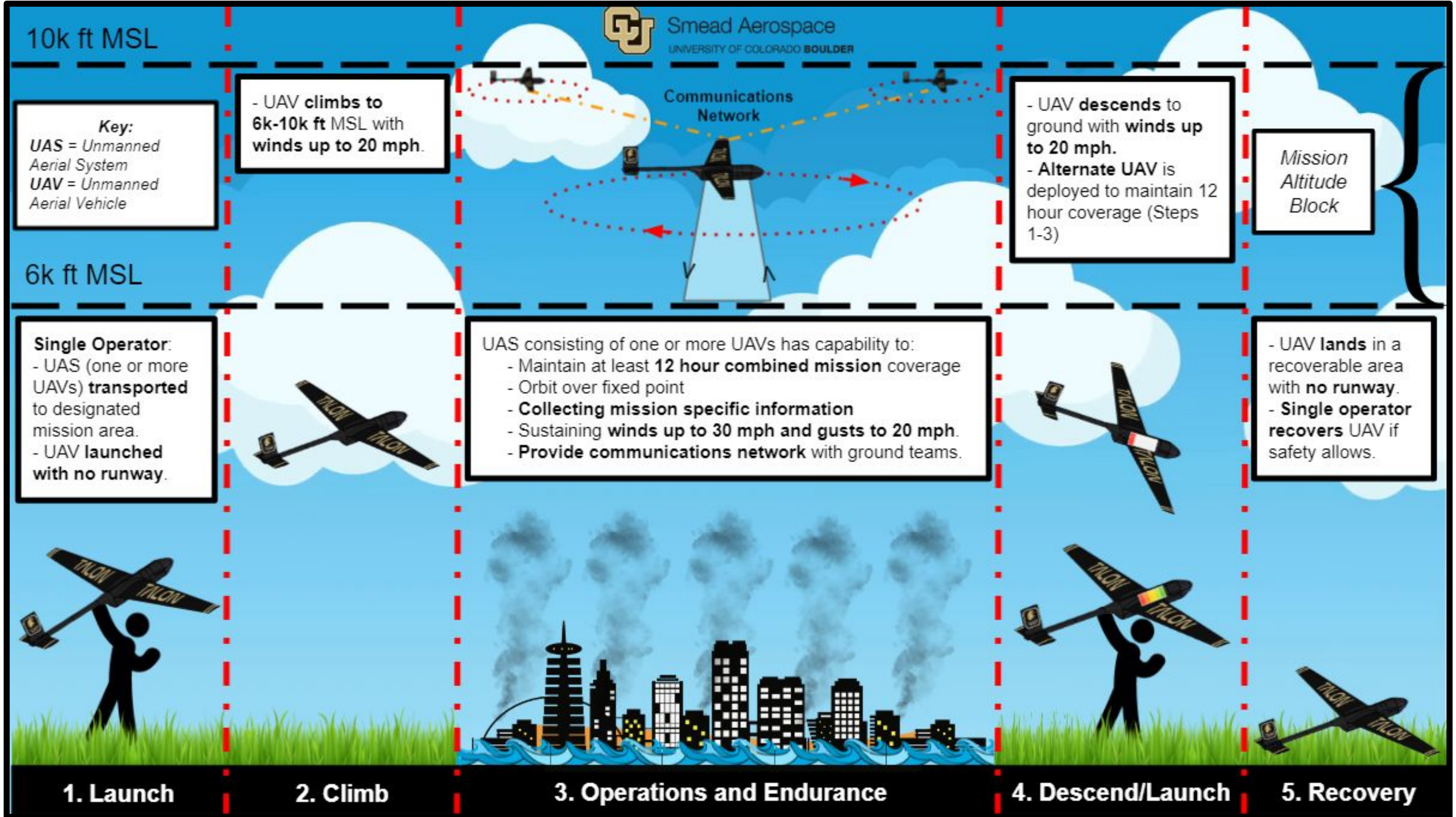
Overview and Design Solution Updates

Project Overview - Mission Statement

Project TALON's purpose is to develop a high endurance, human-portable, rapidly deployable unmanned aerial vehicle. The aircraft will be capable of supporting multiple mission overwatch profiles that demand agility, low cost, high persistence, and broad coverage capability.

TALON
HERD CU

TALON CONOPS



Smead Aerospace
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10k ft MSL
6k ft MSL
Key:
UAS = Unmanned Aerial System
UAV = Unmanned Aerial Vehicle
- UAV climbs to 6k-10k ft MSL with winds up to 20 mph.
Communications Network
- UAV descends to ground with winds up to 20 mph.
- Alternate UAV is deployed to maintain 12 hour coverage (Steps 1-3)
Mission Altitude Block
Single Operator:
- UAS (one or more UAVs) transported to designated mission area.
- UAV launched with no runway.
UAS consisting of one or more UAVs has capability to:
- Maintain at least 12 hour combined mission coverage
- Orbit over fixed point
- Collecting mission specific information
- Sustaining winds up to 30 mph and gusts to 20 mph.
- Provide communications network with ground teams.
- UAV lands in a recoverable area with no runway.
- Single operator recovers UAV if safety allows.
1. Launch
2. Climb
3. Operations and Endurance
4. Descend/Launch
5. Recovery

Project Overview - Functional Requirements & Levels of Success

Category	Level 1	Level 2	Level 3
FR 1	**The UAS shall provide a continuous overwatch window of 12 hours through the use of one or more UAVs.**		
	UAV maintains **1 hour** of continuous overwatch.	UAV maintains **3 hours** of continuous overwatch.	UAV maintains **4 hours** of continuous overwatch.
FR 2	**UAS shall be transported, launched, recovered, and operated by a single person to satisfy Requirement 1 under a 10 minute launch window per UAV.**		
FR 3	**UAS shall have short takeoff and landing capabilities to deploy in areas with unprepared launch surfaces and obstructed climb windows as specified by the customer.**		
	UAS shall be able to takeoff in an open clearing with a **100 ft.** radius and clear a **10 ft.** obstacle at the end of launch radius.	UAS shall be able to takeoff in an open clearing with a **75 ft.** radius and clear a **15 ft.** obstacle at the end of launch radius.	UAS shall be able to takeoff in an open clearing with a **50 ft.** radius and clear a **20 ft.** obstacle at the end of launch radius.
FR 4	**UAS shall provide a payload bay to house a sensor suite.**		

Project Overview - Functional Requirements & Levels of Success

Category	Level 1	Level 2	Level 3
FR 5	**UAS shall operate up to a maximum altitude of 10,000 ft. MSL.**		
	UAS shall be capable of operating at a minimum altitude of **5,000 ft.** MSL.	UAS shall be capable of operating at a minimum altitude of **7,500 ft.** MSL.	UAS shall be capable of operating at a minimum altitude of **10,000 ft.** MSL.
FR 6	**UAS shall adhere to FAA 14 CFR Part 107, SMALL UNMANNED AIRCRAFT SYSTEMS, contingent on waivers.**		
FR 7	**UAS shall maintain a minimum of 80% operational capabilities in customer specified environmental conditions.**		
	UAS shall maintain a minimum of **100%** operational capabilities at room temperature.	UAS shall maintain a minimum of **80%** operational capabilities in a temperature range between **32 and 90℉**	UAS shall maintain a minimum of **80%** operational capabilities in a temperature range between **-20 and 110℉**
FR 8	**UAS will maintain a FMC standby posture.**		
FR 9	**UAS total flyaway cost shall not exceed 5,000 USD for a single air vehicle along with the required launch and recover system.**		

Project Overview - Critical Project Elements

CPE	Description	Functional Requirement
Aerodynamics	Maximizing lift-to-drag decreases power required enhancing endurance.	FR1
Electronics and Batteries	Inefficient electronics waste energy which could be used for propulsion. Custom batteries allow for compact packaging and efficient discharge.	FR1
Propulsion System	Propulsion must provide adequate power to climb, without being oversized for cruise.	FR1 & FR3
Structures	Aircraft structures must survive turbulence and landing while minimizing mass and maintaining portability.	FR2, FR3 & FR4

Design Solution - Functional Block Diagram

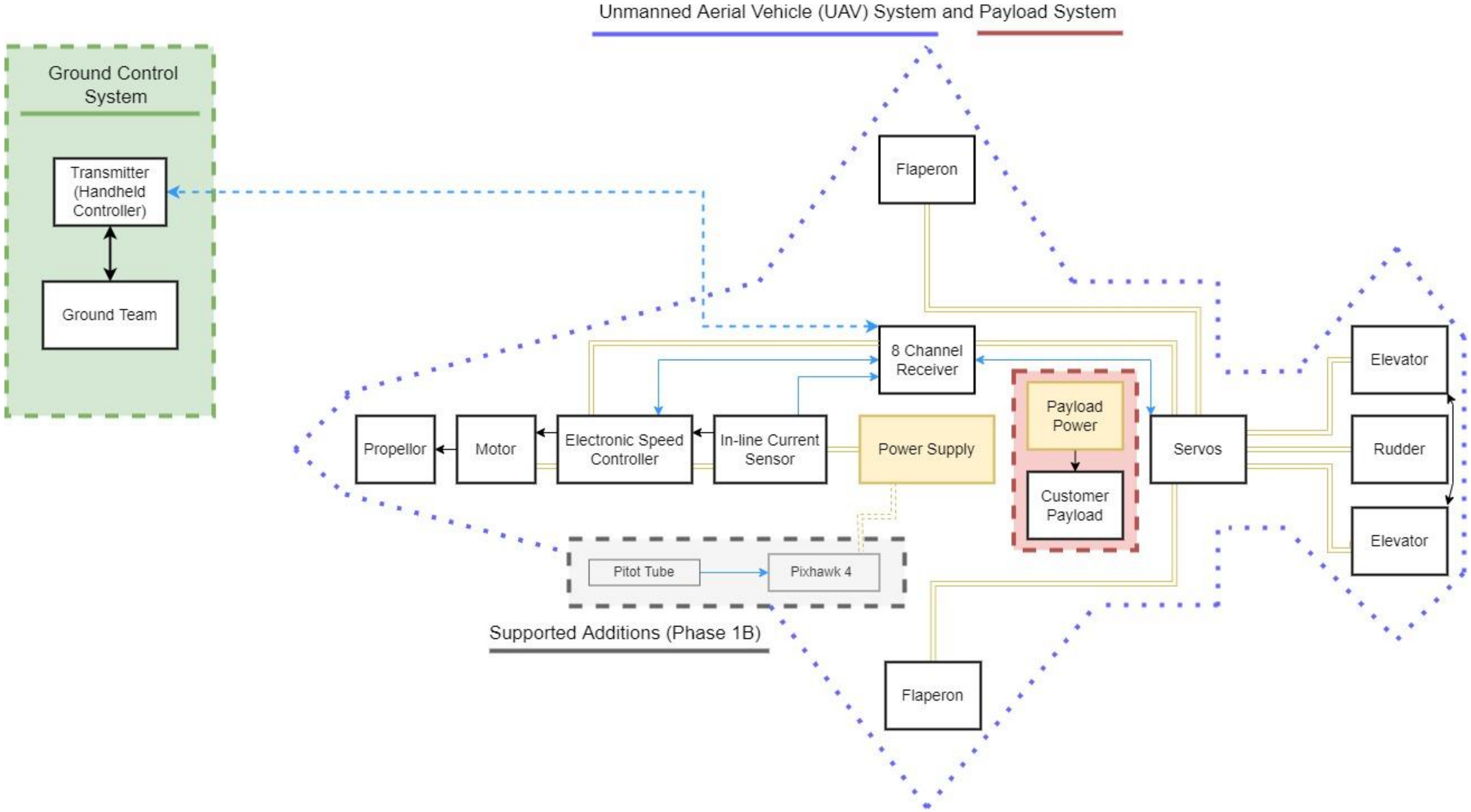
KEY:

Physical connections

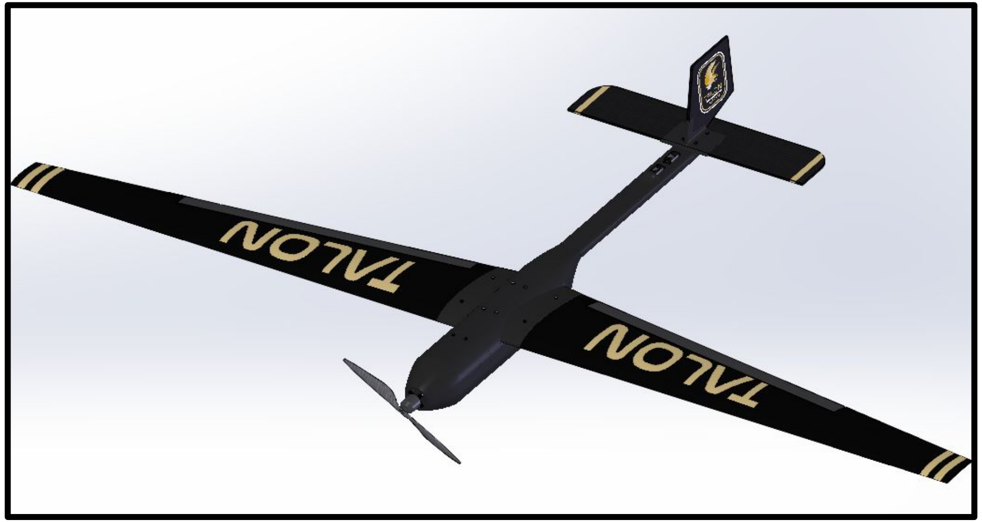
Data Connections

Data Connections via wireless method

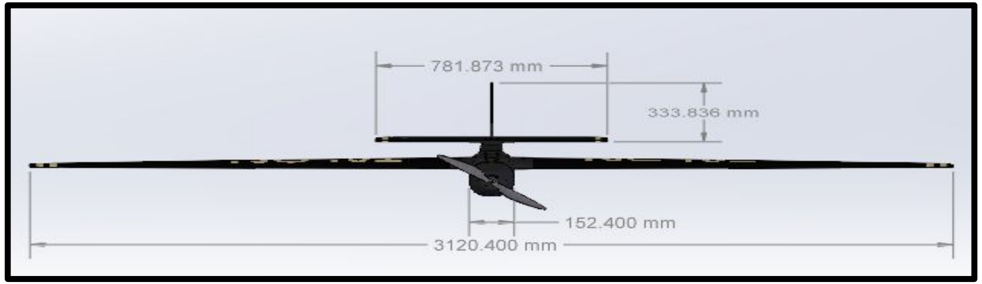
Power supply connections (illustrate subsystem complexity and importance)



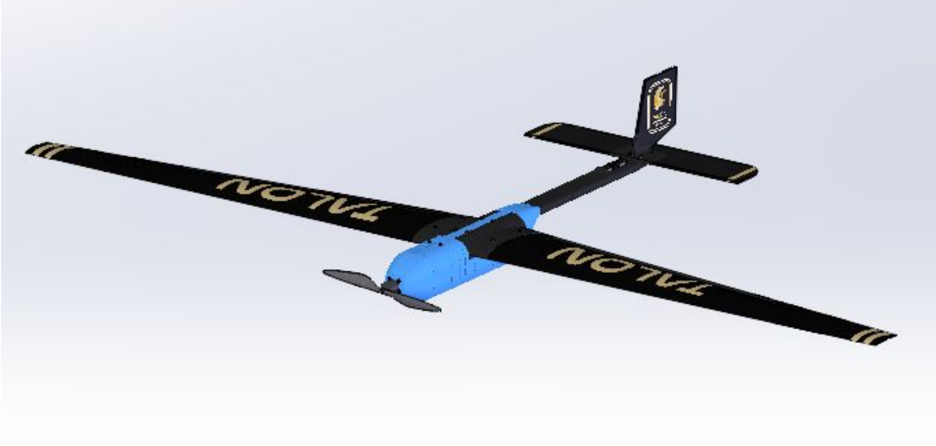
Design Solution - Final Design Overview

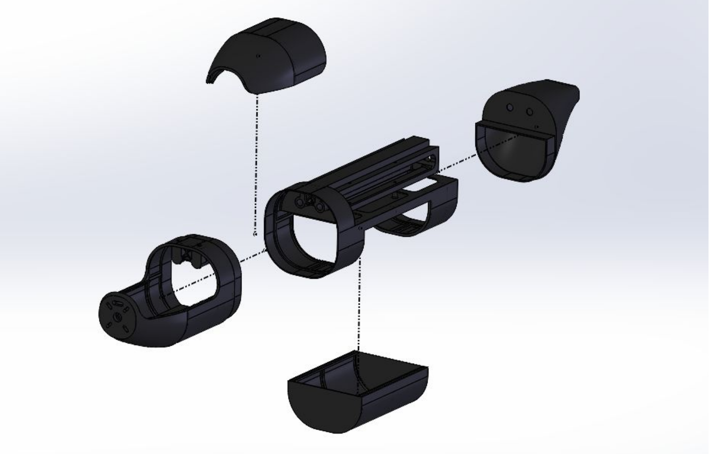


TALON	Specification
Wingspan	3,120 mm
AR	14.25
Airfoil	NACA4412 - NACA4406
Mass	7.4 kg (16.25 lbs)



Design Solution - Fuselage

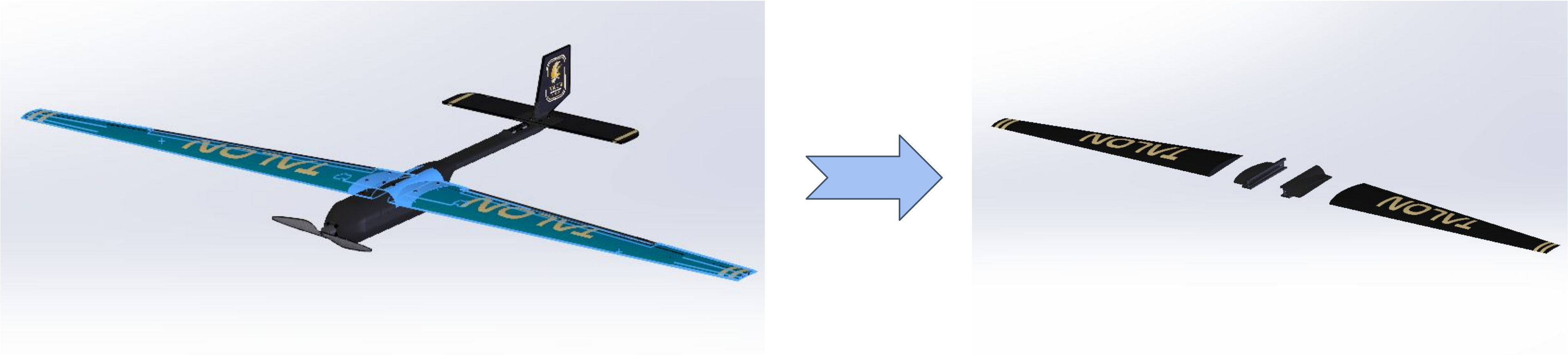




Focus: Provide seamless access to electrical components and a volume for a mission specific payload.

Features: Rapidly removable canopy for ease of access into electronics bay and interchangeability payload bay for various user defined payloads.

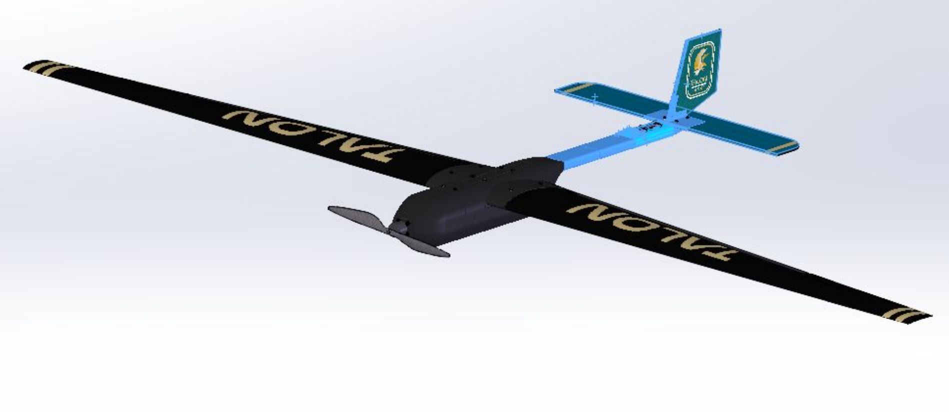
Design Solution - Wing Harness

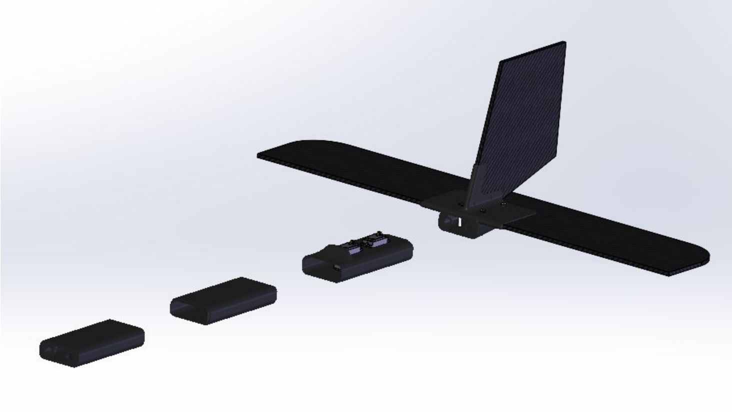


Focus: Integrating the wing with fuselage while providing enhanced structural support.

Features: Three piece system based on dovetail connections for rapid interchangeability and servicing. Structural reinforcement for wings at critical shear point along the fuselage interface.

Design Solution - Tail





Focus: Providing pitch and yaw stability while minimizing flow disturbance.

Features: Aerodynamic sleeving leading up to the empennage decreases turbulent flow to tail. Reinforced control surfaces with upper mounted servos to ensure survival and reusability upon landing.

Critical Project Element Modifications

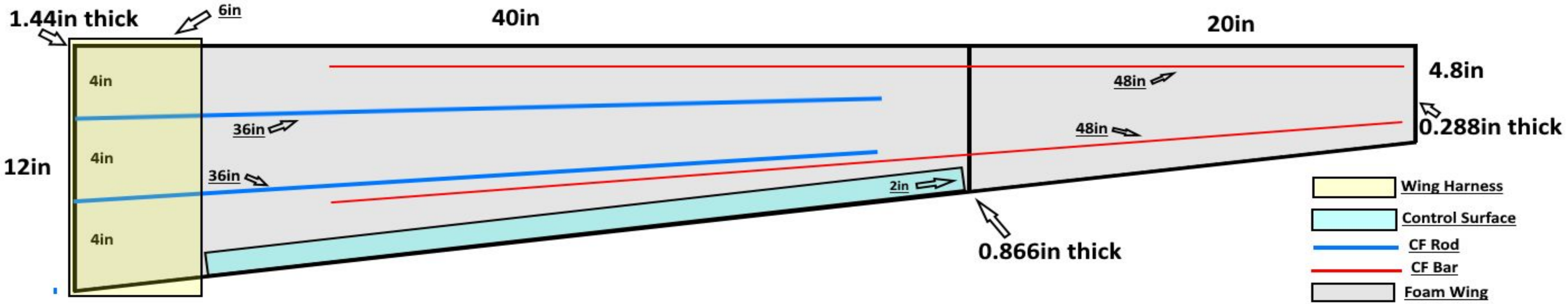
Design Solution - Original Wing Design

Original Design:

- Segmented carbon fiber rods and bars

Concerns:

- Original Design was susceptible to greenstick fracture/failure
- Forces experienced within the airfoil cannot travel into the fuselage, resulting in force build up within the wing, increasing the probability of a structural failure
- Foam delamination/fatigue may occur over time due to large wingtip deflections



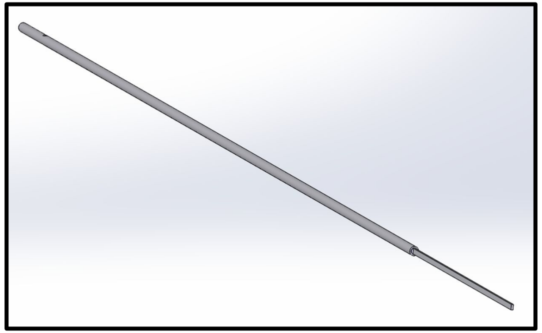
Design Solution - New Wing Design

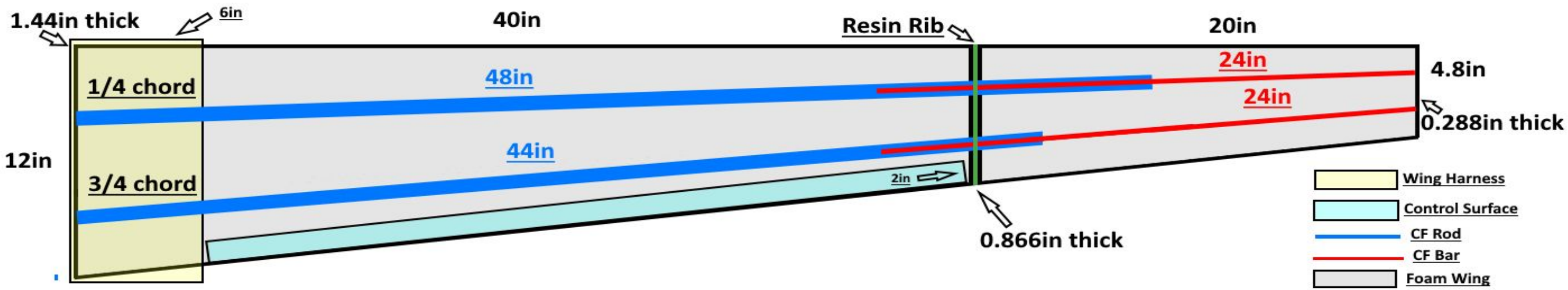
New Design:

- Contiguous Rods
- Rib at 40in

Features:

- CF bars will be inserted & secured inside of CF tubes, creating a continuous structure
- Force will be transferred through the wing and dissipated throughout the harness/fuselage
- CF tubes have been extended further out towards the wingtip to minimize deflection
- CF tube thickness was increased to improve rigidity





