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 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.
### Project Overview - Functional Requirements & Levels of Success

<table>
<thead>
<tr>
<th>Category</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR 1</td>
<td>The UAS shall provide a continuous overwatch window of 12 hours through the use of one or more UAVs.</td>
<td>UAV maintains <strong>1 hour</strong> of continuous overwatch.</td>
<td>UAV maintains <strong>3 hours</strong> of continuous overwatch.</td>
</tr>
<tr>
<td>FR 2</td>
<td>UAS shall be transported, launched, recovered, and operated by a single person to satisfy Requirement 1 under a 10 minute launch window per UAV.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FR 3</td>
<td>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.</td>
<td>UAS shall be able to takeoff in an open clearing with a <strong>100 ft.</strong> radius and clear a <strong>10 ft.</strong> obstacle at the end of launch radius.</td>
<td>UAS shall be able to takeoff in an open clearing with a <strong>75 ft.</strong> radius and clear a <strong>15 ft.</strong> obstacle at the end of launch radius.</td>
</tr>
<tr>
<td>FR 4</td>
<td>UAS shall provide a payload bay to house a sensor suite.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Overview and Updates

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

Testing:
- Power and Propulsion
- Full-System
- Budget

Overview and Updates
- Schedule
- Electronics
- Structures
<table>
<thead>
<tr>
<th>CPE</th>
<th>Description</th>
<th>Functional Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerodynamics</td>
<td>Maximizing lift-to-drag decreases power required enhancing endurance.</td>
<td>FR1</td>
</tr>
<tr>
<td>Electronics and Batteries</td>
<td>Inefficient electronics waste energy which could be used for propulsion. Custom batteries allow for compact packaging and efficient discharge.</td>
<td>FR1</td>
</tr>
<tr>
<td>Propulsion System</td>
<td>Propulsion must provide adequate power to climb, without being oversized for cruise.</td>
<td>FR1 &amp; FR3</td>
</tr>
<tr>
<td>Structures</td>
<td>Aircraft structures must survive turbulence and landing while minimizing mass and maintaining portability.</td>
<td>FR2, FR3 &amp; FR4</td>
</tr>
</tbody>
</table>
Design Solution - Functional Block Diagram

KEY:

Physical connections

Data Connections

Data Connections via wireless method

Power supply connections (illustrate subsystem complexity and importance)

Overview and Updates

Schedule

Testing: Electronics

Testing: Structures

Testing: Power and Propulsion

Testing: Full-System

Budget
Design Solution - Final Design Overview

TALON Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wingspan</td>
<td>3,120 mm</td>
</tr>
<tr>
<td>AR</td>
<td>14.25</td>
</tr>
<tr>
<td>Airfoil</td>
<td>NACA4412 - NACA4406</td>
</tr>
<tr>
<td>Mass</td>
<td>7.4 kg (16.25 lbs)</td>
</tr>
</tbody>
</table>

TALON Overview and Updates

- Testing: Power and Propulsion
- Testing: Structures
- Testing: Electronics
- Testing: Full-System
- Budget
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.
**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.
**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

1.44in thick
6in
40in
20in
4.8in
0.288in thick

12in
4in
36in
2in
0.866in thick

Overview and Updates
Schedule
Testing: Electronics
Testing: Structures
Testing: Power and Propulsion
Testing: Full-System
Budget
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

Testing:
- Power and Propulsion
- Overview and Updates
- Schedule
- Testing: Electronics
- Testing: Structures
- Testing: Power and Propulsion
- Testing: Full-System
- Budget
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
## Current Primary Sub System Test Plan

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

Grade Mode

VC4S displays “REAL CAPACITY” of the battery after "Charge→Discharge→Fully Charge".
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

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

<table>
<thead>
<tr>
<th>Validation of Functional Requirements Through Battery Testing:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FR1</strong></td>
</tr>
<tr>
<td><strong>DR 1.2.1</strong></td>
</tr>
<tr>
<td><strong>FR8</strong></td>
</tr>
<tr>
<td><strong>DR 8.1.1</strong></td>
</tr>
<tr>
<td><strong>DR 8.2</strong></td>
</tr>
</tbody>
</table>

### Verification of Functional Requirements

| **FR1 & FR8** | FR1 - Verified by Full System Testing  
FR8 - Verified after manufacturing and before Full Scale Testing |

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**Overview and Updates** | **Schedule** | **Testing: Electronics** | **Testing: Structures** | **Testing: Power and Propulsion** | **Testing: Full-System** | **Budget**
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
Testing Structures - Whiffletree Test

Procedure:
1. Insert wing into 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. Measure wing deflection at a load of 37.8N
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
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
Testing Structures - Cycling Test

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: Power and Propulsion
Testing: Full-System
Testing: Electronics
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
## Validation of Functional Requirements Through Structures Testing:

<table>
<thead>
<tr>
<th>FR3</th>
<th>The UAV shall have short takeoff capabilities as specified by the customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>DR 3.3.1</td>
<td>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</td>
</tr>
<tr>
<td>DR 3.3.2</td>
<td>The UAV shall be capable of withstanding 10 impacts to the belly while 'fully loaded' from 1.5 ft. without a structural failure</td>
</tr>
<tr>
<td>FR7</td>
<td>UAS shall maintain a minimum of 80% operational capabilities in customer specified environmental conditions</td>
</tr>
<tr>
<td>DR 7.3</td>
<td>The UAV shall withstand 100 rapid and successive 30 feet-per-second sharp vertical wind gust cycles without failure</td>
</tr>
</tbody>
</table>

## Verification of Functional Requirements:

<table>
<thead>
<tr>
<th>FR3 &amp; FR7</th>
<th>FR3 - Verified through Full System Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FR7 - Verified by testing individual DR’s in adverse environments</td>
</tr>
</tbody>
</table>

### Schedule

- Overview and Updates
- Testing: Electronics
- Testing: Structures
- Testing: Power and Propulsion
- Testing: Full-System
- Budget
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
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

6S 22.2V

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

<table>
<thead>
<tr>
<th>E-flight 470kv</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected</td>
<td>Required</td>
</tr>
<tr>
<td><strong>Max Thrust</strong></td>
<td>Greater than 14.0 lbs</td>
<td>8.1 lbs</td>
</tr>
<tr>
<td><strong>Peak Amps</strong></td>
<td>Less than 67.0A</td>
<td>Less than 70A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spektrum 480kv</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected</td>
<td>Required</td>
</tr>
<tr>
<td><strong>Max Thrust</strong></td>
<td>Greater than 10.0 lbs</td>
<td>8.1 lbs</td>
</tr>
<tr>
<td><strong>Peak Amps</strong></td>
<td>Unknown</td>
<td>Less than 70A</td>
</tr>
</tbody>
</table>
## Validation of Functional Requirements through Propulsion Testing

<table>
<thead>
<tr>
<th>FR1</th>
<th>The UAS shall provide a continuous overwatch window of 12 hours through the use of one or more UAVs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DR 1.1.1</td>
<td>The UAV's power supply shall be capable of providing at least 120% of the maximum expected amperage draw of the UAV</td>
</tr>
<tr>
<td>DR 1.2.1</td>
<td>The UAV’s power supply shall provide 70 amps of continuous discharge</td>
</tr>
<tr>
<td>DR 1.3.1</td>
<td>The UAV’s motor and propeller combination shall provide no less than 53 Newtons of thrust at full throttle</td>
</tr>
<tr>
<td>FR3</td>
<td>The UAV shall have short takeoff capabilities as specified by the customer</td>