Schedule

Schedule - Manufacturing Update

1st Prototype Wing Complete:

- Addresses structural concerns from CDR
- Implemented hybrid “wing box” configuration

Front Fuselage has been refined:

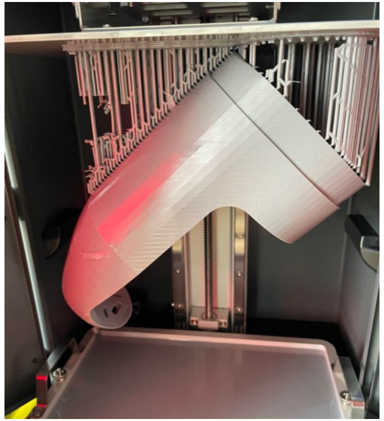
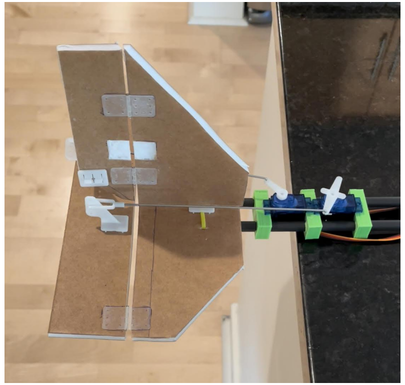
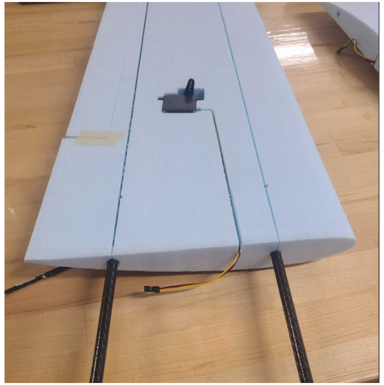
- Decreased weight through rib structure design
  - Fuselage: 37.5% reduction in weight
  - Canopy: 61.5% reduction in weight

Empennage has been optimized:

- Weight has been decreased by 35% through Lw-Pla
- Top mounted servo configuration has been conceptually proven through a basic tail mock up

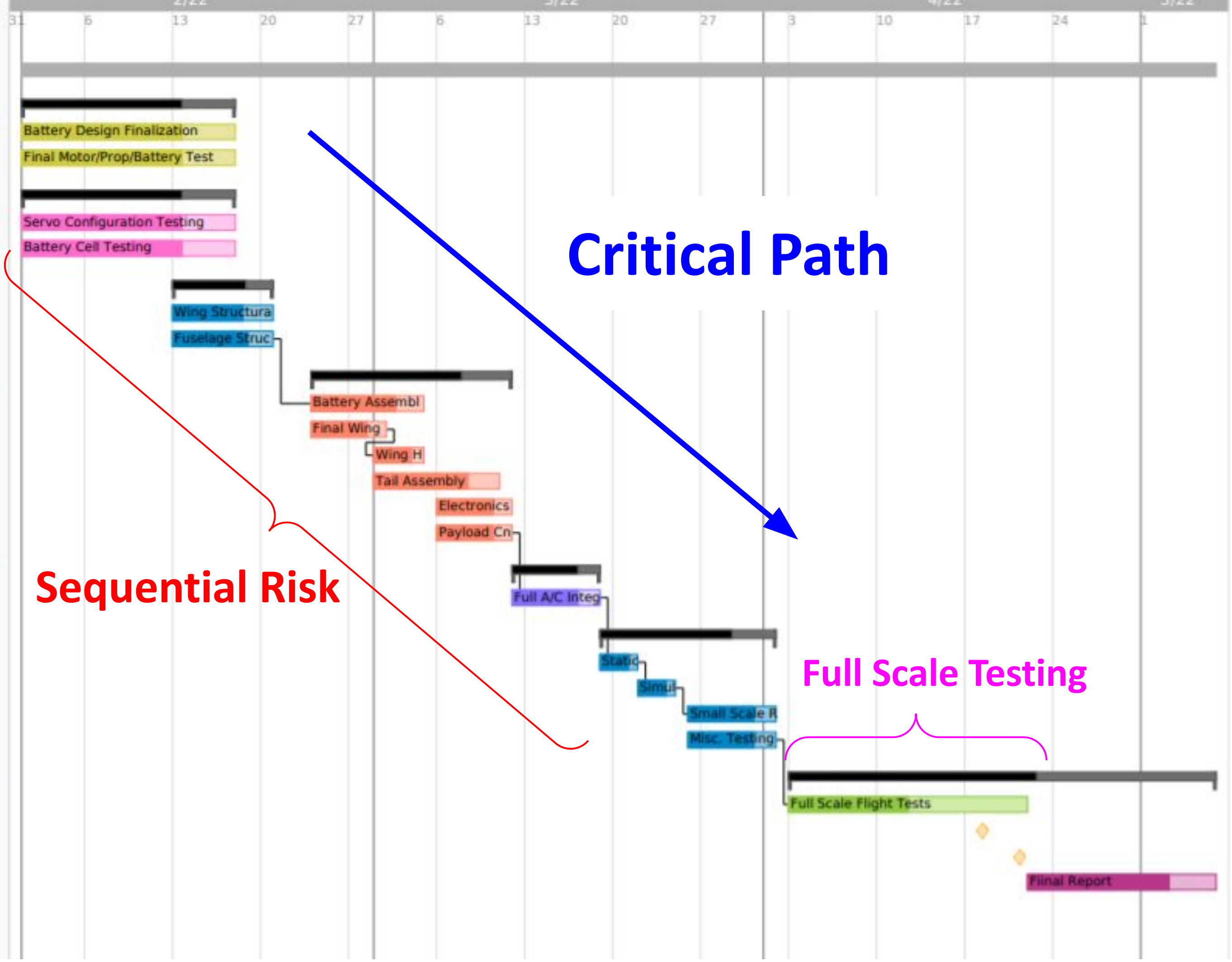
Other Notables:

- Propulsion testing continues
- All ordered components have been delivered

Assembly & Test Focused Gantt

CU HERD PHASE 1A	start	end	0h
Propulsion Testing	**02/01/22**	**02/17/22**	**0h**
Battery Design Finalization	02/01	02/17	0
Final Motor/Prop/Battery Test	02/01	02/17	0
Avionics Testing	**02/01/22**	**02/17/22**	**0h**
Servo Configuration Testing	02/01	02/17	0
Battery Cell Testing	02/01	02/17	0
Structures Testing	**02/13/22**	**02/20/22**	**0h**
Wing Structural Testing	02/13	02/20	0
Fuselage Structural Test	02/13	02/20	0
Sub System Assembly	**02/24/22**	**03/11/22**	**0h**
Battery Assembly	02/24	03/04	0
Final Wing Assembly	02/24	03/01	0
Wing Harness Assembly	03/01	03/04	0
Tail Assembly	03/01	03/10	0
Electronics Assembly	03/06	03/11	0
Payload Cnfg	03/06	03/11	0
Full System Integration	**03/12/22**	**03/18/22**	**0h**
Full A/C Integration	03/12	03/18	0
Full Scale Testing	**03/19/22**	**04/01/22**	**0h**
Static Avionics Testing	03/19	03/21	0
Simulated Landing Stress Test	03/22	03/24	0
Small Scale Refinement/ Reprint	03/26	04/01	0
Misc. Testing	03/26	04/01	0
Flight Testing	**04/03/22**	**05/06/22**	**0h**
Full Scale Flight Tests	04/03	04/21	0
AES Symposium	04/18	04/18	0
Spring Final Review	04/21	04/21	0
Fiinal Report	04/22	05/06	0



Current Primary Sub System Test Plan

Large Scale Sub System Testing Schedule						
Subsystem	**Test**	**Goals**	**Dates**	**Location**	**Equipment**	**Progress**
Propulsion	Thrust Testing on Static Test Stand	· **Verify 5S capability** · **Determine flight envelope**	2/1/22 - 2/17/22	Aerospace Building - Test Cell	Static Test Stand Motors & Props Spektrum Avionics Equipment	In Progress
Structures	Wiffle Test Fatigue Test	· **Analyze final wing structural/material properties**	2/13/22 - 2/20/22	ITLL / Aerospace Building	ITLL material testing machines Cyclic Testing equipment Full Scale Composite wing	In Progress
Structures	Landing Simulation	· **Determine if the airframe can successfully belly land under normal conditions**	2/13/22 - 2/20/22	Aerospace Building/Parking Lot	Elevated Platform, support system, ropes and full A/C	In Progress
Electronics	Battery Analysis	· **Determine battery cell true capacity & resistance** · **Estimate overall capacity**	2/1/22 - 2/17/22	Aerospace Building	XSTAR VC4S battery charger/grader	In Progress

Full Scale Flight Testing

Full Scale Flight Testing						
Subsystem	**Test**	**Goals**	**Dates**	**Location**	**Equipment**	**Progress**
Whole UAV	Environmental Testing	· **Determine operability in adverse conditions as specified by customer**	3/19/22 - 4/1/22	Arvada Airpark Sod Farm Local Ranch	Entire UAS Spare Battery Packs	Not Started
Whole UAV	Portability testing	· **Determine aircraft portability and single user operation**	4/1/22 - 5/6/22	Outside/Hiking Trails	Full UAS Hiking Gear	Not Started
Whole UAV	Time to Assemble Testing	· **Determine the time it takes to assemble a UAV in the field**	4/1/22 - 5/6/22	Outside/Hiking Trails	Full UAS Hiking Gear	Not Started
Whole UAV	Initial Flight Test	· **Confirm UAV airworthiness and analyze flight characteristics**	4/1/22 - 5/6/22	Arvada Airpark Sod Farm Local Ranch	Entire UAS	Not Started

TALON Test Readiness

Test Readiness - Key Focus Areas

1	Electronics	• Individual battery cell analysis • Final battery capacity projection
2	Structures	• Wing failure & fatigue test • Fuselage failure test
3	Propulsion	• Quantify thrust & amp draw for final propulsion configuration
4	Full Scale Flight Testing	• Layered "Day in the life" testing

Testing Readiness Electronics: Battery

Battery Testing - Scope

Rationale For Testing:

- **Abnormal battery cell variation can have catastrophic effects on constructed battery characteristics**
  - Safety risks
  - Performance degradation

Equipment & Facilities:

- **XTAR VC4S - Battery Charger & Tester**

Overview:

- **XTAR VC4S Battery Tester measures actual capacity, resistance and voltage of each battery cell**
  - Individual battery metrics are contrasted against manufacture specifications
  - Averages derived from the sample population are utilized to estimate the TALON's overall 45 cell battery pack capacity, voltage and resistance

Battery Testing - Procedure

Battery Grading Procedure:

1.) Up to 3 individual battery cells are placed into the XTAR VC4S battery grader at a time

2.) XTAR VC4S is placed into "Grade" mode

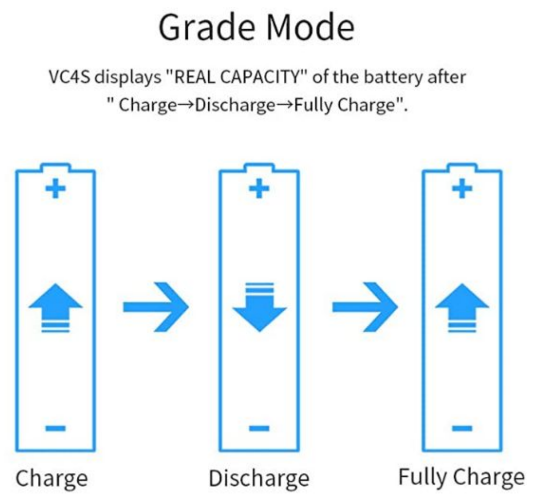
3.) Batteries undergo a full charge cycle

4.) Batteries are discharged to safe minimum voltage

5.) Batteries are fully charged again and true capacity, internal resistance and voltage are measured

6.) Battery metrics are recorded for later statistical analysis

7.) Batteries are discharged to a safe storage voltage



Battery Testing - Expected Results

Expected Results:

- **Graded batteries will feature:**
  - Capacity between 4,800 - 5,000 mAh
  - Nominal Voltages of 3.65V
  - Internal resistance ≤ 20 mΩ

Statistical Analysis:

- **Two Tail T tests will be conducted to determine the following metrics**
  - Confidence intervals
  - Mean & σ

Preliminary Results:

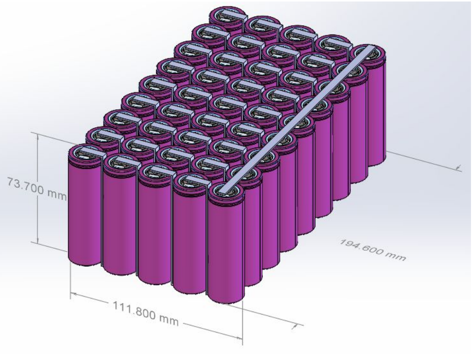
- **Status:**
  - 13 out of 50 cells tested
- **Faulty cells:**
  - Lower than expected voltage has been discovered in 1 cell so far

Lishen 21700 Battery	Sample Means	95% Confidence Interval	Manufacturer Specifications
True Capacity	4,919 mAh	4,888 - 4,950 mAh	4,800 - 5,000 mAh
Nominal Voltage	3.71V	3.65 - 3.76 V	3.65 V
Internal Resistance	18.9 mΩ	16.1 - 21.7 mΩ	≤ 20 mΩ

Battery Testing - Risk Mitigation

Safety Risks:

- **Battery overheating**
  - Individual cells with higher than normal internal resistance increase heat dissipation
- **Excess charge and discharge rates of the battery cells**
  - Increased pressure build up results in battery "swelling"
  - Alteration of chemical properties results in fires



Performance Degradation:

- **Large capacity variation within individual cells**
  - Decreases overall capacity of TALON, impeding on flight times

Risk Mitigation:

- **Down selection of battery cells reduces the probability failure and increases confidence in the TALON's performance**
  - Statistical battery analysis will allow for the standardization of the TALON power system going forward

Model Validation:

- **Theoretical Battery Endurance and Performance Model**

Battery Testing - Functional Requirements

Validation of Functional Requirements Through Battery Testing:	
FR1	**The UAS shall provide a continuous overwatch window of 12 hours through the use of one or more UAVs.**
DR 1.2.1	The UAV's power supply shall provide 70 amps of continuous discharge
FR8	**UAS will maintain a Fully Mission Capable standby posture**
DR 8.1.1	The UAV's entire avionics suite (including the power supply) shall be installable and removeable by hand and/or using hand tools
DR 8.2	The UAV's power supply shall maintain 95% capacity after being stored for 120 hours
Verification of Functional Requirements	
FR1 & FR8	**FR1 - Verified by Full System Testing** **FR8 - Verified after manufacturing and before Full Scale Testing**

Testing Readiness: Structures

Testing Structures - Whiffletree Test

Rationale For Testing:

- Simulate max stress condition on wing during climbout

Test Fixture:

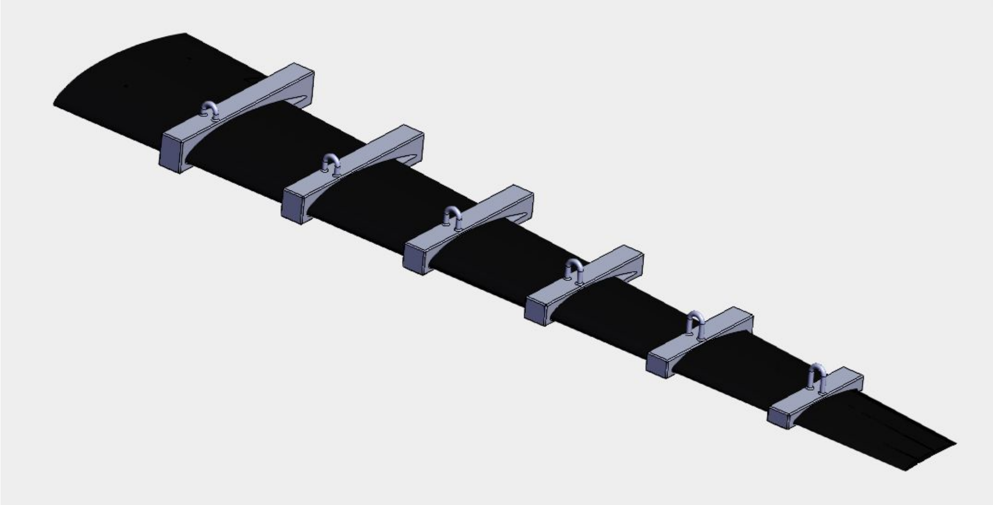
- 3D printed harness to connect wing and Whiffle tree

Equipment and Facilities:

- Whiffletree test fixture, C-Clamps
- Lockheed Martin Senior Projects Storage Room

Overview:

- Whiffletree allows for even distribution of load across the wing for accurate wing loading

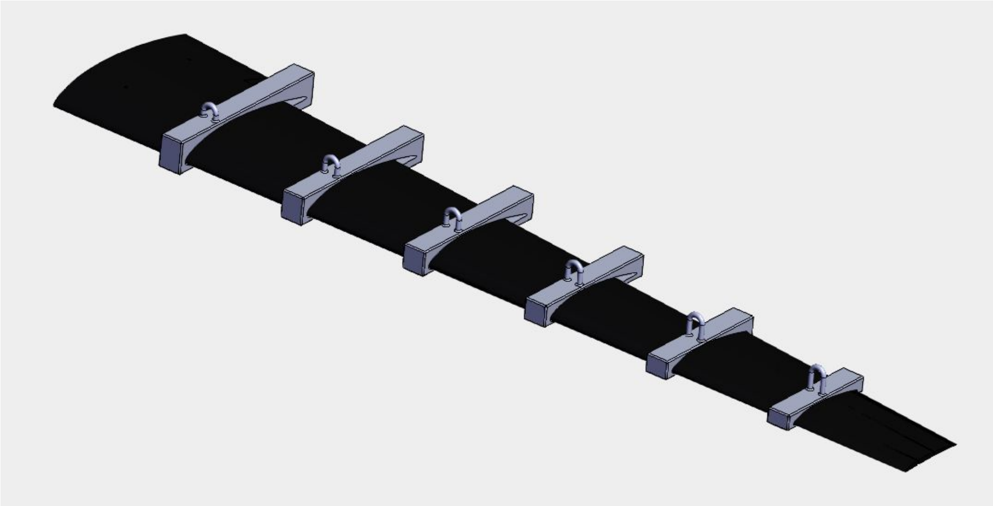


Whiffletree test setup

Testing Structures - Whiffletree Test

Procedure:

1. Insert wing in to 3D printed harness
2. Flip wing upside down and secure root to table
3. Hang whiffle tree from wing harness
4. Apply loads until failure to measure a FoS
5. Mesure wing deflection at a load of 37.8N



Whiffletree test setup

Testing Structures - Whiffletree Test

Expected Results

- Wing must sustain load of 37.8N
- Wing will withstand 56.7N load for a 1.5 FoS

Models to Be verified:

- ANSYS wing bending model
- MATLAB beam bending model

Risk Reduction:

- Demonstrates that the wing is capable of withstanding the most extreme forces found in normal flight

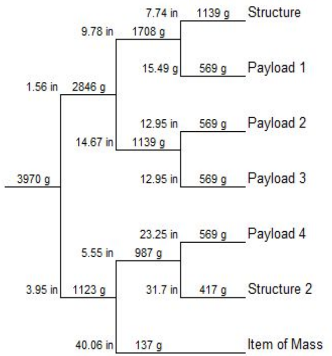
Testing Status:

- Wing is built and ready for testing
- Using whiffle tree software to determine proper loading

ID 9F
Number of Loading Points: 7
Loading Direction: X
Warning Length: 2
Factors 3*1.15*1.1
Space: 3
Input Dialog: Up-left
Catia Scale: 25.4
Unit L: in
Unit W: g
Decimal L: 2
Decimal W: 0

Clear | Clear All | Help
Start/Start Over | Whiffletree | Multi-Whiffletree | Modify | Finish/Update | ID | Material | Data | Rod | Edit/Update Tree | Check | CATIA

ID	Name	Weight	X	Y	Z	Load	Dist	Rod
1	Harness	300.00	606.91	-79.79	243.42	1138.5	7.74	
2	Structure 1	150.00	600.80	-71.00	221.92	569.3	15.49	
3	Structure 2	150.00	600.80	-87.45	221.92	569.3	12.95	
4	Structure 3	150.00	613.20	-71.00	201.92	569.3	12.95	
5	Structure 4	150.00	613.20	-87.45	201.92	569.3	23.25	
6	Structure 5	110.00	618.47	-78.90	256.20	417.5	31.70	
7	Wing tip	36.00	629.68	-68.60	267.87	136.6	40.06	
8	1 + 2			-76.86	236.25	1707.8	9.78	
9	3 + 4			-79.23	211.92	1138.5	14.67	
10	5 + 6			-83.83	224.88	986.7	5.55	
11	7 + 10			-81.98	230.11	1123.32	3.95	
12	8 + 9			-77.80	226.52	2846.25	1.56	
13	11 + 12			-78.99	227.54	3969.57		



2D Whiffletree setup calculator

Testing Structures - Cycling Test

Rationale For Testing:

- Accurately reflect rapid wing loading during sharp vertical gusts and simulate multiple flights on wing structure

Test Fixture:

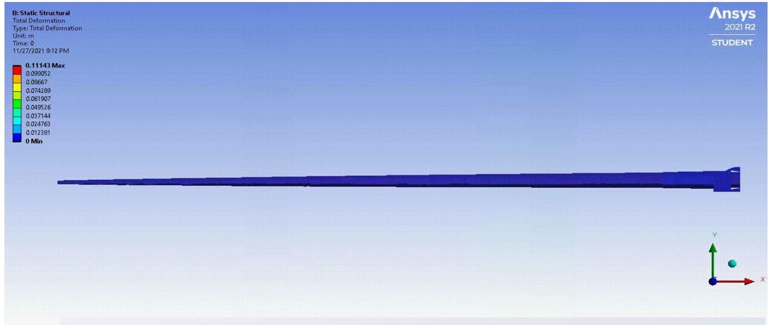
- C-Clamps and Piston

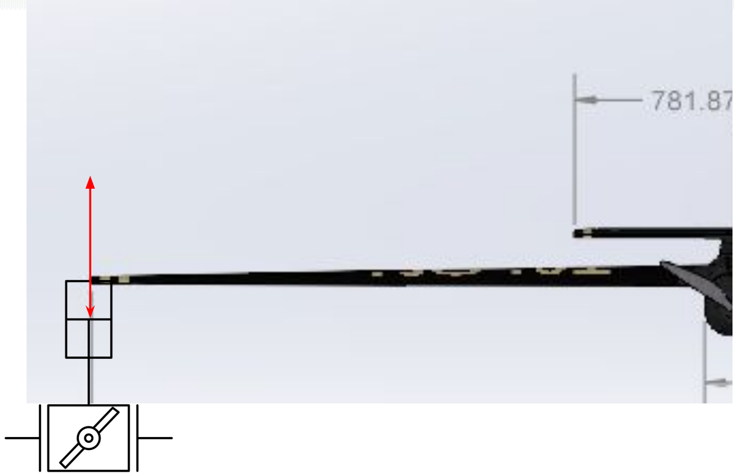
Equipment & Facilities:

- C-Clamps, Piston, Software/hardware required for piston
- Aerospace Building Facilities

Overview:

- Test the structural longevity of the wings under small, rapid loading conditions similar to flight





Procedure:

1. Fix wing root end of wing
2. Fix actuator rod end to wing tip
3. Set travel distance for actuator to maximum tip deflection from whiffletree test
4. Cycle actuator 500 times
5. Check for any structural failure

Expected Results:

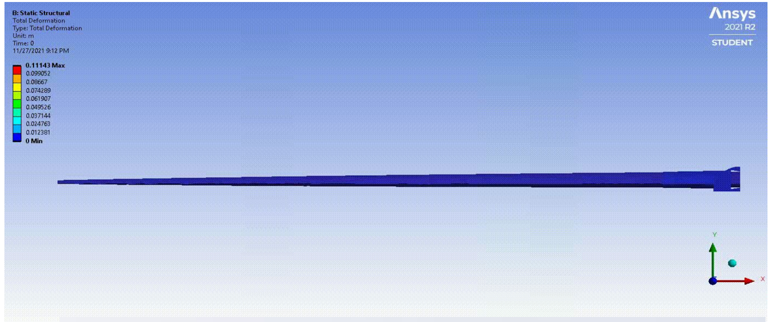
- No permanent deformation, delamination, or material separation

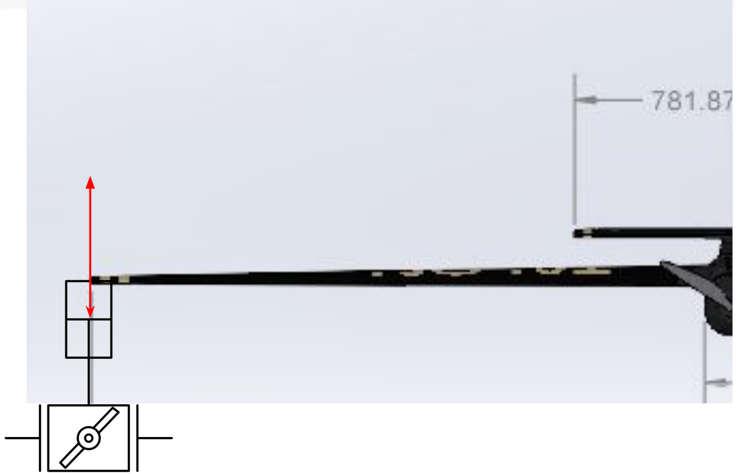
Risk Reduction:

- Demonstrates that the wing is capable of withstanding repeated deflection to combat vertical gusts and multiple flights

Testing Status:

- Wing is built and ready for testing
- Source actuator, required hardware/software





Testing Structures - Fuselage Drop Test

Rationale For Testing:

- **Landings and crashes pose risks to overall vehicle structural integrity and reusability**

Test Fixture:

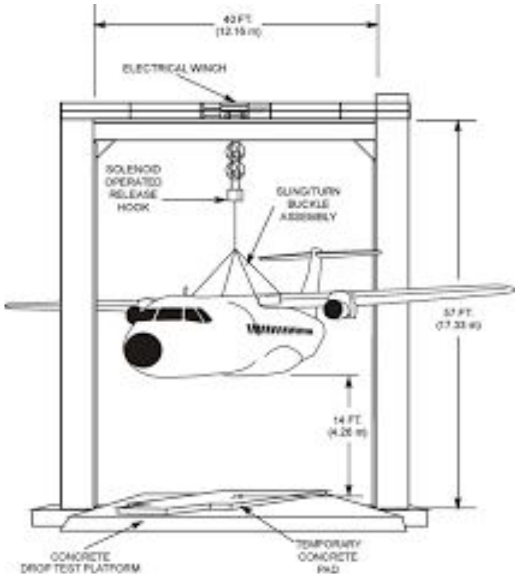
- **Drop test from elevated platform**

Equipment & Facilities:

- **Elevated surface and a pull string**
- **Suitable elevated surface and a representative landing zone**

Overview:

- **Binary test to determine maximum height of fuselage in a free-fall scenario**
- **Full fuselage assembly with mock electronics, batteries, linkages, etc.**
- **Will:**
  - Display overall structural integrity of design
  - Uncover areas of high stress concentrations, if present, for redesign
  - Evaluate electronics placement for optimal survivability



Testing Structures - Fuselage Drop Test

Procedure:

1. Add weight to fuselage to simulate full A/C weight
2. Fix fuselage above ground at set height
   a. Tilt fuselage to simulate pitch angle for landing
3. Drop fuselage in a wings-level configuration
4. Record damage
5. Increase height and repeat process until structural failure

Expected Results:

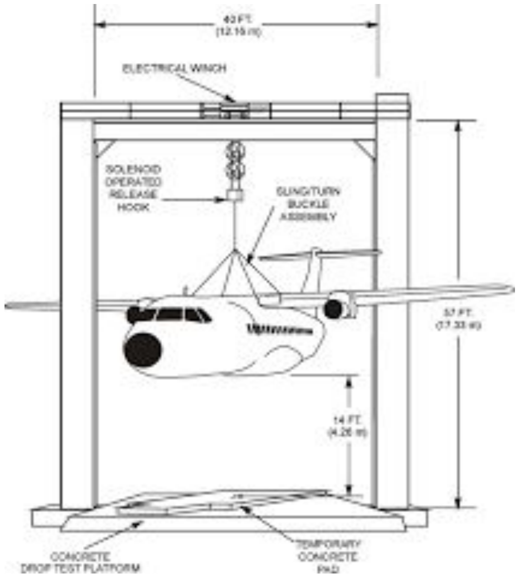
- No permanent deformation or compromised payload bay from 3 ft.

Risk Reduction:

- Determines greatest height TALON can survive in a freefall
- Establishes limitations for TALON landing operations

Testing Status:

- Fuselage is constructed
- Ready for testing



Structures Testing - Functional Requirements

Validation of Functional Requirements Through Structures Testing:	
FR3	**The UAV shall have short takeoff capabilities as specified by the customer**
DR 3.3.1	The UAV shall be capable of absorbing an impact to the belly while 'fully loaded' from a height of 3 ft. without a structural failure
DR 3.3.2	The UAV shall be capable of withstanding 10 impacts to the belly while 'fully loaded' from 1.5 ft.without a structural failure
FR7	**UAS shall maintain a minimum of 80% operational capabilities in customer specified environmental conditions**
DR 7.3	The UAV shall withstand 100 rapid and successive 30 feet-per-second sharp vertical wind gust cycles without failure
Verification of Functional Requirements:	
FR3 & FR7	**FR3 - Verified through Full System Testing** **FR7 - Verified by testing individual DR's in adverse environments**

Testing Readiness - Propulsion

Propulsion Testing - Scope

Rationale For Testing:

- **Measuring static thrust of various propeller and motor configurations allows for adequate propulsion system down selection**
- **Extensive testing allows for thrust optimization to satisfy functional requirements while minimizing amp draw**

Test Fixture:

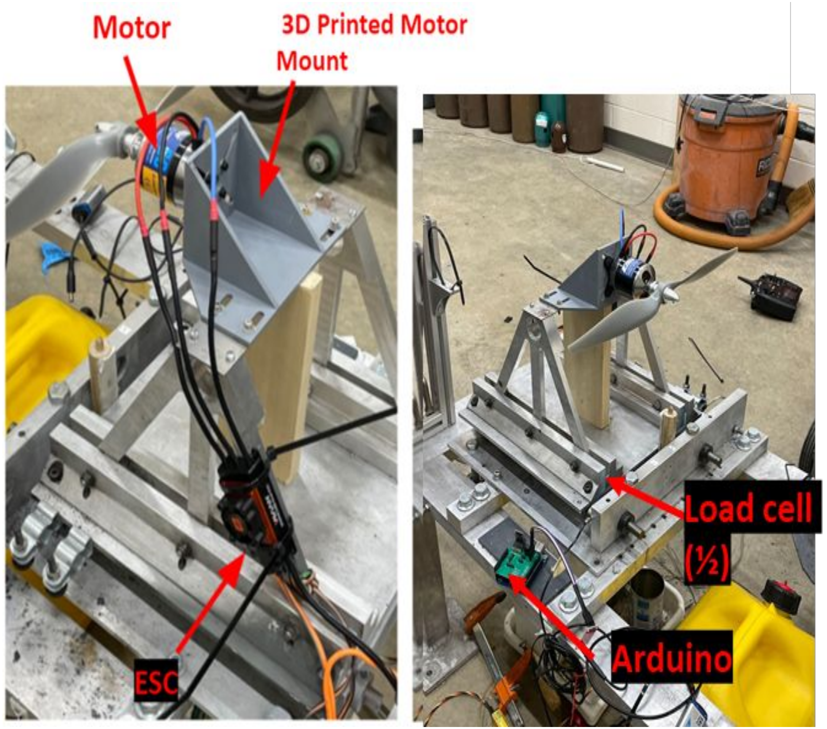
- Smead Aerospace Test Cell

Equipment and Facilities:

- Static thrust stand, arduino, 3D printed test mount, ESC, motor, propeller, mini crane force scale
- Smead Aerospace Garage

Overview:

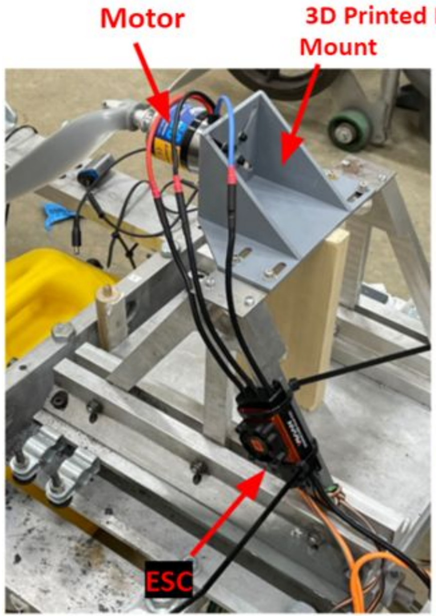
- **Various motor and propeller configurations are being tested to determine thrust and corresponding amp profiles**
  - First round of 5S battery pack testing completed
  - Targeting 470kv, 17X7E, 5S battery combination

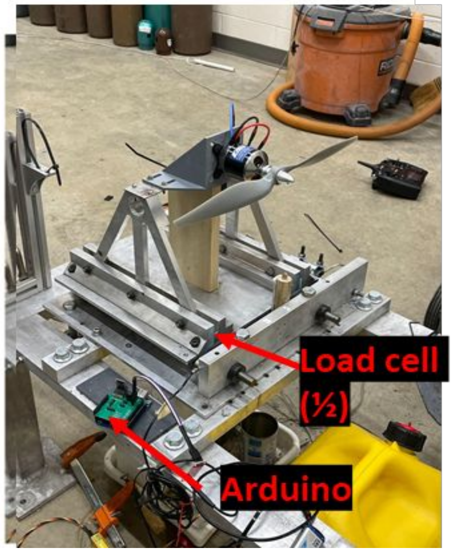


Propulsion Testing

Procedure:

1.) Static test load cell calibration test via mini crane force tool
2.) Securely fasten motor mount to static test stand and connect ESC and battery to motor
3.) Ensure propeller secured to mount
4.) Connect Arduino to load cell with Arduino battery unplugged
5.) Remove wooden stopper
6.) Insert micro SD card into Arduino, then plug in battery
7.) Insure all persons outside the testing room
8.) Begin throttling motor via transmitter at time = 0 sec.
9.) After testing, power down motor and set transmitter to 'safe'
10.) Retrieve micro SD card for data collection
11.) Analyze test data in Python



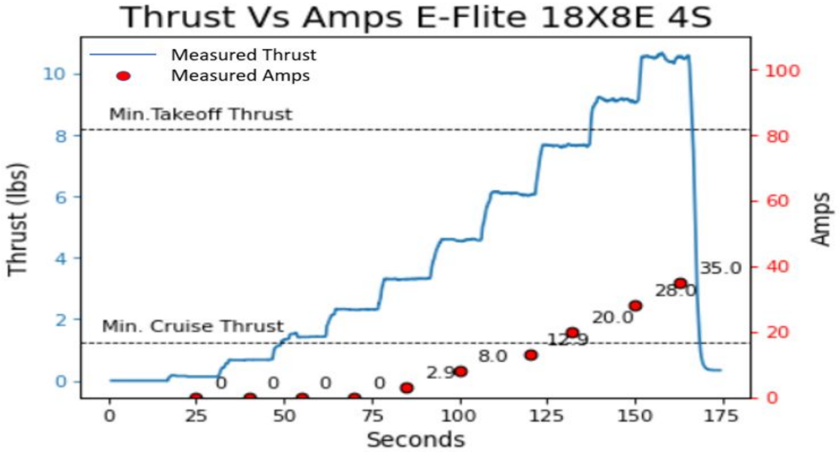


Propulsion Testing - Preliminary Results

Battery Sizing Results

- 18x8E propeller was chosen to maximize motor strain and amp draw
  - Thrust for 4S 14.8V = 10.7 lbs
  - Thrust for 6S 22.2V = 17.6 lbs

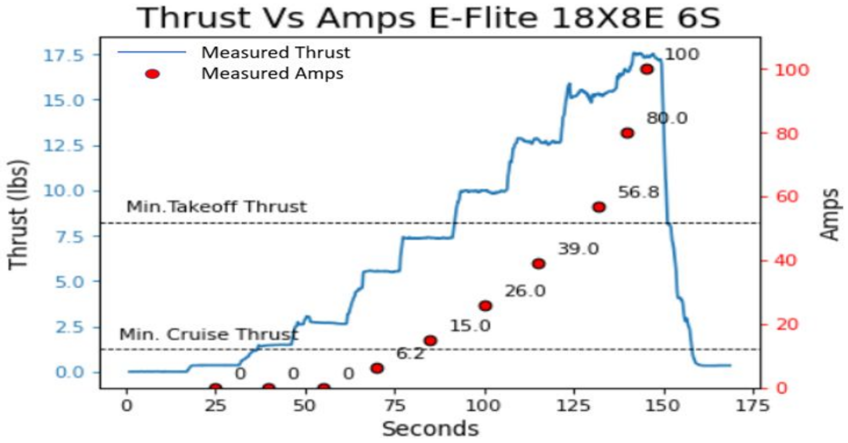
4S 14.8V



5S 18.5V

Expected 5S Success for Requirements due to High thrust for 4S & 6S

6S 22.2V



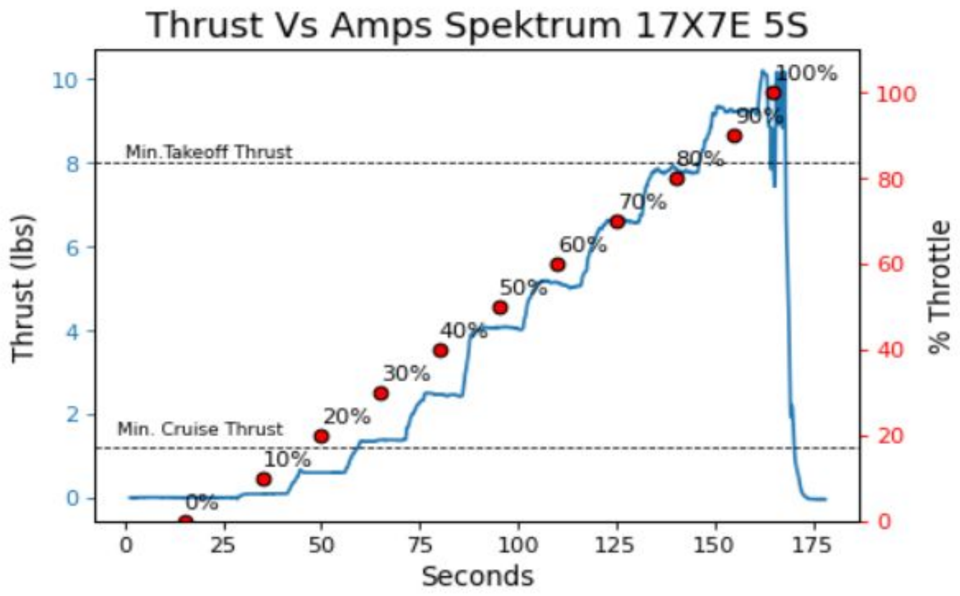
Propulsion Test Continued - 5S Battery Testing

Testing Results:

- **Spektrum 480kv, 5S, 17x7E propeller combination**
  - Maximum thrust: 10.2 lbf
  - Thrust Margin: 24.5%
  - Motor saturation at 100% throttle
- **Spektrum motor features lightweight magnets which result in inconsistent thrust at 100% throttle**
  - **Spektrum 480kv is not viable motor at this time**

Conclusions:

- **E-Flite Motor needs testing**
  - Testing was halted due to unsafe mounting on propeller (damaged part)
- **Collection of amp data is cumbersome for 5S**
  - 5S test pack is not 'Smart Battery'
    - Lacks real time telemetry capability



Note: Spektrum was tested to minimize weight, over 100 grams lighter than E-Flite

Propulsion Testing - Risk Mitigation

Risk Reduction through testing:

- **Proves the adequacy of the TALON propulsion system**
- **Thrust & Amp draw metrics can be used to optimize the TALON's propulsion system**
- **Thrust & Amp Margins can be determined**
  - Compensates for model assumptions and adverse flight conditions

Expected Results:

- **Low KV motor, 5S battery and large propeller combinations are capable of generating over the required 8.0 lb of thrust while minimizing amp draw**

Model validation:

- **Propulsion Model:** Thrust required for flight
- **Rate of climb model:** Thrust required to meet various levels of success
- **Battery Model:** Efficiency approximation (amps per lb of thrust)

Expected Results: 5S Battery

E-flight 470kv		
Data	**Expected**	**Required**
Max Thrust	Greater than 14.0 lbs	8.1 lbs
Peak Amps	Less than 67.0A	Less than 70A

Spektrum 480kv		
	Expected	**Required**
Max Thrust	Greater than 10.0 lbs	8.1 lbs
Peak Amps	Unknown	Less than 70A

Propulsion Testing - Functional Requirements

Validation of Functional Requirements through Propulsion Testing	
FR1	**The UAS shall provide a continuous overwatch window of 12 hours through the use of one or more UAVs.**
DR 1.1.1	The UAV's power supply shall be capable of providing at least 120% of the maximum expected amperage draw of the UAV
DR 1.2.1	The UAV's power supply shall provide 70 amps of continuous discharge
DR 1.3.1	The UAV’s motor and propeller combination shall provide no less than 53 Newtons of thrust at full throttle
FR3	**The UAV shall have short takeoff capabilities as specified by the customer**
Verification of Functional Requirements	
FR1 & FR3	**FR1 & FR3 will be verified during Full System Testing**

Full System Test

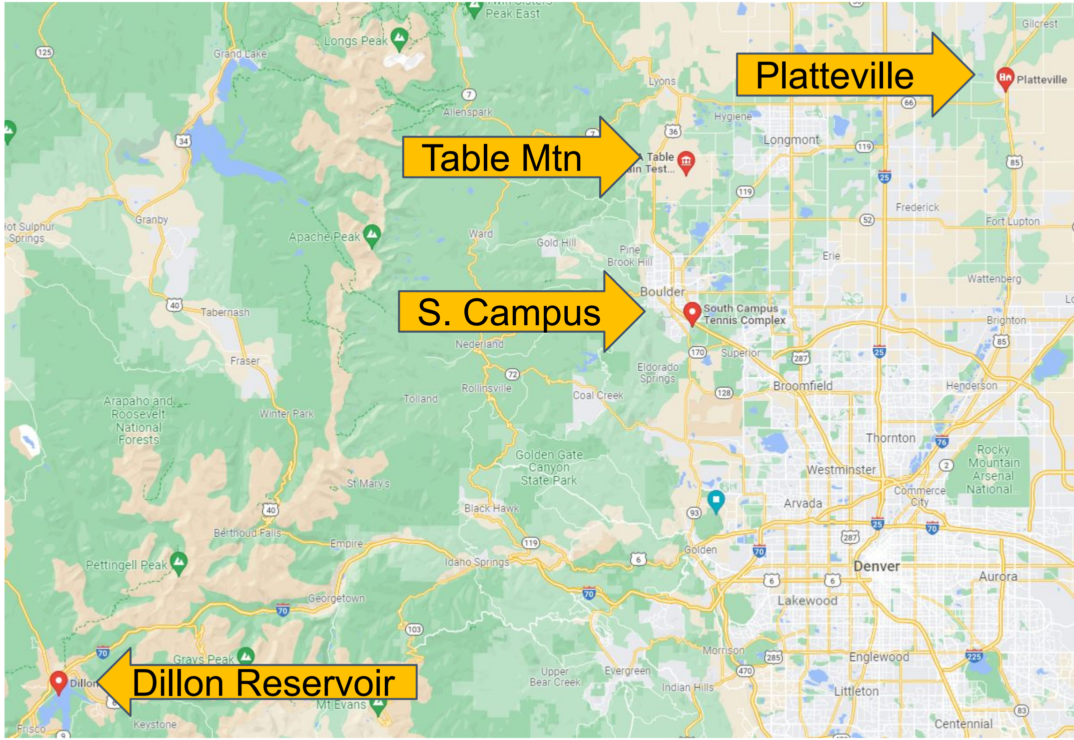
Full System Test

Rationale: **A full scale test proves TALON airworthiness and a simulated CONOPS will allow the team to identify areas for improvement.**

Test Fixture: **N/A**

Equipment and Facilities:

- **TALON system**
- **Locations (Pending Pilot Selection and Capabilities)**
  - North Table Mountain
  - Platteville, CO
  - South Boulder Campus
  - Dillon Reservoir (High Altitude Tests)
- **Pilot List based on FAA Certifications and Availability**
  - IRISS/RECUV Pilots
  - Hobbyist Pilots
- **Dates**
  - 03 April - 06 May



Full System Test

Procedure:

1.) Assemble TALON UAS in fully mission capable standby posture

2.) Transport UAS to the designated area of interest

3.) Conduct an in field assembly of the TALON

4.) A designated operator will hand launch the TALON

5.) TALON climbout will be measured against a known obstacle for reference

6.) The TALON will fly in a circular orbit at 300 ft AGL and establish communications with operators on the ground through the aircrafts LilyGo radio payload

7.) A simulated search and rescue field operation will be conducted with the TALON in the overwatch position

8.) After search and rescue operations have concluded the TALON will descend & land

9.) The UAS will be disassembled and stored in a safe standby configuration

10.) A post flight battery analysis will be conducted and TALON endurance will be quantified

Full System Test

Expected Results:

- **TALON Assembly Time:** ≦ 10 minutes
- **TALON Endurance:** ≧ 3 hours
- **TALON climb out:**
  - Takeoff radius ≦ 75 ft.
  - Climbout ≧ 15 ft at the end of launch radius
- **Communications Payload:** Single node communication radius > 3 miles

Risk Reduction:

- **A full scale TALON "day in the life" test will provide performance metrics for the aircraft and allow for functional requirement verification.**
- **Full scale flight testing will highlight areas of weakness within the TALON aircraft**

Key Functional Requirements to be Verified:

FR1: The UAS shall provide a continuous overwatch window of 12 hours through the use of one or more UAVs.		
Level 1	**Level 2**	**Level 3**
1 hour of overwatch.	3 hours of overwatch.	4 hours of overwatch.

FR 2	**3 UAS shall be transported, launched, recovered, and operated by a single person to satisfy Requirement 1 under a 10 minute launch window per UAV.**

FR3 :UAS shall have short takeoff and landing capabilities to deploy in areas with unprepared launch surfaces and obstructed climb windows as specified by the customer.		
Level 1	**Level 2**	**Level 3**
Altitude of 10 ft. within 100 ft.	Altitude of 15 ft. within 75 ft.	Altitude of 20 ft. within 50 ft.

FR 4	**UAS shall provide a payload bay to house a sensor suite.**

Budget

Cost Plan - Budget

Status:
- **All components have been ordered and have been delivered**

Budget:
- **75% of budget has been expended**
  - Includes testing materials & extra components
- **Remaining balance: $1,244**

Vehicle Cost:
- **Final TALON production cost: $2,284**

Margin:
- **Margin has been applied to the remaining budget reserves and estimated replacement cost**
  - Electronics salvage allows a backup TALON to be produced for as little as $300
  - A near total loss of a TALON aircraft can be reproduced for $900

TALON Budget Summary		
Sub System	Actual	Margin
Electronics	$ 1,178.65	$ -
Structures	$ 2,576.91	$ -
Total Spent	$ 3,755.56	$ -
Total Budget	$ 5,000.00	$ -
Remaining Balance	$ 1,244.44	$ 1,057.77
Approxiamte Cost To Replace Crashed Vehicle	$ 911.98	$ 1,048.78
Remaining Budget after 1 TALON Replacement	$ 332.46	$ 9.00

Cost Plan - Itemized Budget

Item	Vendor	Price	Price Margin	Quantity	Shipping	Shipping Margin	Total	Total Margin	Use	Purchase Status	Order Number
Spektrum RC DX8e G2 2.4GHz DSMX 8 Channel Radio System	Action Hobbies RC Aircraft Ce	$ 309.99	0	1	$ -	0.00	$ 309.99	**$ 309.99**	Transmitter for ground to vehicle controls	Recieved	N/A
Spektrum RC AR8020T DSMX 8 Channel Air Telemetry 2.4GHz Receiver	Action Hobbies RC Aircraft Ce	$ 89.99	0	1	$ -	0.00	$ 89.99	**$ 89.99**	Recieves transmitter signal on vehicle	Recieved	N/A
Spektrum RC Avian 120 Amp Brushless Smart ESC	Action Hobbies RC Aircraft Ce	$ 99.99	0	1	$ -	0.00	$ 99.99	**$ 99.99**	Regulates power and yields telemetry data	Recieved	N/A
D645MW Servo	https://www.horizonhobby.com	$ 39.99	0	5	$ -	0.00	$ 199.95	**$ 199.95**	Moves vehicle control surfaces	Recieved	#114-6690257-5568218
Lishen 21700 5000mAh 9.6A Battery (LR2170SD)	Lishen 21700 5000mAh 9.6A I	$ 4.25	0	50	$ 12.42	0.00	$ 224.92	**$ 224.92**	Batteries for vehicle	Recieved	#274565
Spektrum Avian 4260-480Kv Outrunner	Action Hobbies RC Aircraft Ce	$ 99.99	0	1	$ -	0.00	$ 99.99	**$ 99.99**	Vehicle's main motor	Recieved	N/A
Nylon/Glass Propeller, 15 x 8E	Action Hobbies RC Aircraft Ce	$ 8.42	0	1	$ -	0.00	$ 8.42	**$ 8.42**	Vehicle's main Propeller	Recieved	N/A
Nylon/Glass Propeller, 16 x 8E	Action Hobbies RC Aircraft Ce	$ 7.10	0	1	$ -	0.00	$ 7.10	**$ 7.10**	Vehicle's main Propeller	Recieved	N/A
PHROZEN 3D Printer Rapid Aqua-Gray 4K Resin	Amazon.com: PHROZEN 3D F	$ 35.99	0	9	$ 173.48	0.00	$ 497.40	**$ 497.40**	Resin for printing feusilage	Recieved	#PHZ179232022
ColorFabb Black LW-PLA Filament	ColorFabb Black LW-PLA Filar	$ 54.99	0	2	$ -	0.00	$ 109.98	**$ 109.98**	PLA for printing farious components	Recieved	101-0000194-4207001
Clevis Pin with Retaining Ring Groove 3/16" X 1-5/8" (Pack of 5)	McMaster-Carr	$ 9.10	0	2	$ -	0.00	$ 18.20	**$ 18.20**	Pins for Wing and nose	Recieved	0105EFLEER
Clevis Pin with Retaining Ring Groove 3/16" X 3" (Pack of 1)	McMaster-Carr	$ 7.25	0	4	$ -	0.00	$ 29.00	**$ 29.00**	Pins for Feusilage	Recieved	0105EFLEER
Carbon Fiber Tube 0.465" OD 72" long	McMaster-Carr	$ 75.73	0	2	$ 67.46	0.00	$ 218.92	**$ 218.92**	Rods for Feusilage assembly	Recieved	0105EFLEER
Carbon Fiber Tube 0.378" OD 72" long	McMaster-Carr	$ 83.33	0	6	$ -	0.00	$ 499.98	**$ 499.98**	Rods for Wing assembly	Recieved	0105EFLEER
Carbon Fiber Bar 39" long	McMaster-Carr	$ 13.11	0	3	$ -	0.00	$ 39.33	**$ 39.33**	Bars for wing support	Ordered	0105EFLEER
Foam Wings (5 sets)	Foam Wing Cores | MohrCom	$ 732.50	0	1	$ -	0.00	$ 732.50	**$ 732.50**	Wings for vehicle	Recieved	1459060410
Weather-Resistant Hook and Loop	McMaster-Carr	$ 16.59	0	1	$ -	0.00	$ 16.59	**$ 16.59**	For Nose Enclosure	Recieved	0105EFLEER
MonoKote Black 6'	Action Hobbies RC Aircraft Ce	$ 18.99	0	1	$ -	0.00	$ 18.99	**$ 18.99**	Coating for wings	Recieved	N/A
Nylon Shaft Grommet	McMaster-Carr	$ 2.61	0	2	$ -	0.00	$ 5.22	**$ 5.22**	For Pin to rod interface	Recieved	0105EFLEER
Liquid Electrical Tape, 4oz	McMaster-Carr	$ 11.55	0	1	$ -	0.00	$ 11.55	**$ 11.55**	Securing electronics	Recieved	N/A
Robart Hinge Point Hinge system Aileron Pins	Action Hobbies RC Aircraft Ce	$ 31.11	0	1	$ -	0.00	$ 31.11	**$ 31.11**	For Aileron	Recieved	N/A
Du-Bro Heave Duty Hinges	Action Hobbies RC Aircraft Ce	$ 8.25	0	1	$ -	0.00	$ 8.25	**$ 8.25**	For Aileron	Recieved	N/A
MonoKote Platinum 6'	Action Hobbies RC Aircraft Ce	$ 21.99	0	1	$ -	0.00	$ 21.99	**$ 21.99**	Coating for wings	Recieved	N/A
Insta-Cure+ Gap Filling Medium CA	Action Hobbies RC Aircraft Ce	$ 9.99	0	1	$ -	0.00	$ 9.99	**$ 9.99**	For securing Resin Components	Recieved	N/A
Super-Gold+ Gap Filling Medium Foam-Safe CA	Action Hobbies RC Aircraft Ce	$ 8.99	0	1	$ -	0.00	$ 8.99	**$ 8.99**	For securing Foam Components	Recieved	N/A
Zip Kicker CA Accelerator	Action Hobbies RC Aircraft Ce	$ 6.99	0	1	$ -	0.00	$ 6.99	**$ 6.99**	For setting the CA Glue	Recieved	N/A
Carbon Fiber 3/16" Drill bit - Brad Point	McMaster-Carr	$ 26.50	0	1	$ -	0.00	$ 26.50	**$ 26.50**	For Drilling into CF Rods	Recieved	0105EFLEER
Ultra-Low Friction Teflon PTFE Tape, 15'	McMaster-Carr	$ 16.50	0	1	$ -	0.00	$ 16.50	**$ 16.50**	Securing electronics Under Wing	Recieved	0105EFLEER
Fabric Grommets (Pack of 50)	McMaster-Carr	$ 5.33	0	1	$ -	0.00	$ 5.33	**$ 5.33**	For Pin to rod interface	Recieved	0105EFLEER
TTGO T-Beam 915Mhz WiFi Bluetooth Module	https://www.amazon.com/gp/	$ 48.50	0	3	$ 8.32	0.00	$ 153.82	**$ 153.82**		Recieved	#114-9238862-1625069
PHROZEN 3D Printer Rapid Aqua-Blue Resin	Amazon.com: PHROZEN 3D F	$ 37.99	0	4	$ -	0.00	$ 151.96	**$ 151.96**	Resin for printing feusilage	Recieved	#114-6296214-0405056
Misc Build Hardware	McGuckin Hardware	$ 76.12	0	1	$ -	0	$ 76.12	**$ 76.12**	Hardware and supplies for vehicle construction	Recieved	

Questions?

Appendix

Notes from Emma and Le Moine Meeting:
Critical Path needs emphasis - one slip pushes everything
Swap order for Testing Gantt and Testing Tables
Overall - Emma feels like we are missing details on test design and setup
Emma is not seeing expected results and model validation

Battery - Unclear what your data output is here. Pick a pass criteria for your battery, make it explicit (1 sigma etc)
Cycling test - Unclear on Pass Criteria - be more specific and clear on pass fail for all tests.
Cycling - Are you really validating any models with this? We need to clear this up. Can the composite wing design survive this test
Drop Test - What constitutes a successful landing? What's our Criteria and pass fail? Say your pass fail!
Propulsion - Flow was odd, procedure is in a weird place
Full System Test - More quantitative, flight path? Establish Comm Network? What data are you looking to get? How are you looking to get it? What is success with this one?

Sub system slide order

- Test rationale
- Design and setup
- Procedure
- Expected results
- Risk reduction to project
-

Design Requirement - Endurance through Electronics

Goal

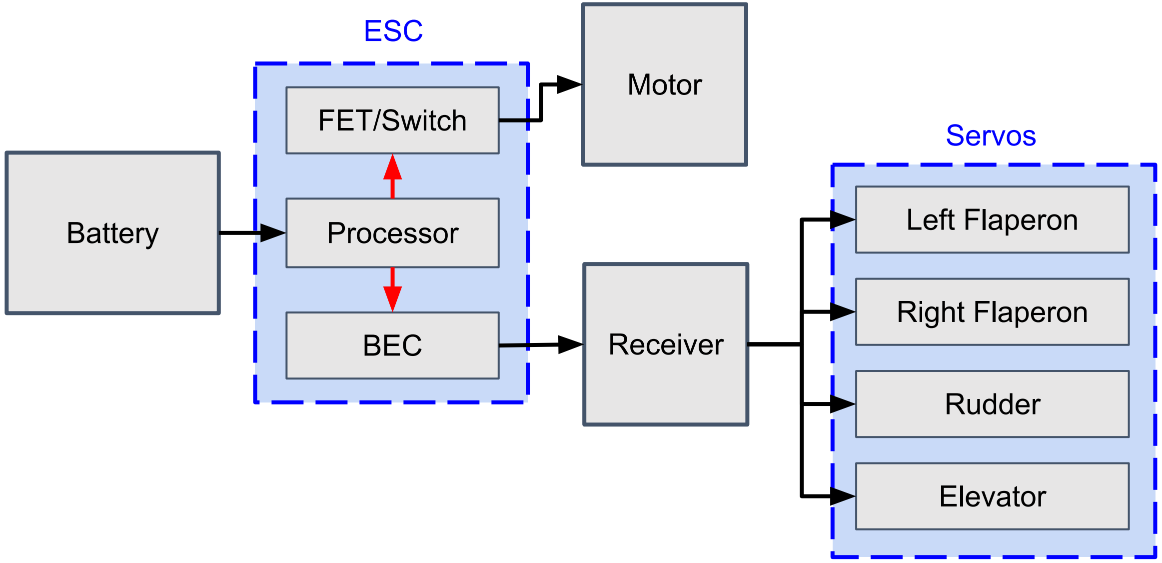
- Efficient power usage through select component choices and custom battery

Power Budget Assumptions

- High loading takeoff conditions
- No adverse wind effects
- No losses in wiring
- Ideal battery
- Ideal motor
- Constant current draw
  - Servos
  - ESC = motor current draw

Solution

- Account for all losses with the margin
  - 20% contingency power



Aerodynamics - Backup

Verification and Validation - Structures

Structures - Wing Whiffletree Test

Objective	Accurately reflect wing loading conditions during climbout, flight, and descent
Description	Test bending, tension, and compression limits of full wing with added structural support of carbon fiber
Model Comparison	ANSYS Wing launch simulation, expected flight loads from lift, sharp-edged vertical gusts and banked turn
Key Results	Structural failure, wing deflection, permanent deformation, material separation, surface delamination
Validation Against FRs	Validates wing can support loading conditions for climbout, flight, and descent - satisfying **FR3**

Design Requirement - Endurance through Aerodynamics

Endurance of Propeller Driven Aircraft

$$E = \frac{\eta}{c}\boxed{\frac{c_L^{3/2}}{c_D}}(2\rho_\infty s)^{1/2}\left(W_1^{-1/2} - W_0^{-1/2}\right) \quad \Longrightarrow \quad E = f(C_L, C_D^{-1})$$

Goals:

- Design Highly Efficient Aerodynamic Bodies

Assumptions:

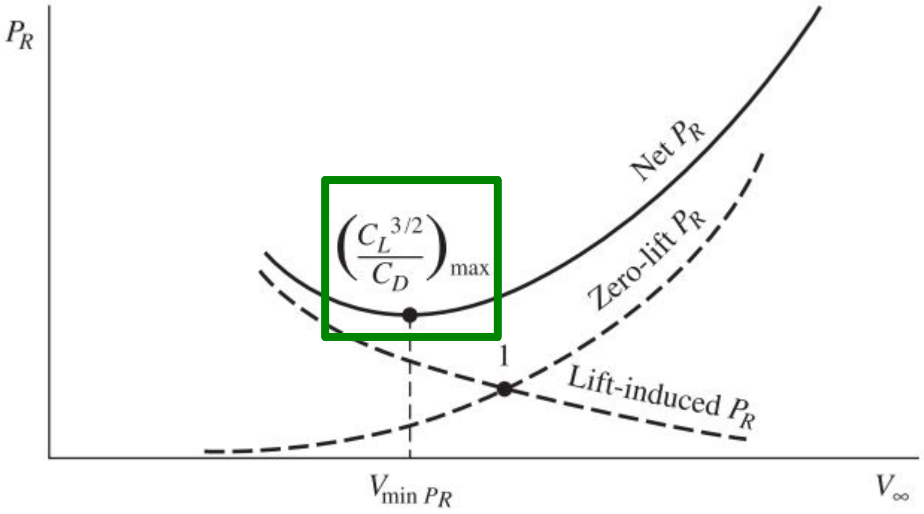
- Steady Unaccelerated Flight

Limitations:

- Ignores Propulsion System & Propeller Efficiency

Design Elements:

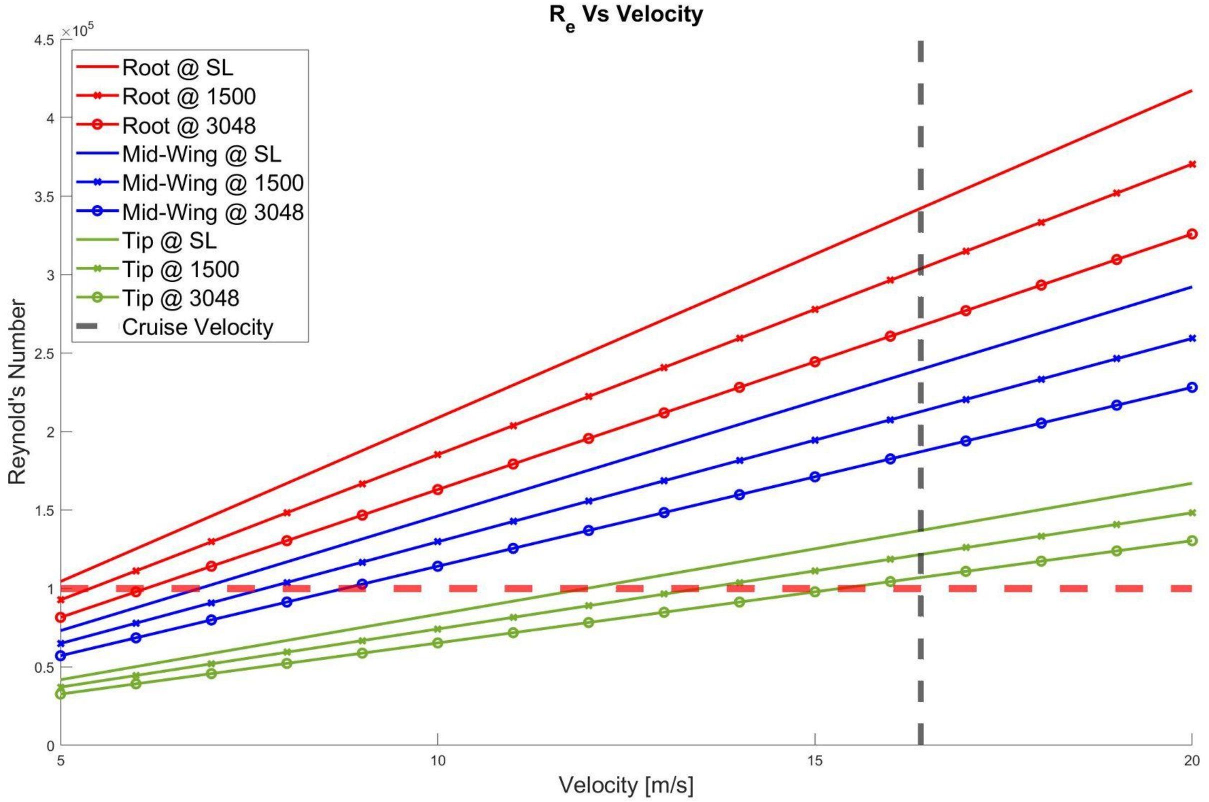
- **Airfoil: NACA 4412 & NACA 4406**
- **Taper Ratio: 0.40**
- **Aspect Ratio: 14.25**



Maximize $L^{3/2}/L_D$ to Meet FR1 (Cruise) and L/D FR3 (Climbout) ✅

Design Requirement - Endurance through Aerodynamics

Wing Tip Stall:



Verification and Validation - Aerodynamics

Aero: Computational Fluid Dynamics

Setup

- 3D Wing
- SST k-ω
- Atmosphere at 10,000ft cruise
- AOA: 0, 3, 6, 9
- Velocity: 12.2 m/s

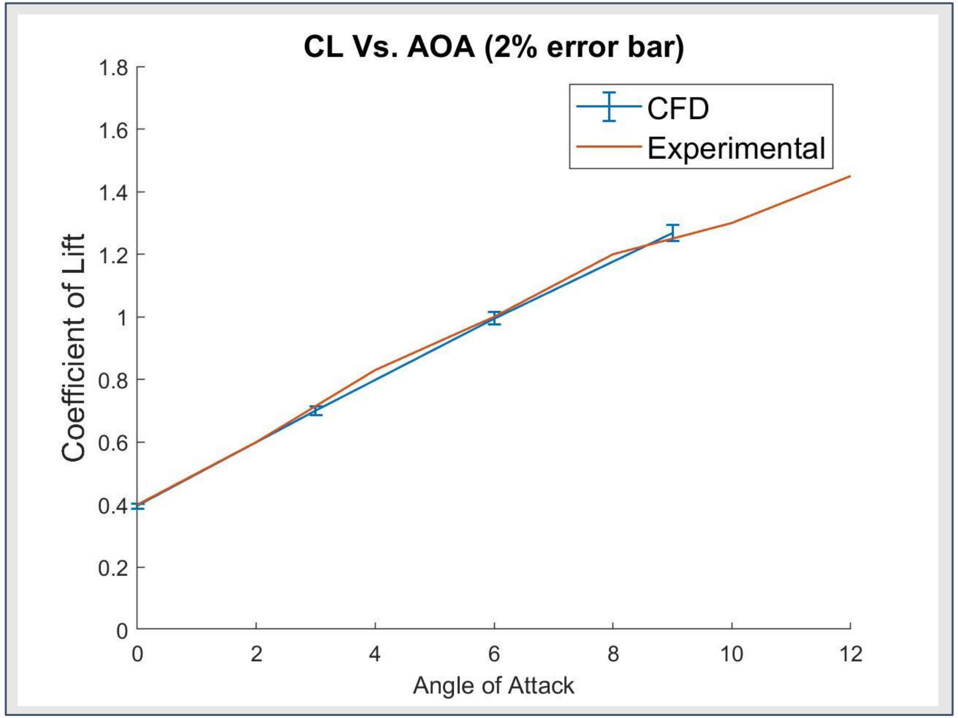
Boundary Conditions

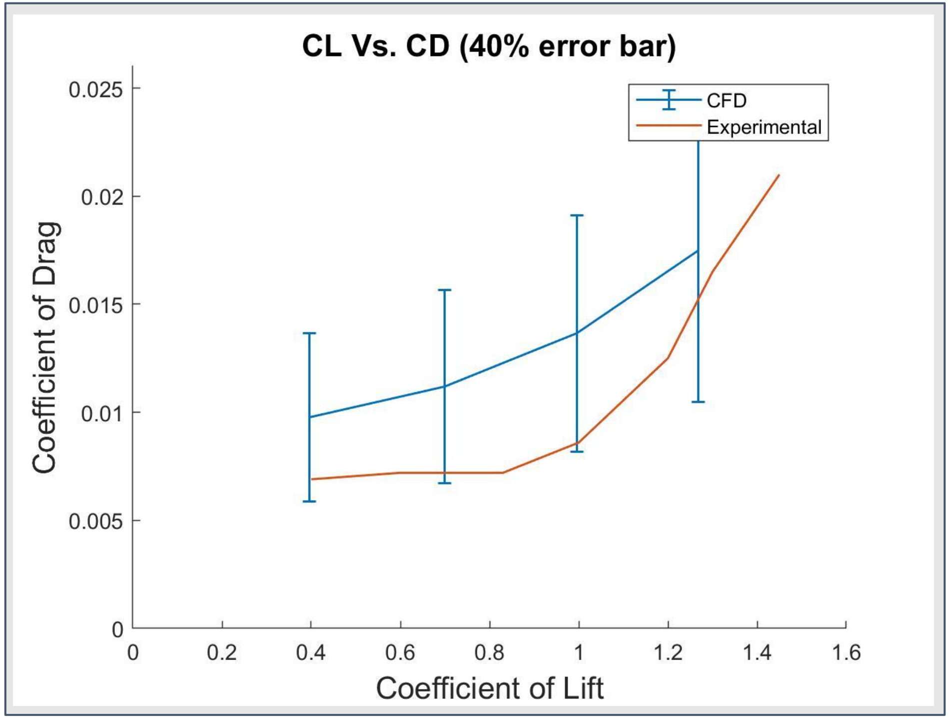
- Inlet: Freestream Velocity Vector
- Outlet: 0 Gauge Pressure
- Wall: No Slip

Objective	Qualitatively Understand Wing Tip Stall
Description	Extend 2D techniques to 3D, and create high fidelity simulation of wing tips including fine boundary layer resolution.
Model Comparison	Compare to literature on low R_e airfoils.
Expectation	Understand whether aerodynamic twist effectively mitigates separation and increases efficiency.
Validation Against FRs	Successfully mitigate wing tip stall increasing efficiency **FR1** & increasing maximum lift **FR3**

Verification and Validation - Aerodynamics

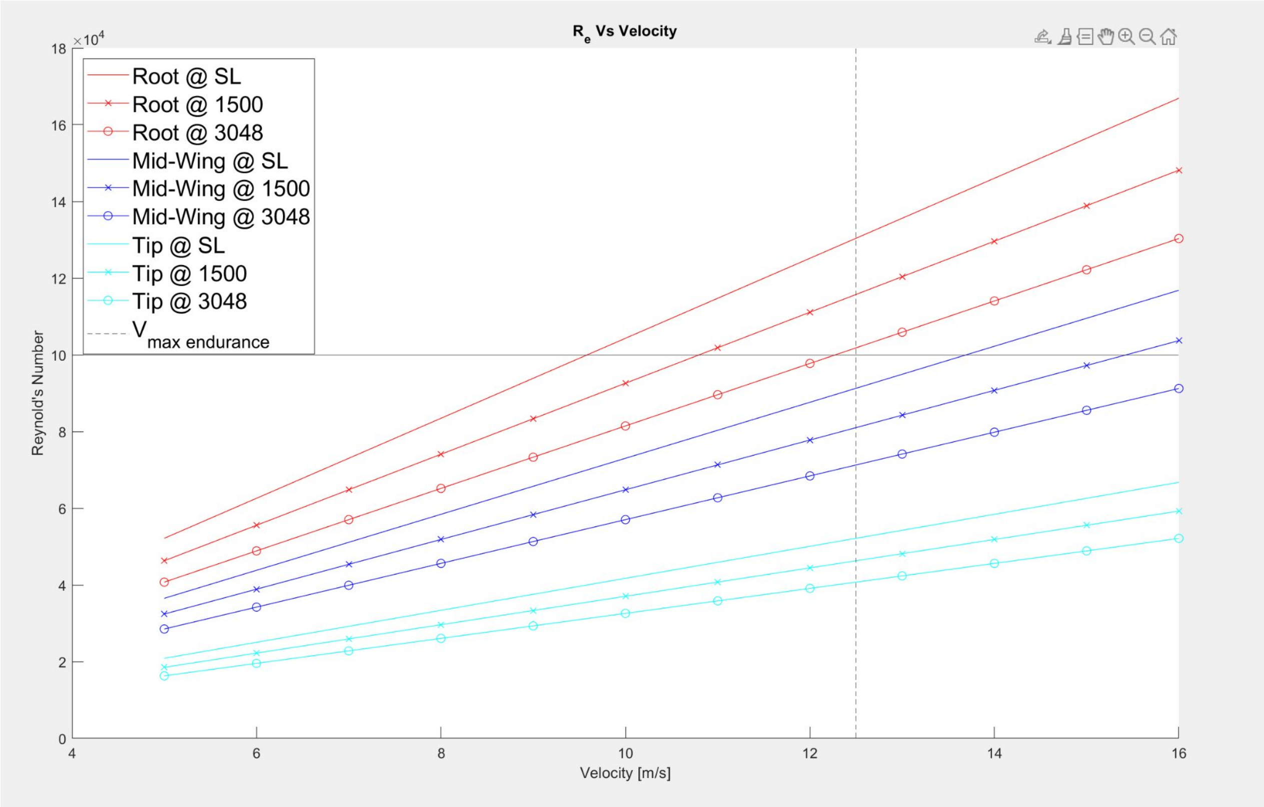
Aero - Computational Fluid Dynamics





Aerodynamics - Backup Prior Reynolds Number Analysis

Appendix Slide



Aerodynamics - Estimation of Body CL and CD

Appendix Slide

Stanford Model:

- **Wetted Area and Flat Plate Skin Friction**

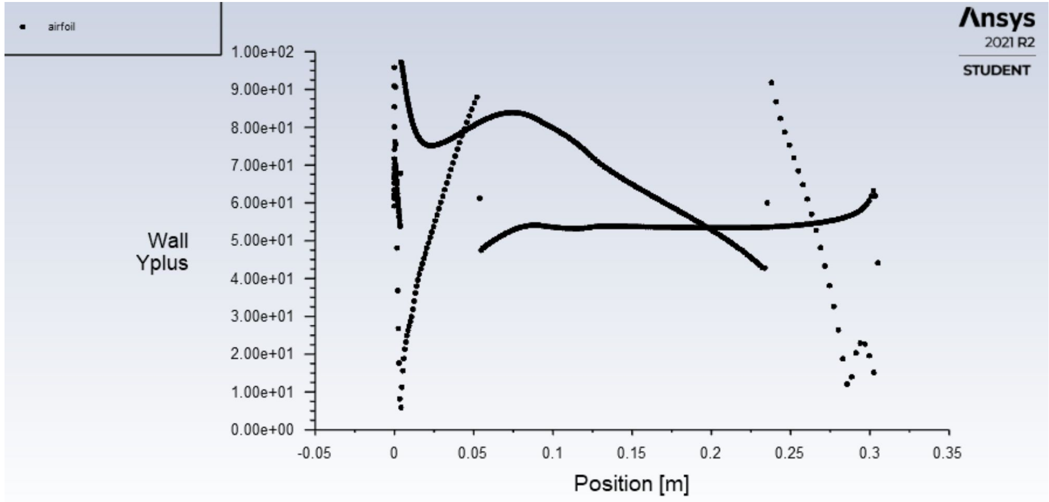
$$\boxed{C_f = \frac{1.328}{\sqrt{\mathrm{Re}_L}} \quad \text{laminar}}$$

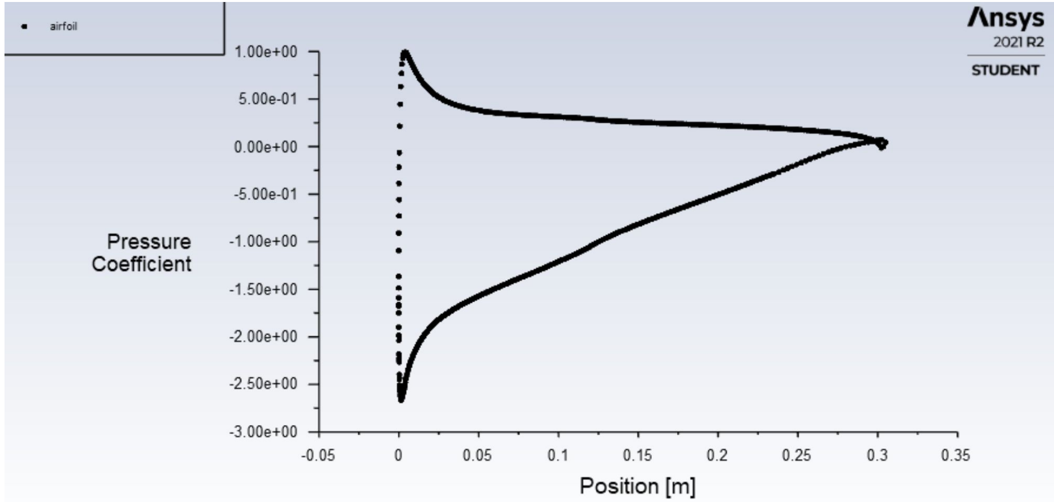
$$\boxed{C_f = \frac{0.074}{\mathrm{Re}_L^{0.2}} \quad \text{turbulent}}$$

Aerodynamics - Backup

Appendix Slide

- CFD: Sensitivity analysis





Aerodynamics Values- Backup

Appendix Slide

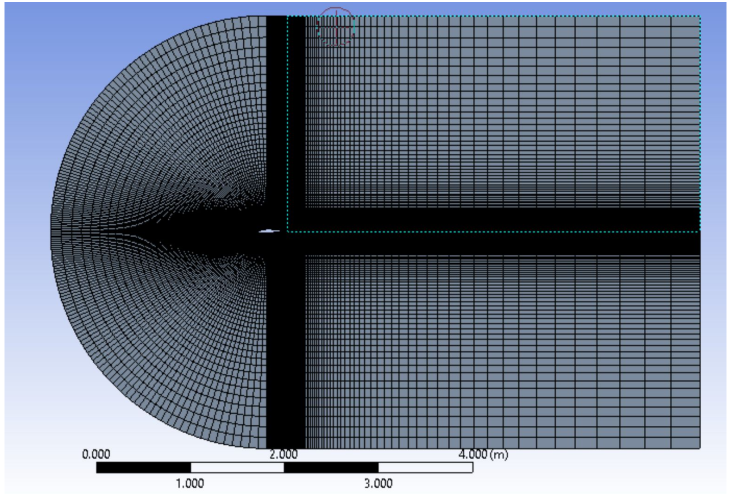
Cruise: 4.8° AOA / 16.4 m/s		Max: 11.5° / 22 m/s	
C_L (Cruise)	0.7991	C_L (Max)	1.402
C_D (Cruise)	0.0319	C_D (Max)	0.0716
C_L/C_D (Cruise)	**25.06**	**C_L/C_D (Max)**	**19.59**
Lift (Cruise)	72.1 (N)	Lift (Max)	199.7 (N)
Drag (Cruise)	5.9 (N)	Drag (Max)	22.9(N)

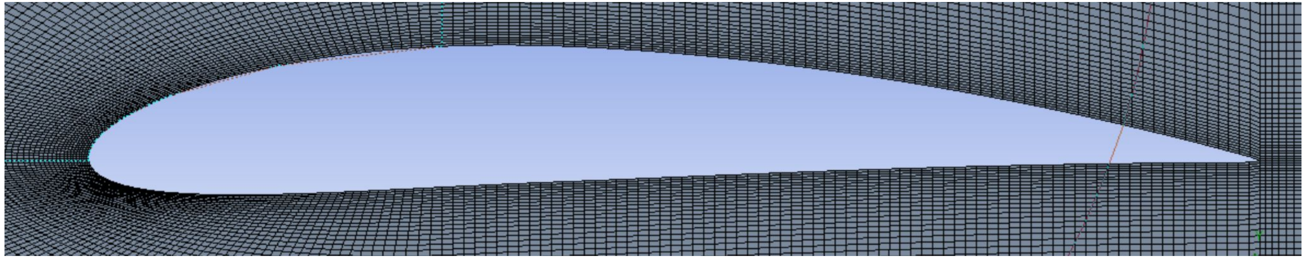
Aerodynamics - Backup

Appendix Slide

Objectives: *CFD model verification*

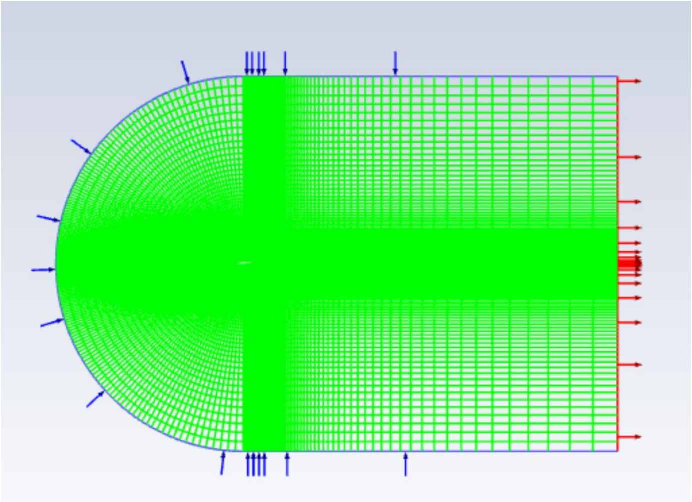
- Total Elements = 45,000

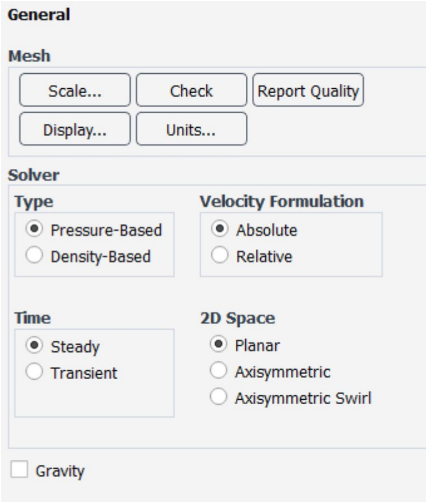


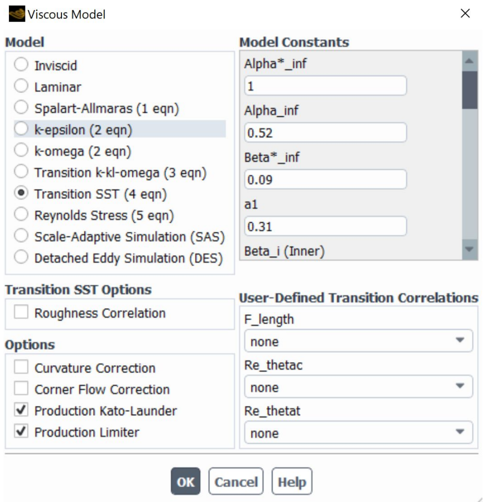


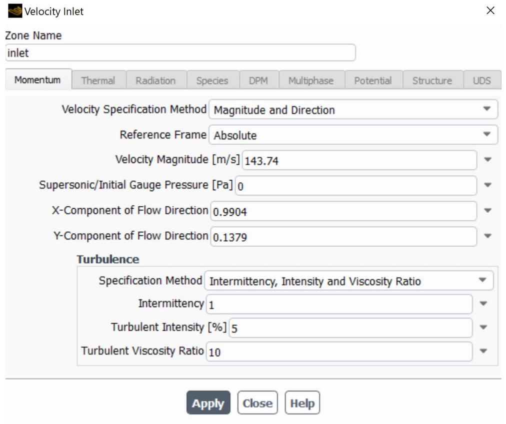
Objectives: *CFD model verification*

- Standard sea level atmospheric conditions applied



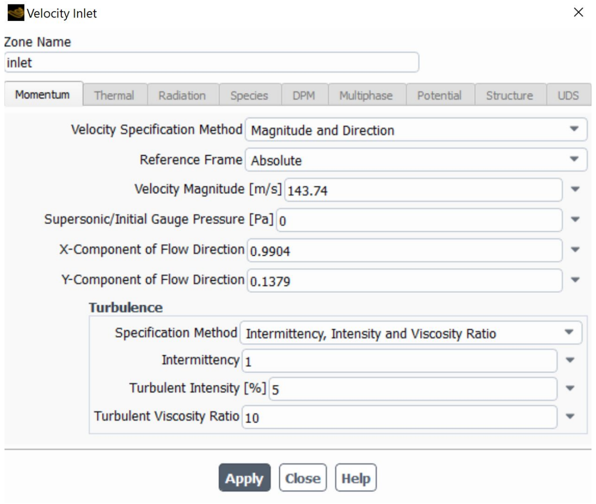


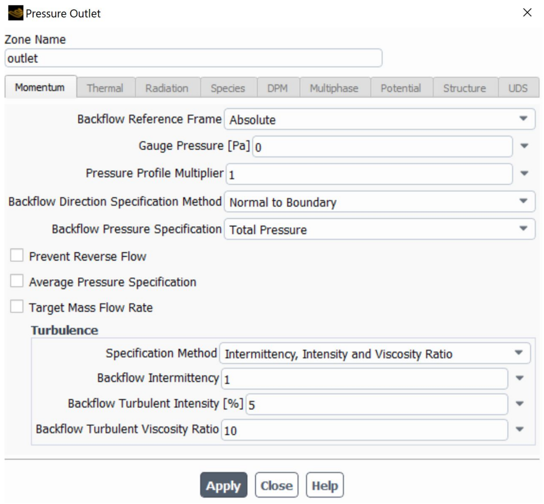


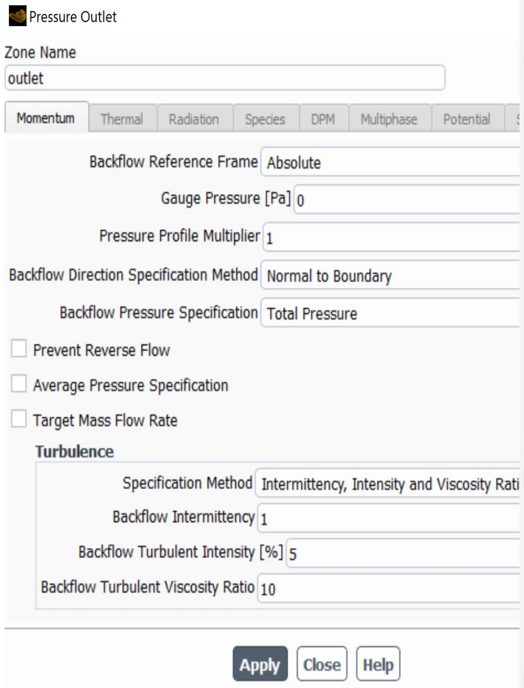


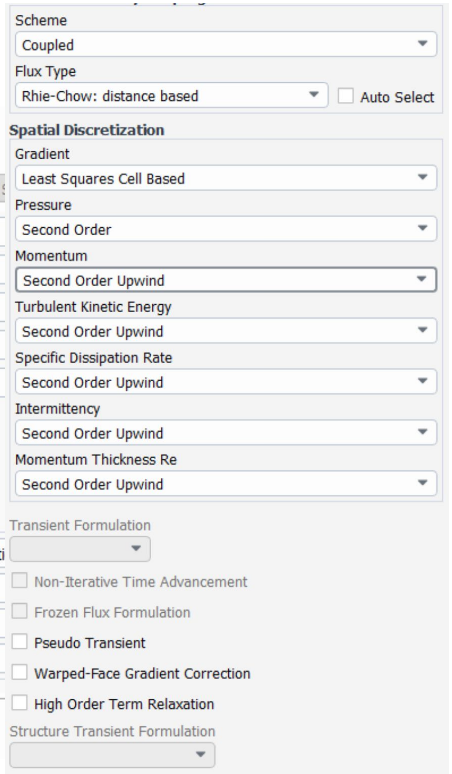
Objectives: *CFD model verification*

-





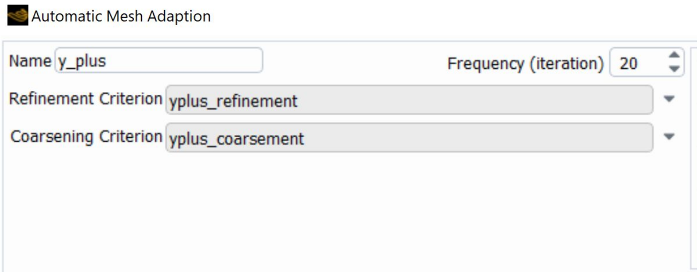


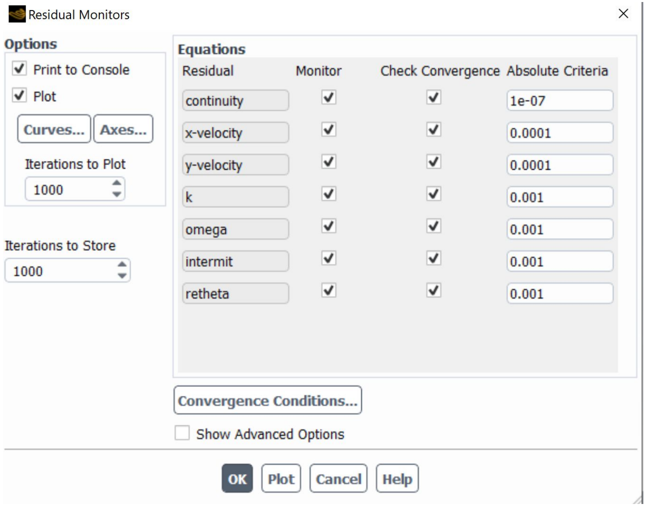


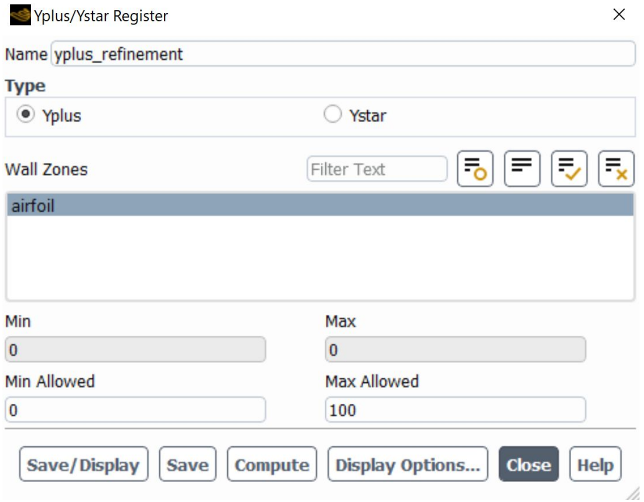
Aerodynamics - Backup

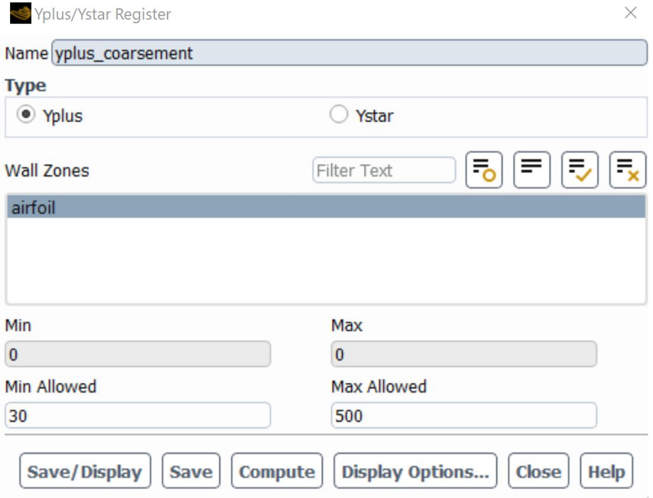
Objectives: *CFD model verification*

-







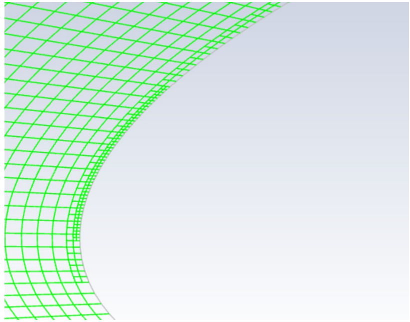


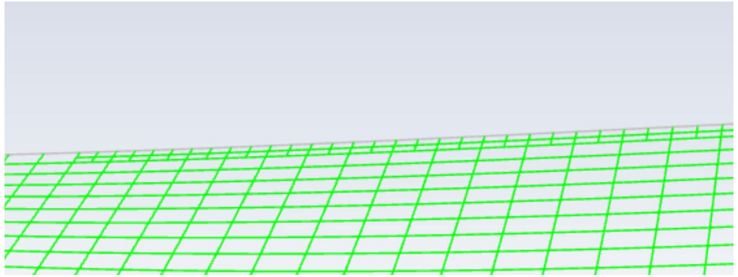
Aerodynamics - Backup

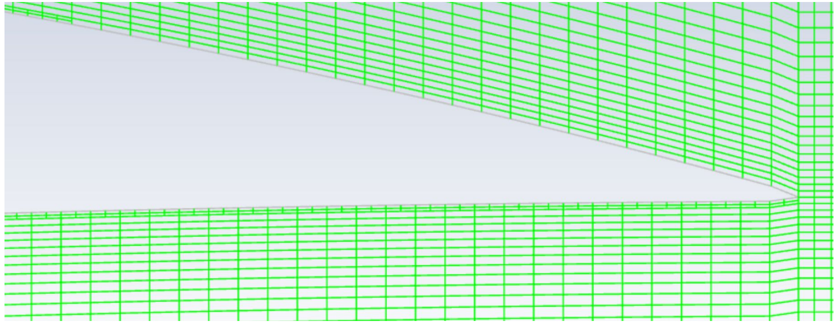
Appendix Slide

Objectives: *CFD model verification*

- Mesh refinement can be seen
- Total number of cells now 45,735





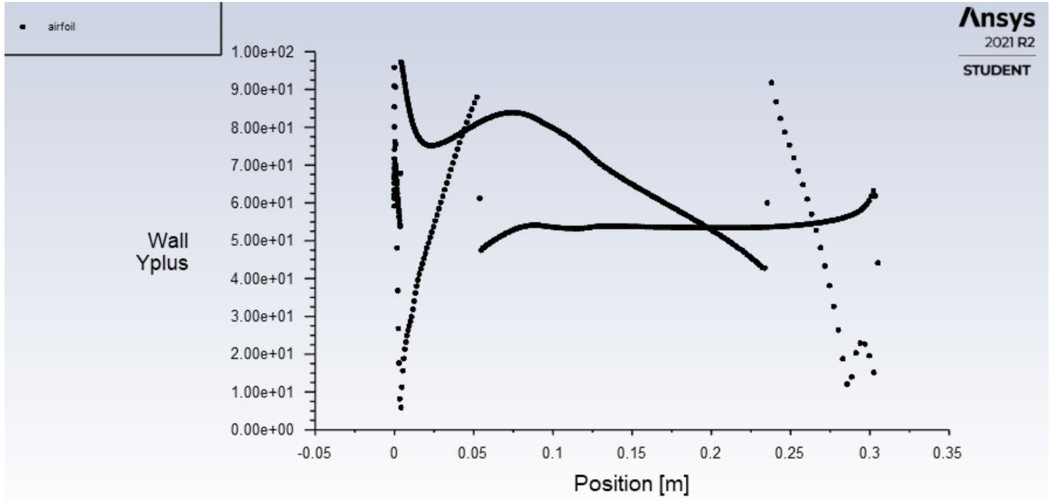


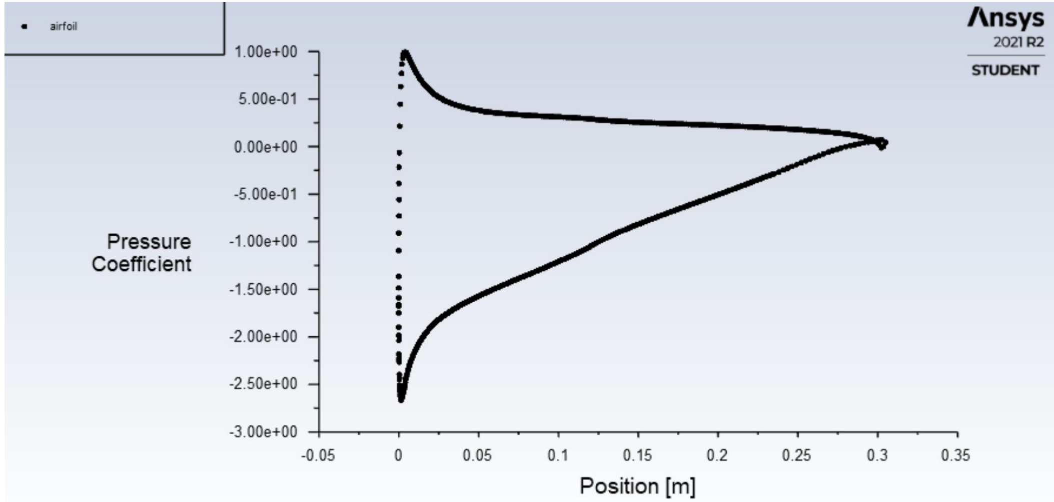
Aerodynamics - Backup

Appendix Slide

Objectives: *CFD model verification*

- Resulting Y+ and Coefficient of Pressure distribution





Verification and Validation - Aerodynamics - Backup

Aero - Wind Tunnel

Setup

- 3D printed model of wing scaled according to Reynold's number
- Use Smead Wind tunnel or TBD

Objective	Verify Aerodynamic Characteristics of Wing and Body
Description	Quantify Lift and Drag
Model Comparison	Potential Flow Estimates of Lift and Drag
Expectation	Increase in Predicted Drag
Validation Against FRs	Aerodynamic surfaces optimize lift and minimize drag to meet **FR1 & FR3**

Propulsion - Backup

Propulsion - Backup

Motor Selection

Criteria:

- Power
- Thrust
- Current Draw
- Weight
- Battery Needed
- Size
- Cost

Target Climbout Power	950-1050 W
Target Climbout Thrust	8.2-8.8 lbf

Propulsion: Max Endurance - Backup

Endurance Maximizing Velocity *(Minimum P_{req})* [1]

$$C_{Do} = \frac{1}{3}kC_L^2 \qquad vel_{end} = \sqrt{\frac{2W}{\rho S}\sqrt{\frac{k}{3C_{D0}}}} \qquad where\ k = \frac{1}{\pi \cdot e \cdot AR}$$

Coefficient of Lift *(Lift = Weight)* [2]

$$C_L = \frac{W}{\frac{1}{2}\rho \cdot vel_{end}{}^2 \cdot S}$$

Thrust *(Thrust = Drag)* [1]

$$T = D = q * S * (C_{D0} + (k \cdot C_L{}^2)) \qquad where\ q = \frac{1}{2} \cdot \rho \cdot vel_{end}{}^2$$

Power [2]

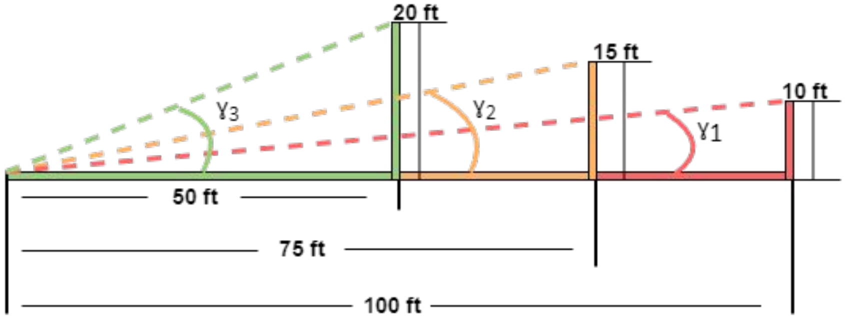
$$P_R = TV_{end} = q_\infty S C_{D0} V_{end} + q_\infty S V_{end} \frac{C_L^2}{\pi e AR} \qquad P_{req} = \frac{P_A}{\eta_{prop}}$$

Endurance Flight satisfies FR1 ✓

Results	IMP	SI
T_{req} *Endurance*	.901 lbf	4.00 N
P_{req} *Endurance*	.109 hp	81.6 W
V_{req} *Endurance*	27.3 mph	12.2 m/s
CL_{req} *Endurance*	1.42	1.42
T_{req} *Climbout*	8.20 lbf	36.5 N
P_{req} *Climbout*	1.28 hp	957 W
CL_{req} *Climbout*	.975	.975
V_{req} *Climbout*	35.1 mph	15.7 m/s
T_{req} *Headwind*	0.78 lbf	3.47 N
P_{req} *Headwind*	0.121 hp	90.4 W
CL_{req} *Headwind*	.871	.871
V_{req} *Headwind*	35 mph	15.6 m/s

Design Requirement - Propulsion System Optimization

Levels of Success for Climbout: *(measured from ground)*



Success:
- Level 1
- Level 2
- Level 3

γ_1 = **5.71°**
γ_2 = **11.3°**
γ_3 = **21.8°****

**outside Small Angle Approx

Rate of Climb (RoC) :

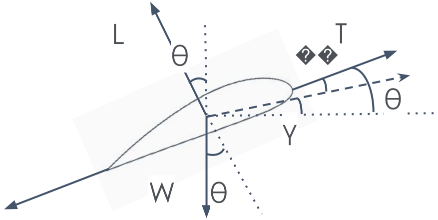
$$RoC = V_\infty \sin\gamma = \frac{TV_\infty - DV_\infty}{W} = \frac{P_{\text{climbout}} - P_{\text{req}}}{W}$$

$$P_{\text{exc}} = P_{\text{climbout}} - P_{\text{req}} \rightarrow P_{\text{climbout}} = P_{\text{exc}} + P_{\text{req}}$$

$$L = \frac{1}{2}\rho V^2 S C_L = W\cos\theta \rightarrow V = \sqrt{2\frac{W\cos\theta}{\rho S C_L}} \quad \text{where} \quad \theta = \gamma + \alpha$$

$$T_{\text{climbout}} = D + W\sin\theta = \frac{1}{2}\rho V^2 S C_D + W\sin\theta \quad \text{where} \quad C_D = C_{D0} + kC_L^2$$

$$P_{req} = \frac{T_{climbout} V_{climbout}}{\eta_{prop}}$$



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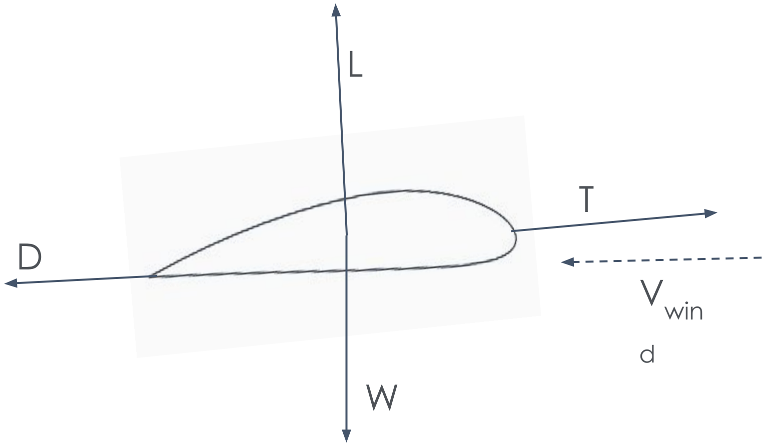
CL_{req} *Headwind*	.871	.871
V_{req} *Headwind*	35 mph	15.6 m/s

Propulsion: Headwind

Requirement for Headwind: *30 mph Headwind*



$$C_L = \frac{W}{\frac{1}{2}\rho \cdot vel_{wind}^2 \cdot S}$$

$$T = D = q * S * (C_{D0} + (k \cdot C_L{}^2))$$

$$where \quad q = \frac{1}{2}\rho V_{wind}^2 S$$

$$P_{req} = \frac{T_{wind} V_{wind}}{\eta_{prop}}$$

Results	IMP	SI
T_{req} *Endurance*	.901 lbf	4.00 N
P_{req} *Endurance*	.109 hp	81.6 W
V_{req} *Endurance*	27.3 mph	12.2 m/s
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CL_{req} *Headwind*	.871	.871
V_{req} *Headwind*	35 mph	15.6 m/s

Propulsion

Appendix Slide

Motor Selection

- T-Motor winner of down-selection process
  - Real-world problems
- Scorpion a strong 2nd place
- E-Flite is a valuable resource for testing

Scorpion SII-4025-520KV

T-Motor AM480 650KV

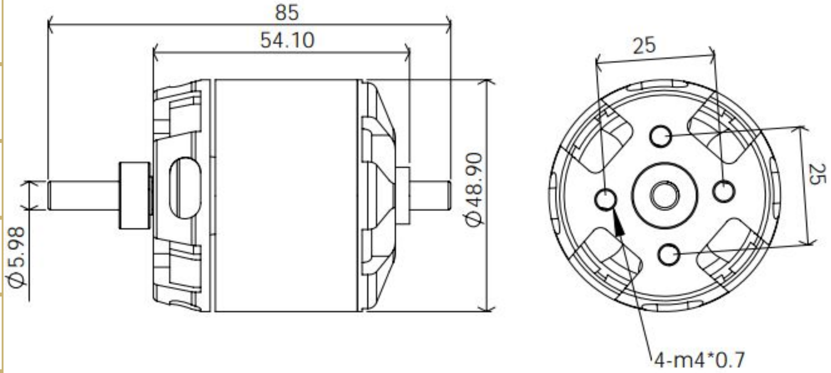
E-Flite 470KV

Propulsion - Backup

Appendix Slide

Scorpion SII 520KV with 15x8E APC Propeller

Performance Criteria	**Motor Specification**	**Target Specification(climbout)**
Power [W]	925.9	950
Thrust [grams]	3970	3950
Current [amps]	50	Lower is Better
Weight [grams]	353	Lower is Better
Cost [$]	150	Lower is Better
Compatible Battery	6s 3500-5000mah	Smaller is Better

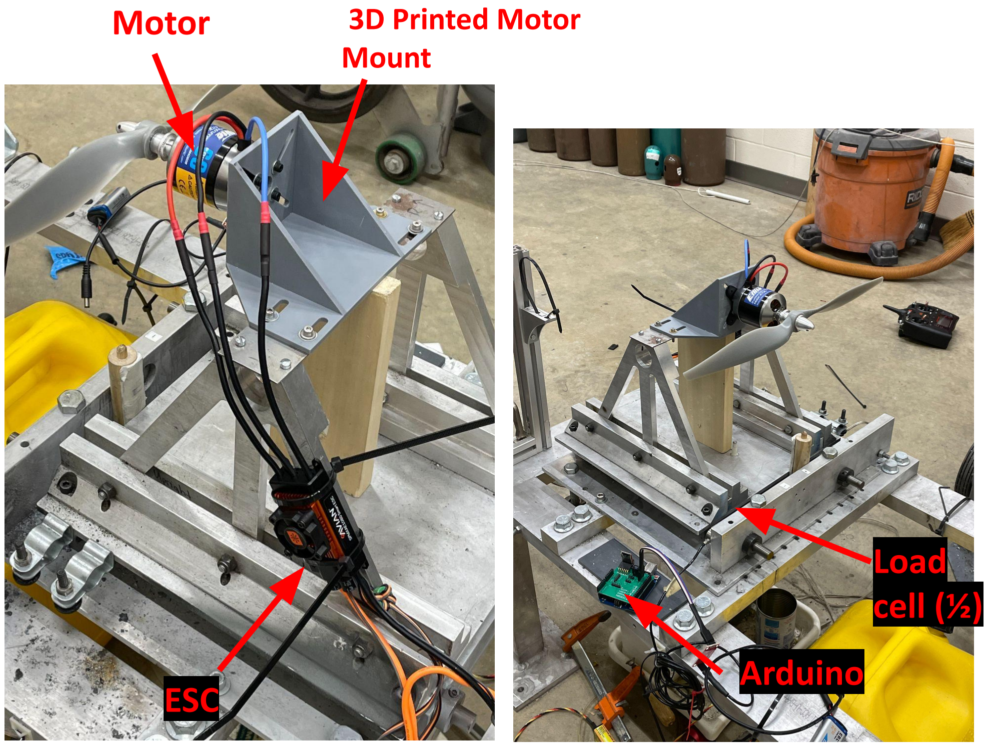


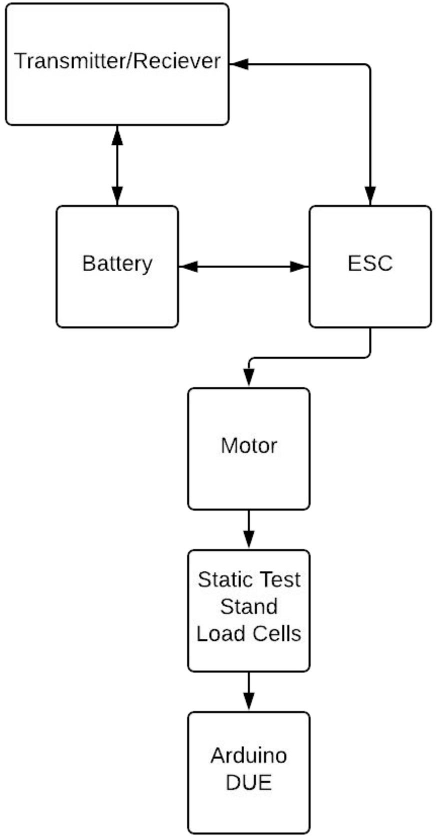
Propulsion - Backup

Appendix Slide

Static Testing

Goal: Obtain quantitative data for thrust dependent of current draw and percent throttle as a means to validate motor specs and pick ideal propeller size

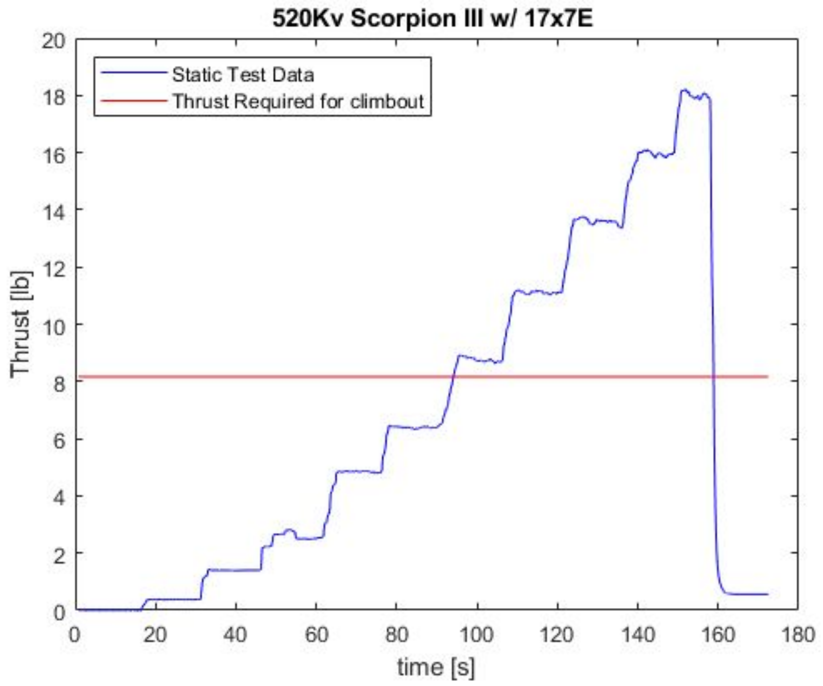


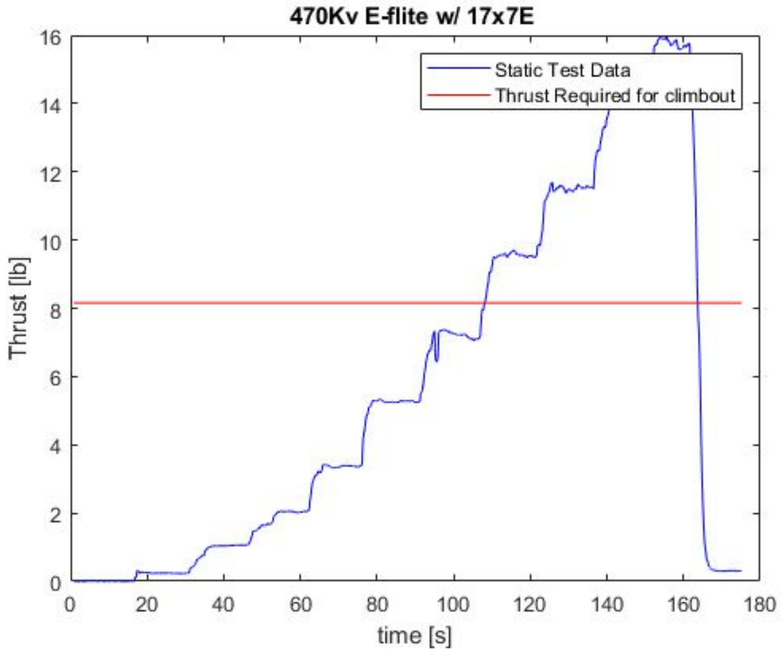


Propulsion - Backup

Appendix Slide

Static Testing

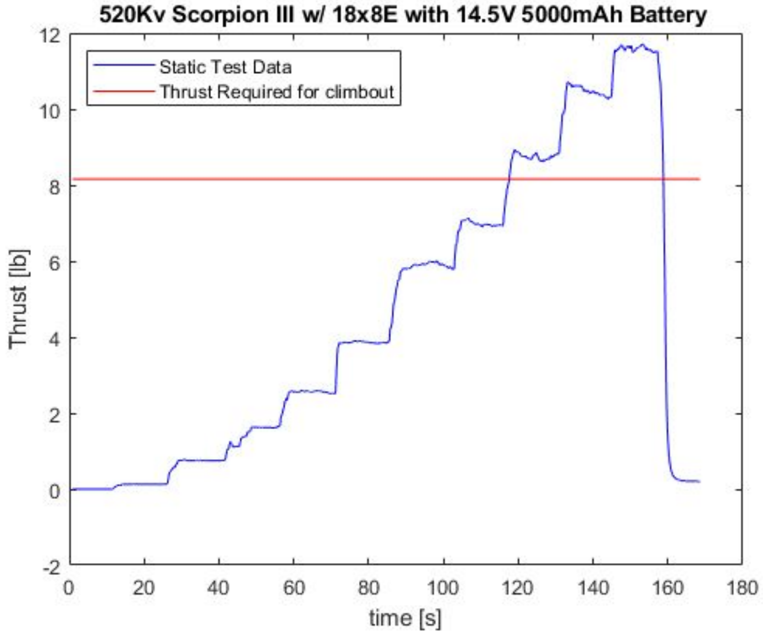


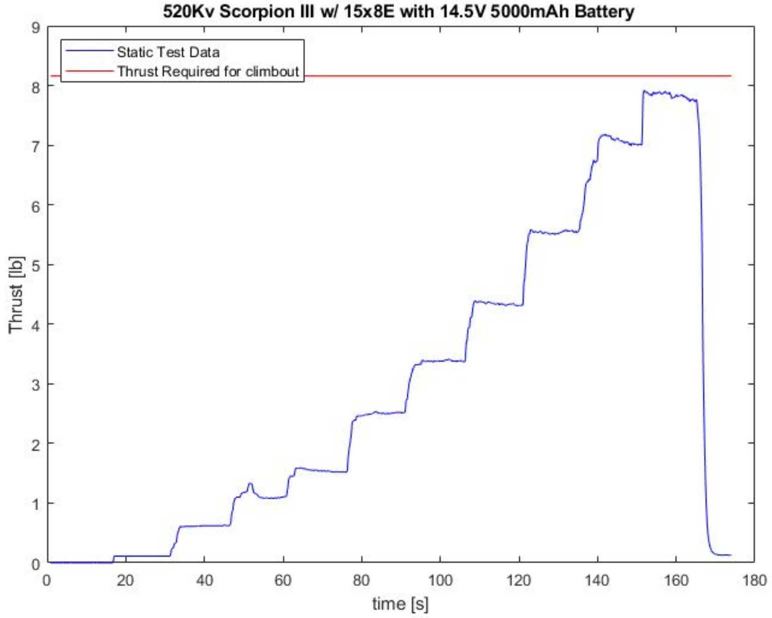


Propulsion - Backup

[Appendix Slide](#)

Static Testing

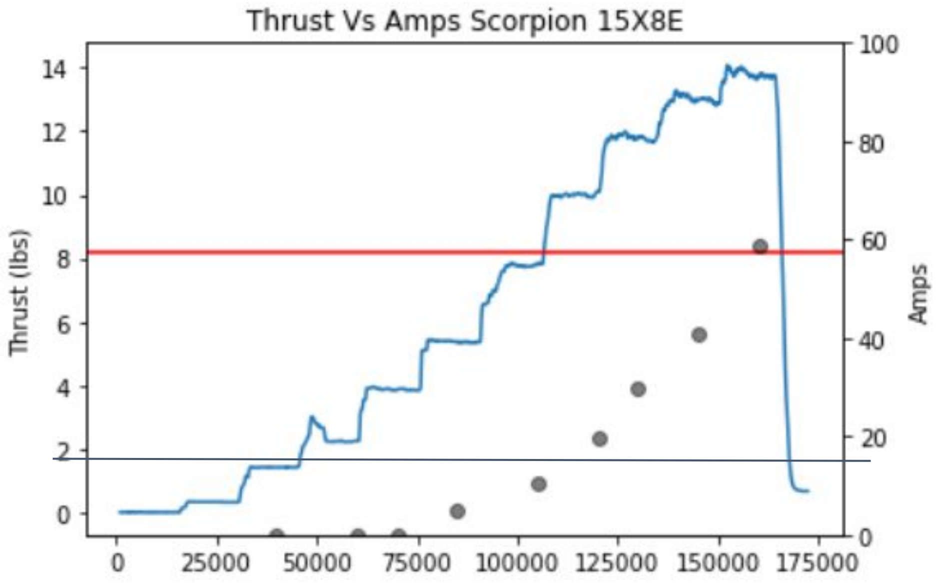


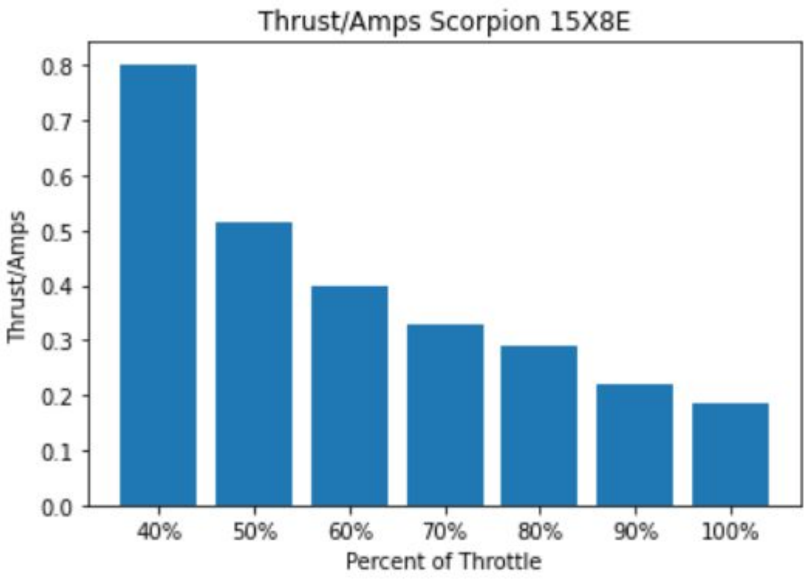


Propulsion - Backup

Appendix Slide

Thrust Vs. Amps Metrics





Electronics - Backup

Electronics - Servo Selection (Assumptions) - Backup

Appendix Slide

Key Assumptions:

- The induced forces on the control surface will be applied to the trailing edge
- When servo is torquing, no jitters from the control surfaces will be experienced (i.e. equilibrium condition is satisfied)
- Air density is set at sea level (**ρ_{SL} = 1.225 kg/m^3**)
- Control surface with largest area will drive calculations
    - **A_{Wing} = 2 in. x 48 in.** (modeled after Tempest Aircraft)

Electronics - Servo Selection (Assumptions) - Backup

Appended Assumptions:

- Aircraft will experience **Incompressible Flow**
- **Reynolds Number = 1×10^5**
- Wing geometry of NACA 4412 airfoil
- Airfoil experiences total velocity of **V_{total} = 25.144 m/s**
- Average chord length, **$\bar{c}$ = 8 in = 0.2032 m**
    - Control surface is hinged at 75% of wing chord

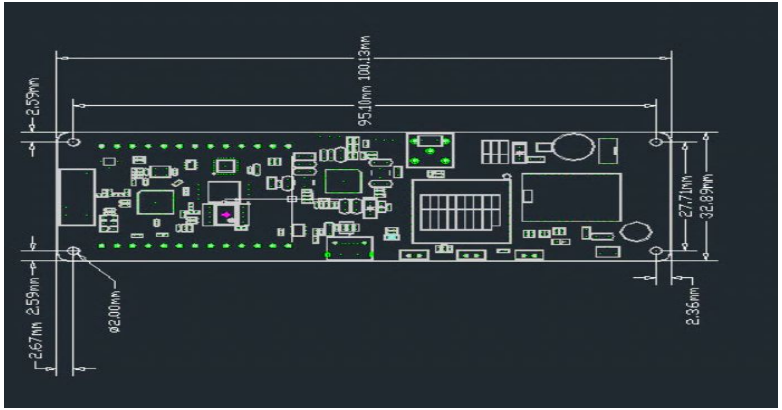
Electronics - Payload

Appendix Slide

LILY GO T-BEAM:

- Portable Long Range Radios
- **18650 Battery:** 72 hours of power
- Multiple frequencies available
  - 433/868/915 Mhz
- GPS Capable
- **Weight:** 82.2g (2.82 oz)
- **Working Temp:** -40℃ + 85℃
- **Cost Effective:** $40 per radio

915Mhz



Electronics - Servo Selection (Torque Calculations) - Backup

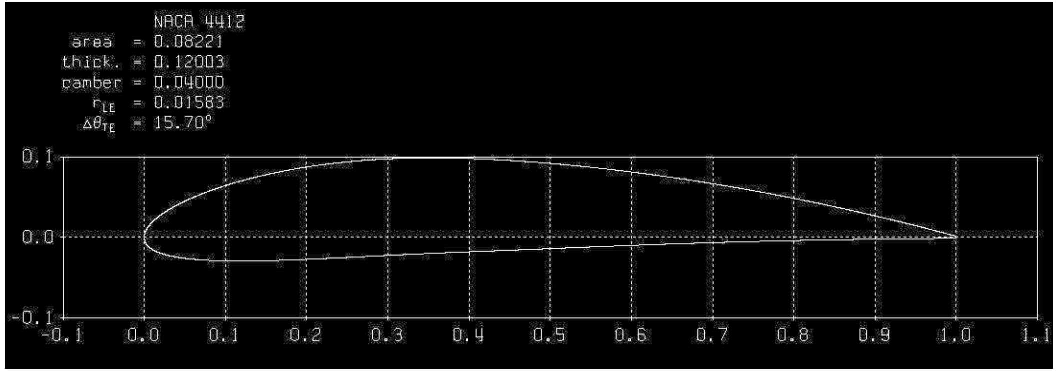
Appendix Slide

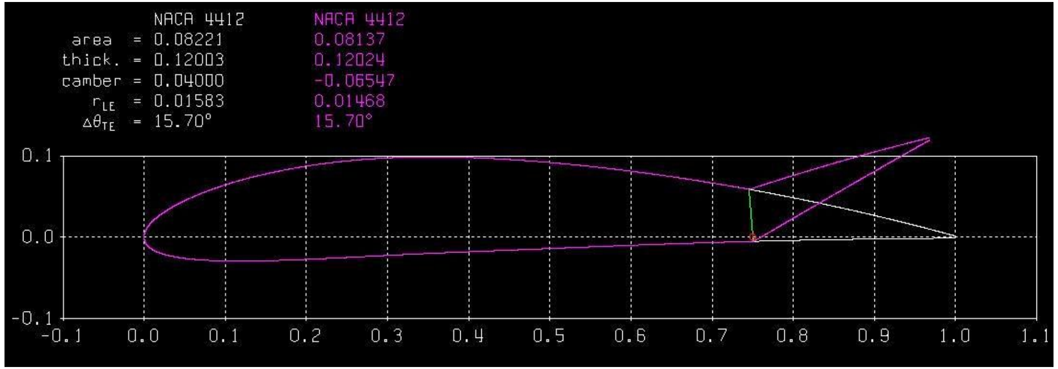
Hinge Moment/Span:

- $$\frac{M_{hinge}}{b} = -0.01455 \cdot (\frac{1}{2} \cdot \rho_{SL} \cdot V_{SL}^2 \cdot \bar{c}^2)$$
- -0.1672 Nm/span
- -0.1698 Nm = -24.05 oz-in.

Selected Servo Properties:

- Factor of Safety (FoS) = 2
- Thin design
- Lightweight





Verification and Validation - Electronics / Servos - Backup

Servo Parameters

- $V_{cruise} = 16.4$ m/s
- Max Gust Speed = 9.144 m/s

$$\eta_{servo} = \frac{P_{out}}{P_{in}} = \frac{P_{mech}}{P_{elec}} = \frac{\tau \cdot \omega}{V \cdot I}$$

Objective	Model servo performance based on manufacture mechanical and electrical details.
Description	Analyze input and output power of servo to calculate servo efficiency and determine operational range.
Model Comparison	N/A. This model is uniquely affected by the aircraft's flight path and weather conditions.
Expectation	High servo loading correlates to high amperage draw and low loading reflects low current draw.
Validation Requirements	Place inline current sensor within circuit during test flight to analyze true amperage demand of servos.

Li-Po vs Li-Ion Batteries - Backup

Appendix Slide

Li-Po Batteries

Pros:

- Lower profile
- Longer lifespan
- Pre assembled units

Cons:

- Higher cost
- Low power density
- Known overheating issues

Li-Ion Batteries

Pros:

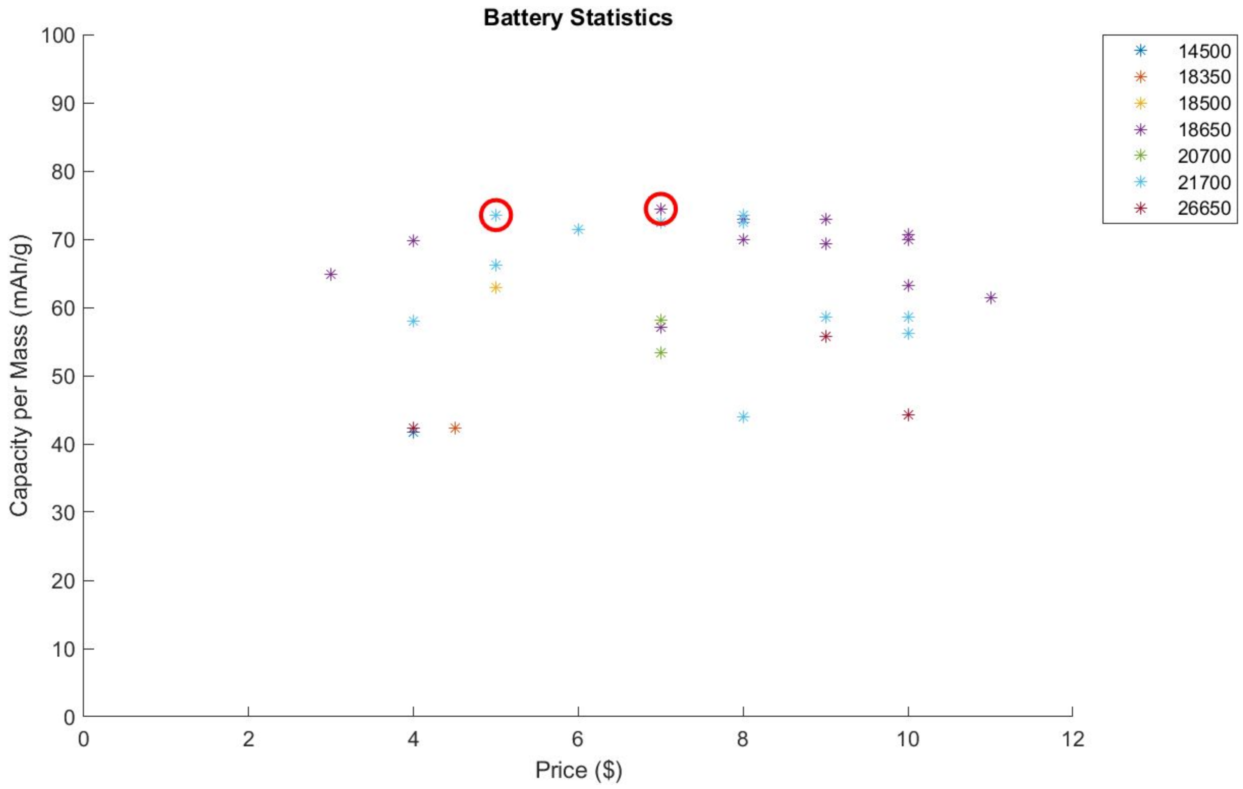
- Higher power density
- Less likely to overheat
- Customizable
  - Voltage
  - Current
  - Capacity

Cons:

- No built in protection
- Shorter lifespan
- Requires additional manufacturing

Li-Ion Trades - Backup

Appendix Slide



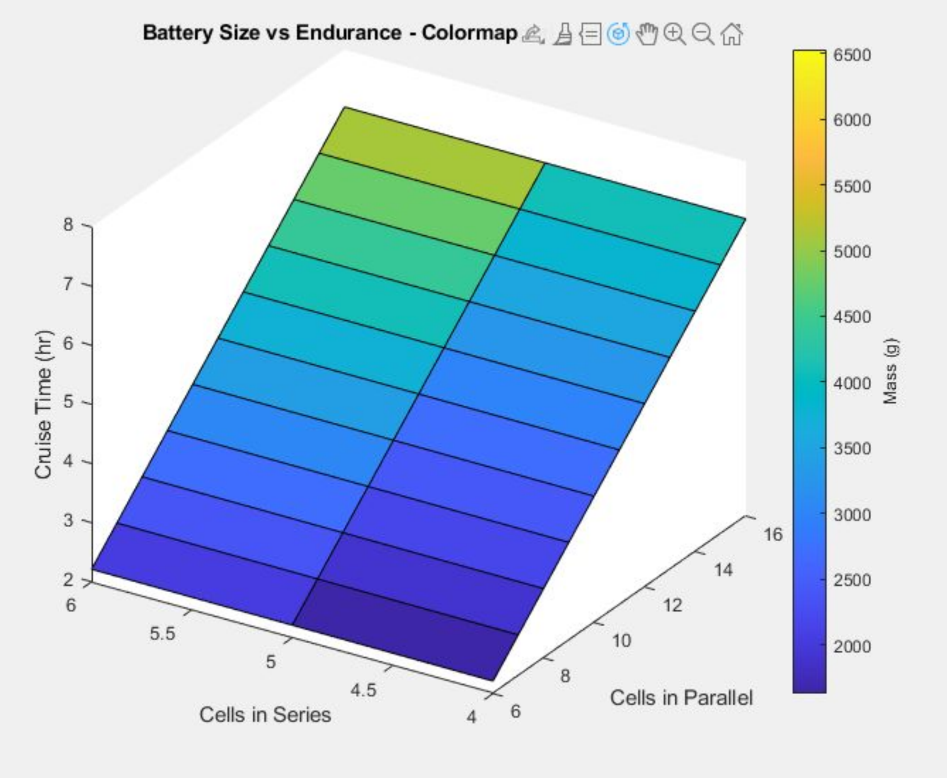
- Best capacity per mass battery:
  - LG F1L1865 (18650)
    - 3350 mAh
    - 4.87 A (Too small)
    - $6.99
    - 45 g
  - Lishen LR2170SD (21700)
    - 5000 mAh
    - 9.6 A
    - $4.99*
    - 68 g

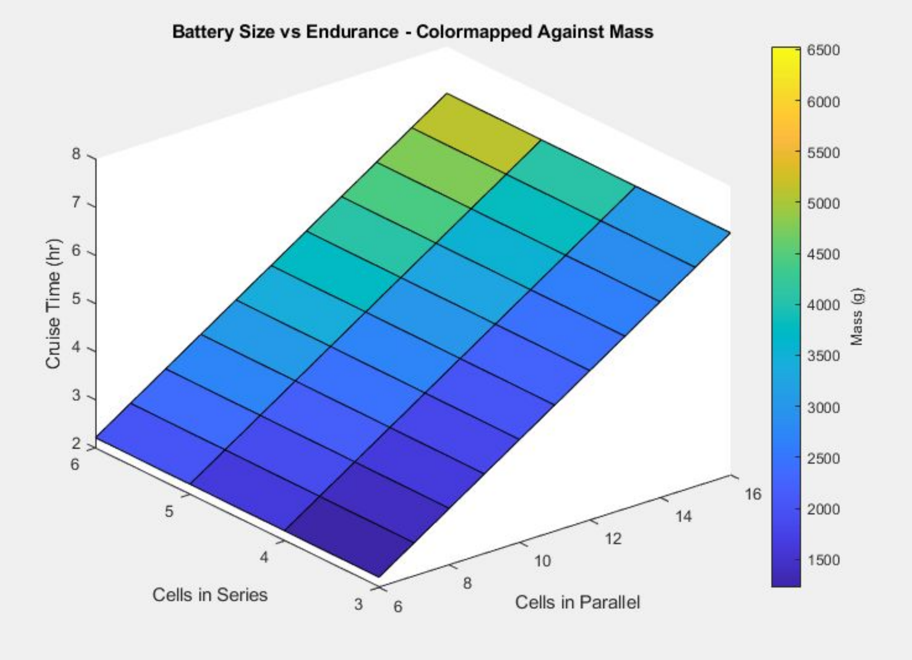
Final selection: Lishen LR2170SD

* Bulk order discount (~ 15 %)

Battery Pack - Backup

Appendix Slide





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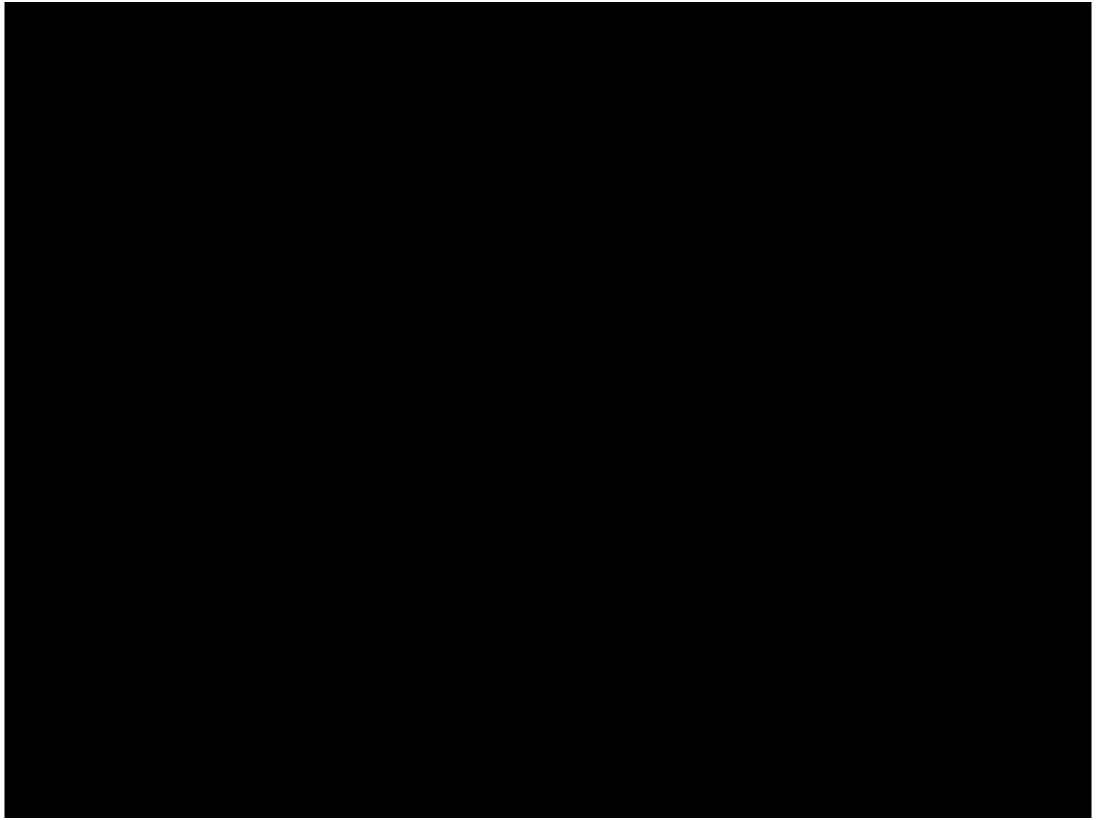
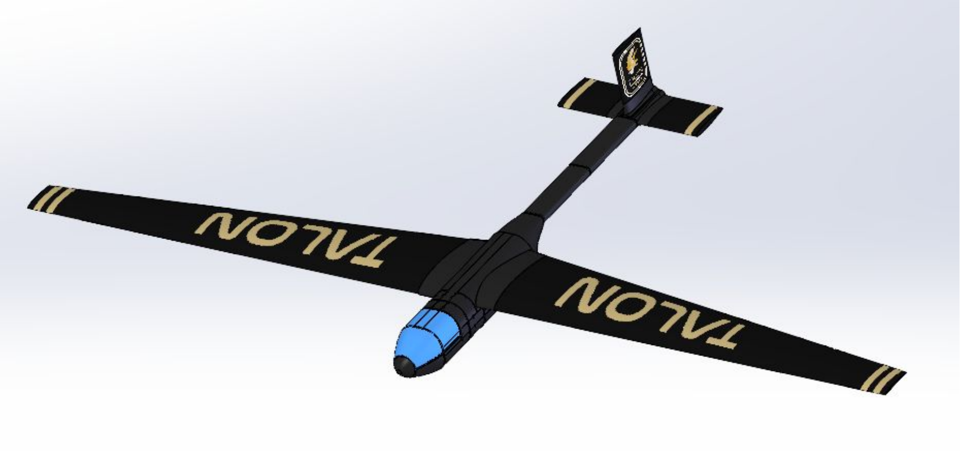
Electronics - Thermal Testing - Backup



CAD Model - Backup

TALON - Electronics Housing Design - Backup

Appendix Slide

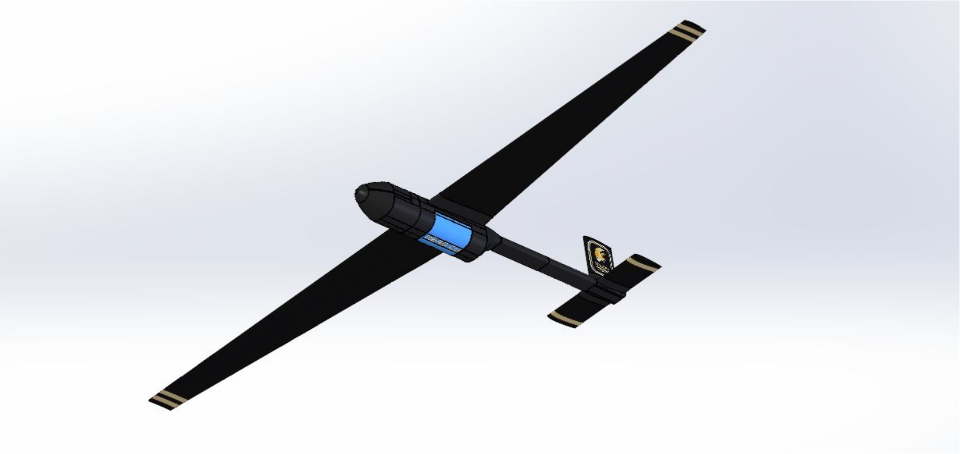


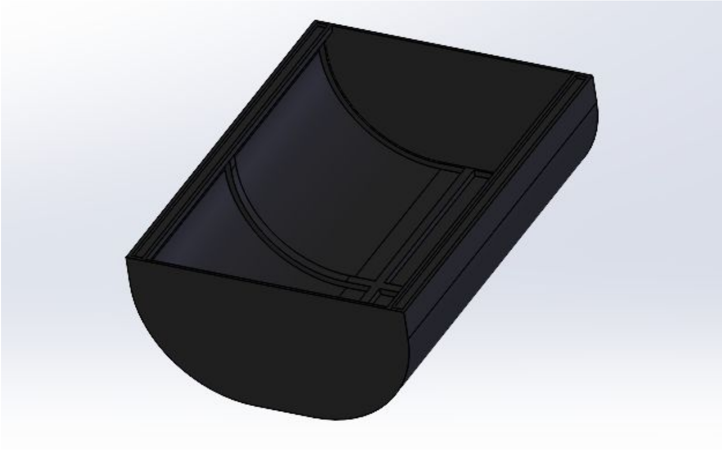
Focus: *Provide seamless access to electrical components such as battery, motor, and flight controller without complete disassembly or hassle*

Features: *Rapidly removable canopy for ease of access into electronics bay*

TALON - Payload Bay Design - Backup

Appendix Slide



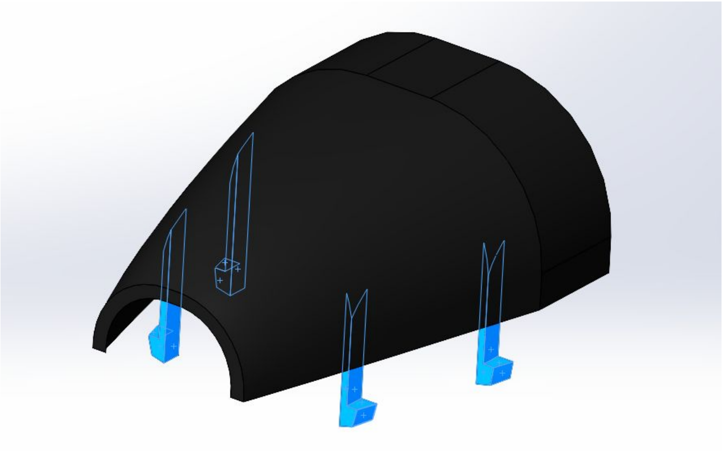


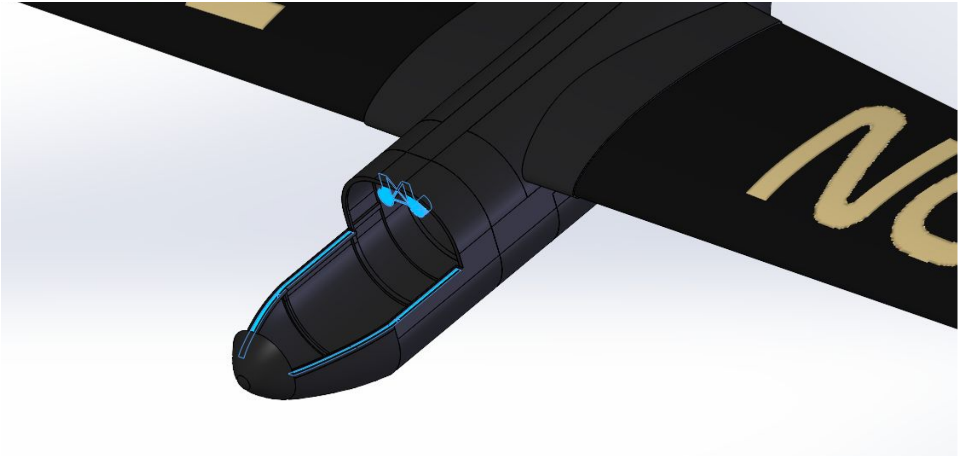
Focus: *Provide a mass and volume for user to fill with mission specific payload while not disturbing aircraft dynamics and flight characteristics*

Features : *Provides rapid interchangeability and spacious room for various user defined payloads*

TALON - Mounting - Backup

Appendix Slide





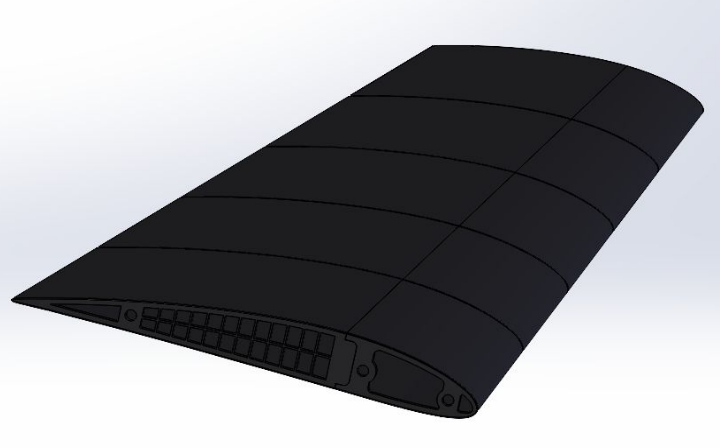
Concepts Considered: *3D printing clips*

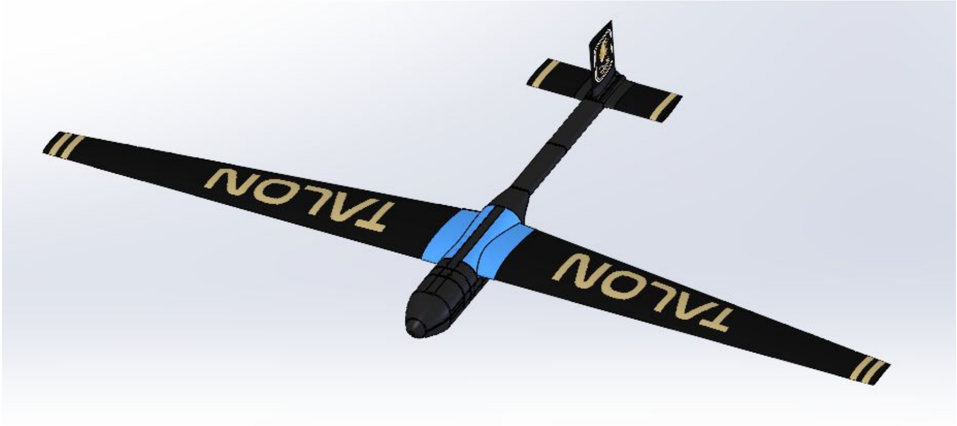
Focus: *Provide access to crucial components without jeopardizing mission performance*

Features: *Rapid removal and securing for minimal down time between service and operation*

TALON - Wing Integration Design - Backup

Appendix Slide





Concepts Considered: *Integrated Wing and FishBAC Control Surfaces*

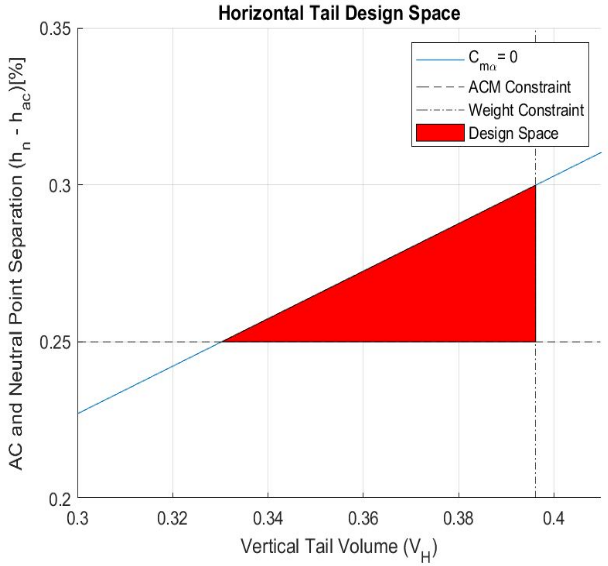
Focus: *Integrating the wing with fuselage while providing structural support*

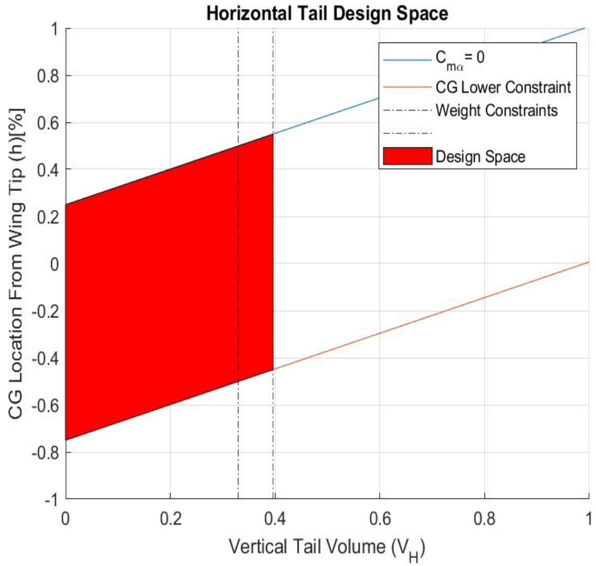
Features: *Three piece system based on dovetail connections for rapid interchangeability and servicing. Structural reinforcement for wings at critical shear point along the fuselage interface*

Aircraft Dynamics - Backup

Appendix Slide

Objective: *Maintain controllability and establish inherent stability to reduce flightpath deviation and energy draw for correction*





Aircraft Dynamics - Backup

Appendix Slide

Objective: *Maintain controllability and establish inherent stability to reduce flightpath deviation and energy draw for correction*

	Volume coefficient	Surface Area [ft^2]	Span [ft]	Weight [lbs]
Horizontal Tail Estimates	0.40	0.85	1.69	0.35
Vertical Tail Estimates	0.02	0.36	0.73	0.15

Aircraft Dynamics - Backup

Appendix Slide

Objective: *Maintain controllability and establish inherent stability to reduce flightpath deviation and energy draw for correction*

- *Cm_alpha = -1.9849*
- *Neutral Point = 51.1% Chord*
- *SM = 0.3377 % chord = 4.05 inches*

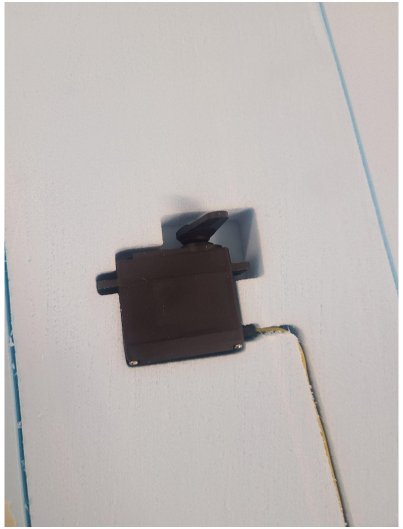
Modular Design - Backup

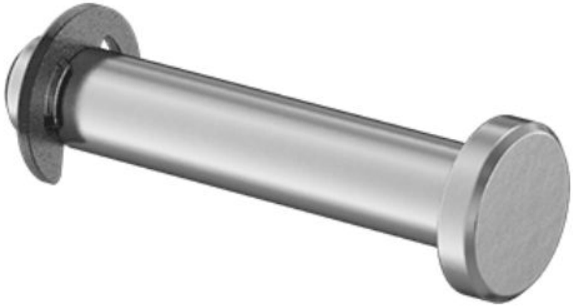
[Appendix Slide]

Carbon Fiber Bar

Carbon Fiber Rod

Clevis Pin





Manufacturing - Backup

Appendix Slide

Build plan developed to provide a repeatable procedure and maintain similar weight between wings

BUILD PLAN

Wings

Measure spar hole diameters
- Front:________________
- Aft:________________

Measure wingspan, chord lengths and thicknesses
- Wingspan:________________
- Root Chord Length:______________
- Tip Chord Length:______________
- Root ThIckness:______________
- Tip ThIckness:______________

Weigh foam wing
- Weight:_______________

Test fit servo (dry)
- Fit Check: [ ]

Test fit CF Rods (0.378" OD)
- Fit Check: [ ]
- Once in place, scribe the root cut and pinhole

Test fit CF Bar
- Fit Check: [ ]

Remove all hardware

Cut CF Rods and bars to length, sharpen rod ends and weigh them
- CF Front rod Weight:______________
- CF Rear rod Weight:______________
- CF Front bar Weight:______________
- CF Rear bar Weight:______________

Test fit CF Rods (0.378" OD)
- Fit Check: [ ]

Test fit CF Bar
- Fit Check: [ ]

Remove all hardware

Measure out ¼ of one tube of epoxy into a mixing cup and mix

Design Requirement - Endurance through Aerodynamics

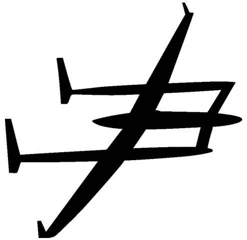
Predicted Aerodynamic Characteristics - Potential Flow Theory

Cruise: 4.8° AOA / 16.4 m/s		**Max: 11.5° / 22 m/s**	
C_L (Cruise)	0.7991	C_L (Max)	1.402
C_D (Cruise)	0.0319	C_D (Max)	0.0716
C_L/C_D (Cruise)	**25.06**	**C_L/C_D (Max)**	**19.59**
Lift (Cruise)	72.1 (N)	Lift (Max)	199.7 (N)
Drag (Cruise)	5.9 (N)	Drag (Max)	22.9(N)

Albatross (Bird)
- 20:1

U-2 (Spy Plane):
- 25.6:1 (12 Hrs)

Rutan Voyager
- 27:1 (216 Hrs)

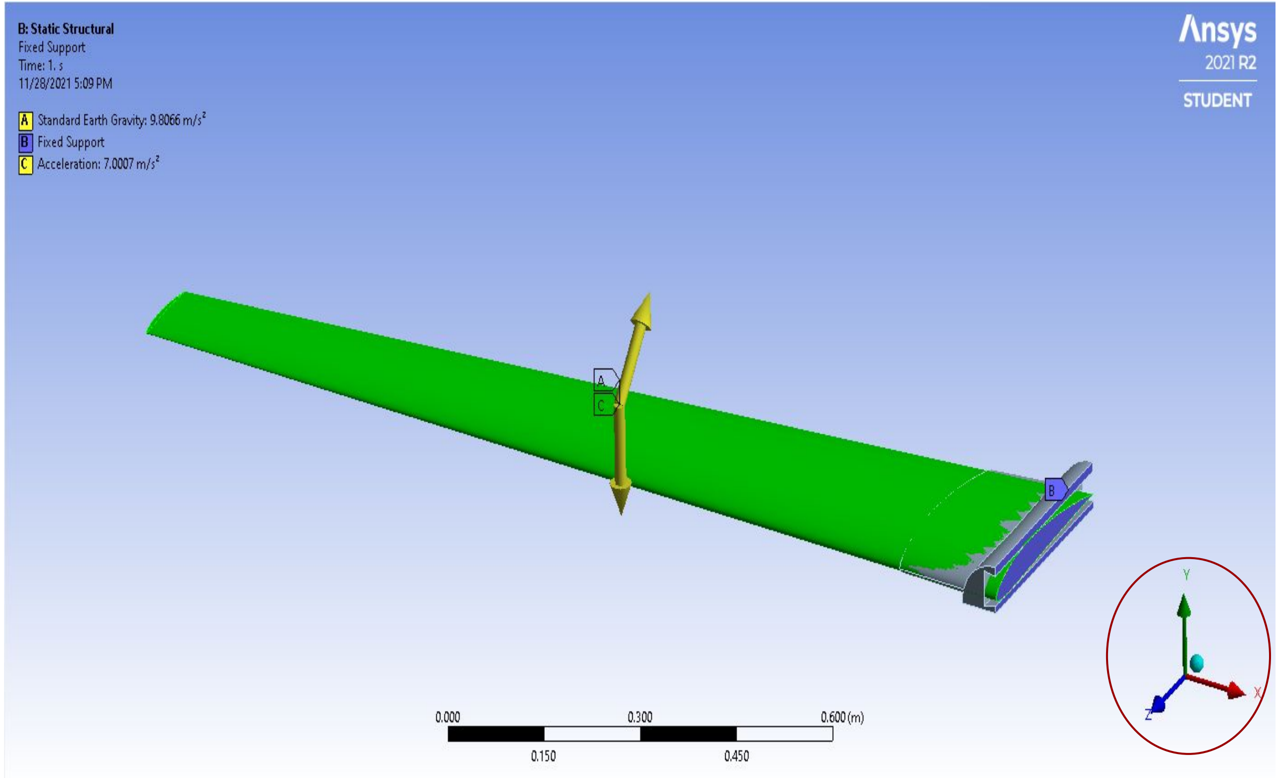


Structures - Backup

Verification and Validation - Structures - Landing

ANSYS Wing Setup - Landing

- Fixed support at wing harness
- Acceleration determined to be:
  - 5.00 m/s² (+y)
  - 4.90 m/s² (-z)
- Standard Earth gravity
- Large deflections ON - account for nonlinear behavior
  - Stiffness changes as material deforms
- Simulation run until 1% solution convergence

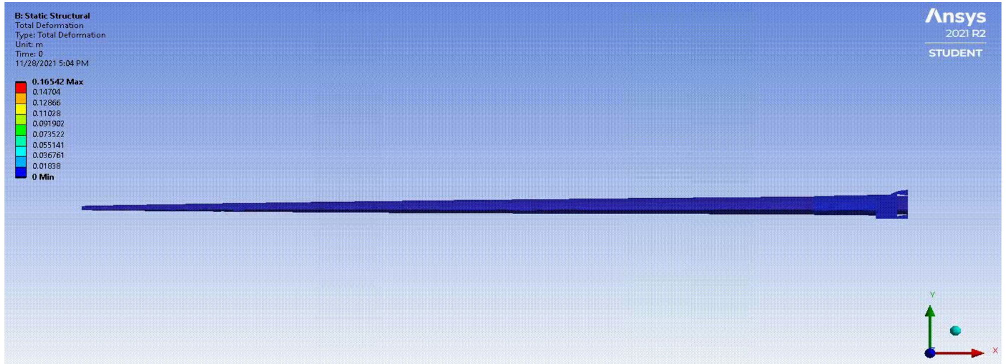


Limitations

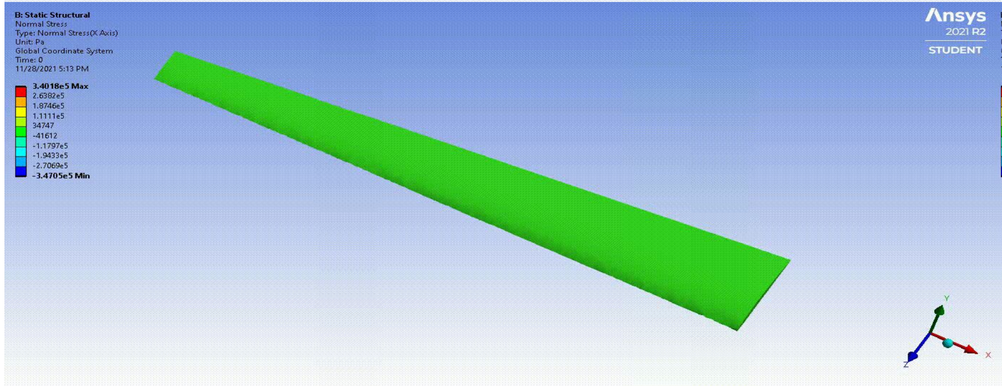
- Assumed entirely solid wing
- Unable to test inclusion of carbon fiber supports
  - Meshing limitations with complex geometry
- Used typical XPS foam values
  - ρ = 48 kg/m³
  - E = 80.12 MPa
- 3D Print properties difficult to estimate - Wing harness set as ABS plastic

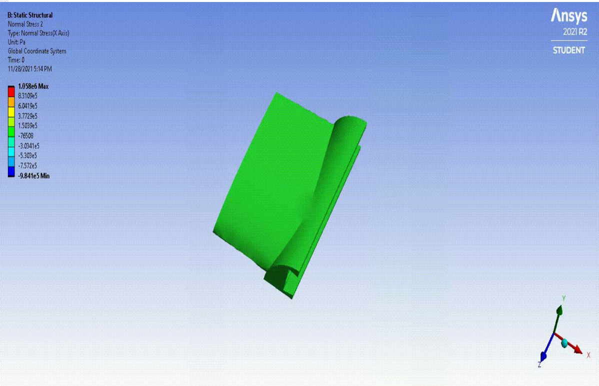
Verification and Validation - Structures - Landing

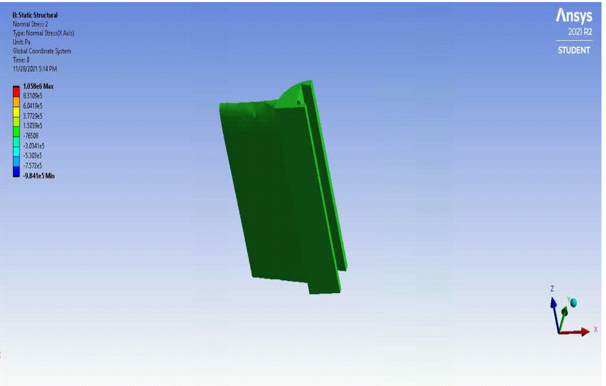
Wing Launch - Total Deformation [Top] / Wing Bending Stress [Bottom] / Harness Bending Stress [Bottom-Right]



Wing Landing Simulation	Wing Results	XPS Wing Allowed	ABS Harness Results	Harness Allowed
Max. Tensile Bending Stress	340 kPa	234 kPa	1.058 MPa	14.85 MPa
Max. Compressive Bending Stress	347 kPa	234 kPa	0.984 MPa	14.85 MPa
Total Tip Deflection	0.165 m 6.5 in	0.08 - 0.2 m 3.0 - 7.8 in	N/A	N/A



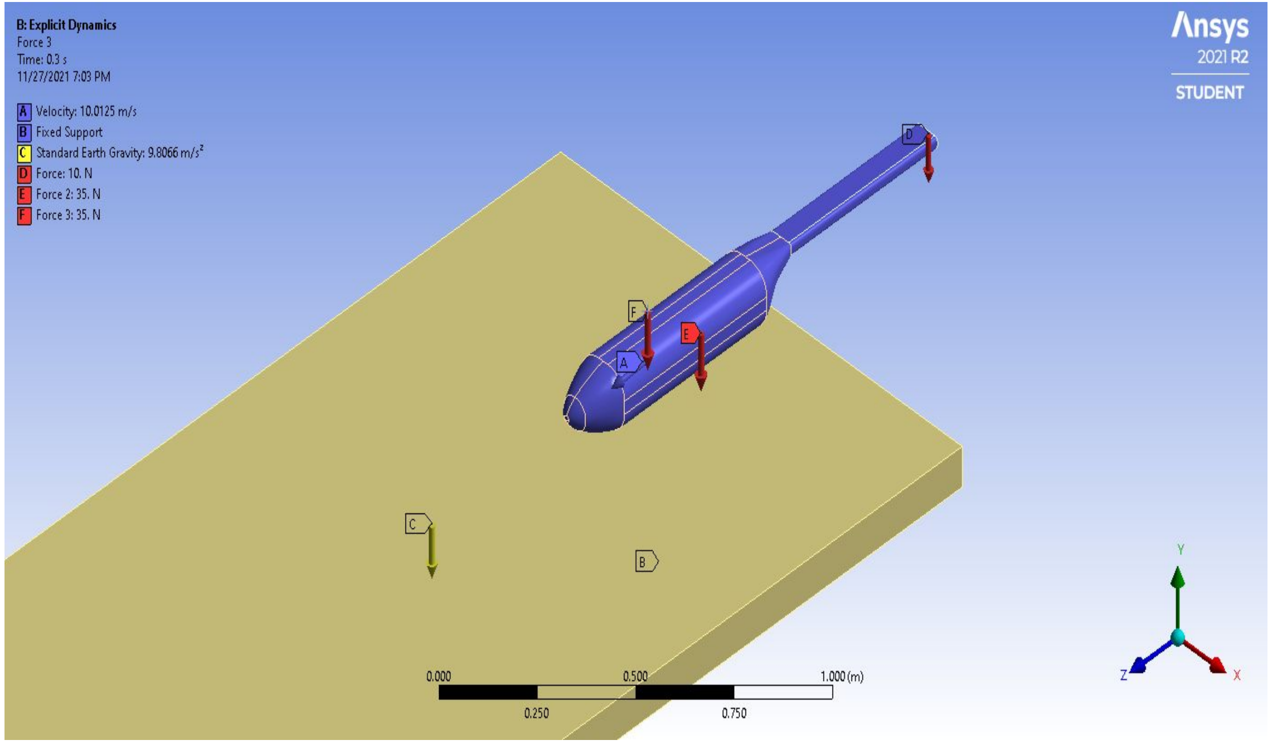




Verification and Validation - Structures - Landing

ANSYS Fuselage Setup - Landing

- Fixed support on furthest side of simulated soil from fuselage
- Velocity of fuselage set to:
  - 0.5 m/s (-y in ANSYS coordinates)
  - 10.0 m/s (+z in ANSYS coordinates)
- Standard Earth gravity over entire system
- Large deflections on to account for potential nonlinear behavior
- Used typical values of soft clay for soil composition
  - $\rho = 1.3\ g/cm^3$
  - E = 3 MPa
  - Coefficient of static/dynamic friction: 0.3/0.2

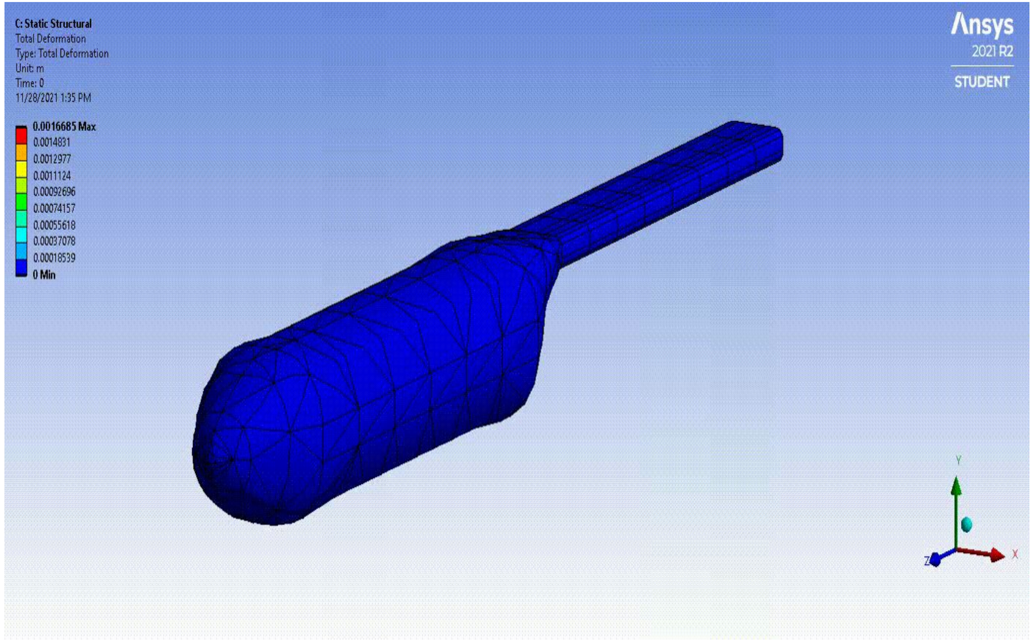


Limitations

- Assumed primary fuselage thickness of 0.5 in.
- Assumed solid ABS plastic for tail connection
  - Meshing limitations with complex geometry
- Main fuselage was assumed to be high density polyethylene plastic with similar properties to 3D printing materials
- External forces applied for weight of wings and tail

Verification and Validation - Structures - Landing

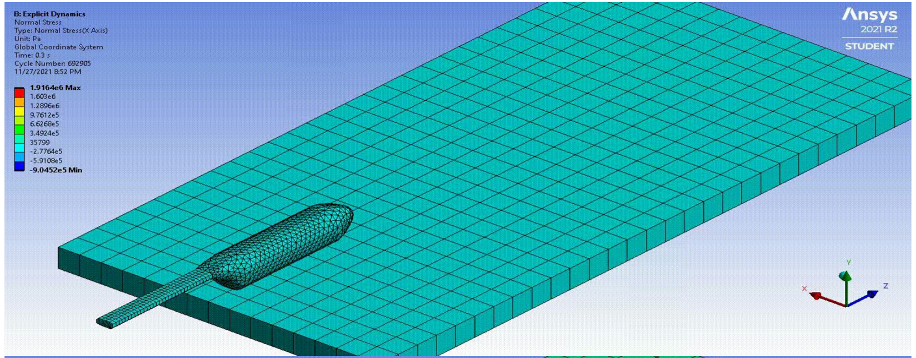
Fuselage Landing - Fuselage deformation on impact

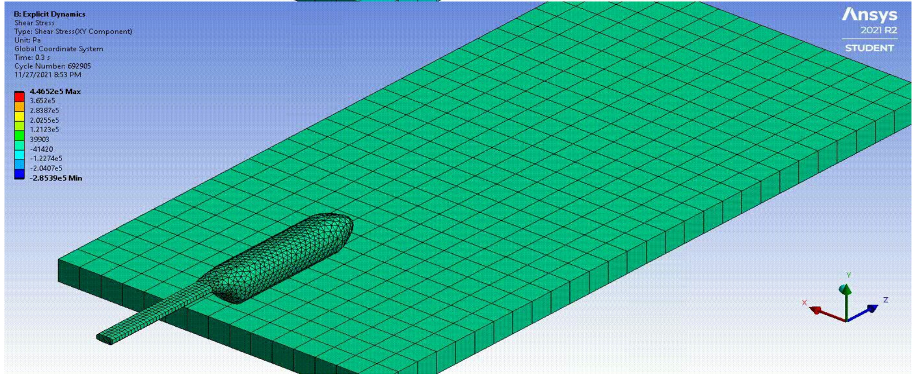


Fuselage Landing Simulation	Results
Max. Tail Connector Deflection	0.6 in

Verification and Validation - Structures - Landing

Fuselage Landing - Normal Stress [Top] / Shear Stress [Bottom]





Wing Launch Simulation	Results
Max. Shear Stress [MPa]	0.447
Max. Normal Stress [MPa]	1.916
Max. Shear Strain [m/m]	0.000749
Max. Normal Strain [m/m]	0.000343

Verification and Validation - Structures

Structures - Wing Tensile Testing

Objective	Confirm that XPS foam reinforced with carbon fiber rods satisfies our aircraft structural requirements
Description	Perform tensile testing on a sample of XPS with carbon fiber rods and strips inserted
Model Comparison	Confirm that tensile testing results are consistent with previously found flexure testing results.
Expectation	Yield Strength greater than 298 kPa with an acceptable factor of safety of 1.5
Validation Against FRs	Wing able to support the takeoff loads imparted by level 3 success of **FR3**

Structures Backup Slide

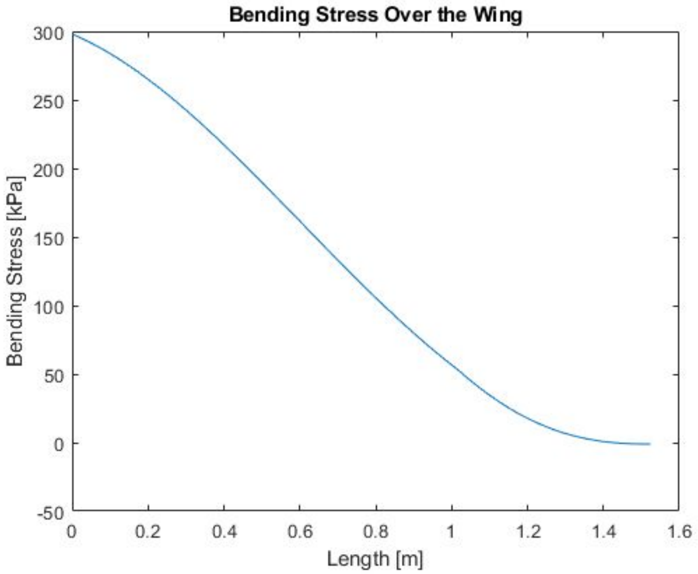
Rectangular Wing Lift Distribution: $W(x) = w_0(1 - \frac{x^2}{L^2})$

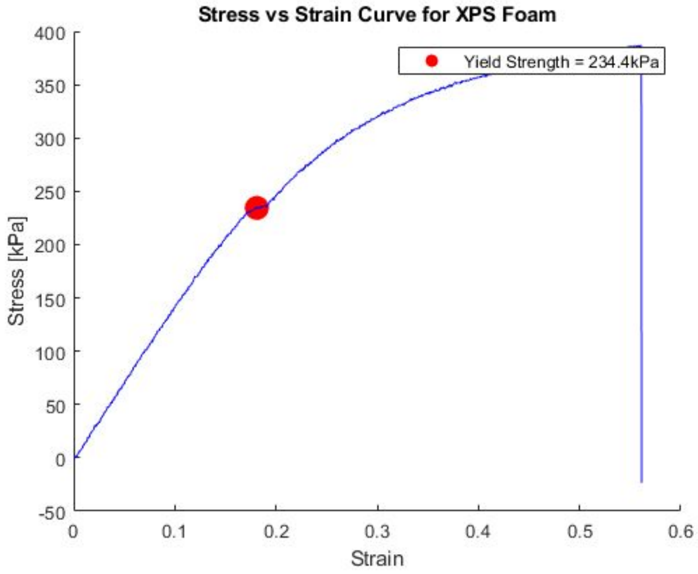
Bending Stress: $\sigma_{bend} = \frac{M * (t/2)}{I}$

Bending Stress Along Wing: $\sigma_{bend}(x) = \frac{M(x)\frac{t(x)}{2}}{I}$

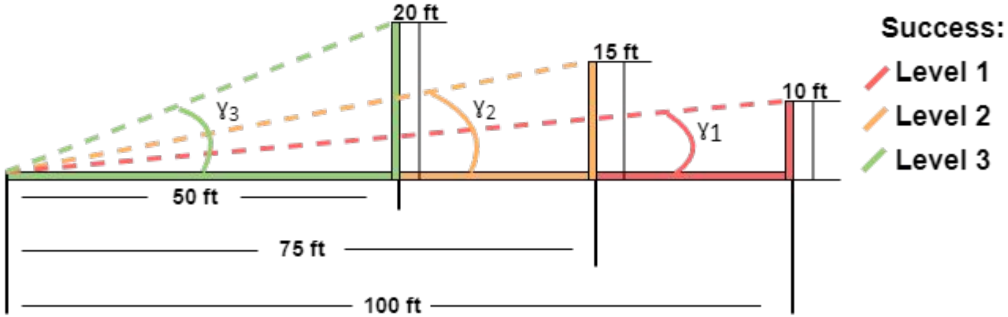
Moment of Inertia of Wing: $I = \frac{L(\frac{t_{root}+t_{tip}}{2})^3}{12}$

Bending Stiffness: $K = \frac{AppliedForce}{Displacement}$





Structures Backup Slide



V_climbout = 16.4m/s

Time to 50 feet = 3.05s

Upwards acceleration to 20ft: 1.31m/s^2

L = m(g + a_z) = 6.4kg(9.81m/s^2 + 1.31m/s) = 75.6N = 37.8N/wing

Payload - Backup

Testing Payload: Scope

Rationale For Testing:

- Establish node system for 3 LilyGo LoRa radios
    - Verify long range radios work and interface properly before flight testing

Equipment & Facilities:

- 3 LoRa LilyGo Radios
- Any outdoor space

Overview:

- Assemble LilyGo radios
- Solder LCD screens
- Establish mesh network
- Confirm Range & Fuselage Transmissivity

Testing & Risk Reduction Payload: LilyGo Radios

Measuring LoRa Radio Characteristics:

- Determine approximate communications range of the LoRa radios
- Determine transmissivity of LoRa radio through TALON payload bay

Risk Reduction Through LoRa Radio Testing:

- Testing verifies the payloads capabilities before flight operations
    - Proves a mesh communications network can be established with multiple TALONS before implementation
- Determination of radio node spacing through range tests provides a baseline requirement for the amount of TALON aircraft required to provide sufficient communications coverage

Verification and Validation - Operator Launch - Backup

Goals:

- Simulate an operator overhead TALON launch

Test Parameters:

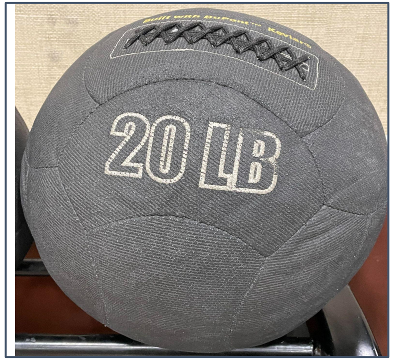
- Controlled Repeatable Launch
  - 1 Step overhead throw
  - Minimal launch angle
- 20lb Med ball
  - 1.33X TALON weight

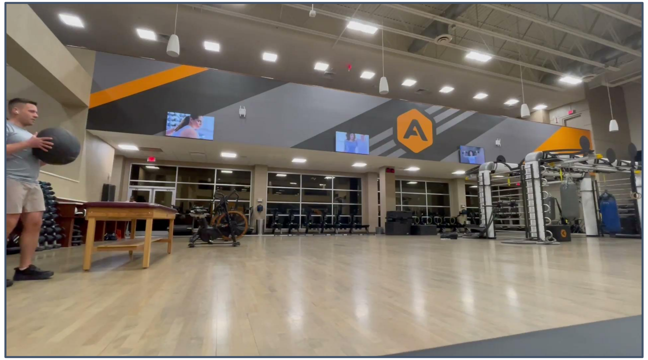
Testing:

- Non fatigued Launch
  - Launch under normal heart rate
- Launch under operational stress
  - Upper body workout + 1 mile run
  - No rest

Results:

- Controlled launch velocity of 6.1 m/s (20 ft/s)
  - 39% of the required 15.7 m/s TALON launch velocity





Risk Matrix Criteria - Scoring - Backup

Appendix Slide

Risk Scoring Matrix

Likelihood	Minimal	Minor	Major	Serious	Catastrophic
Near Certain	5	10	15	20	25
Highly Likely	4	8	12	16	20
Likely	3	6	9	12	15
Low Likelihood	2	4	6	8	10
Improbable	1	2	3	4	5

Consequence

TALON - Risk Matrix Unmitigated

Talon Specific Risk Matrix

Likelihood	Minimal	Minor	Major	Serious	Catastrophic
Near Certain			Over Estimated CL/CD		
Highly Likely				Crash During Full Scale Test	
Likely			Wing Structural Integrity		Harness/Structures Failure
Low Likelihood			Component/ Battery Overheating		Battery Malfunction
Improbable					

Consequence

Dominant Risks:

Crash During Full Scale Test
- Damage due to hard landing

Harness/Structures Failure
- Total Loss of aircraft

Wing Structural Integrity
- Wing durability
- Excessive deflection

Battery
- Total Loss of aircraft due to electronics fire
- Inaccurate charging

CL/CD
- Lift loss due to tip stall
- Basic models do not quantify total drag rise

TALON - Risk Matrix Revised

Talon Specific Risk Matrix

Liklihood	Minimal	Minor	Major	Serious	Catastrophic
Near Certain					
Highly Likely					
Likely		Over Estimated CL/CD	Crash During Full Scale Test		
Low Likelihood			Wing Sstructural Integrity	Harness/Structures Failure	
Improbable		Component/Battery Overheating		Battery Malfunction	

Consequence

Reducing Risk:

Crash During Full Scale Test
- Individual component test/verification
- Margin implemented across all subsystems
- Ground based workup/pre-flight checklist
- Margin to build multiple aircraft

Harness/Structures Failure
- Load simulations performed in ANSYS
- Conduct fatigue and failure testing
- Incorporation of safety factor

Wing Structural Integrity
- Load simulations performed in ANSYS
- Integrated composite reinforcements
- Fatigue and failure testing

Battery
- Collaborate with IRISS on building and servicing custom batteries
- Use of battery management system (BMS)

CL/CD
- Excess thrust & design reduces tip stall

Manufacturing - Timetable

Source	Items	Shipping Lead-times	Shipping Location
Mohr Composites	Foam Wings	1 week	USA
Plastic Anvil Workshop	3D printed materials	6 days	N/A
Mcmaster Carr	Carbon fiber, Misc. hardware	2 days	USA
Hobbytown	Electronics	N/A	N/A
Amazon	Resin for 3D printing	1 day	USA
Fleer Auto Reconditioning	Painting and Monokote	2 days	N/A
Horizon Hobby	Electronics	3 days	USA

Manufacturing - Task List

Task	Time Required	Reliance on prior task completion
Materials Testing	1 day	No
Wind Tunnel Testing	1 day	No
Wing assembly	**11 days**	**Yes**
Wing Testing	**5 days**	**Yes**
Electronics Harness assembly	3 days	No
Electronics Stress Test	**2 days**	**Yes**
Full Vehicle Assembly	**14 days**	**Yes**
Full Vehicle Test	**3 days**	**Yes**

Sources

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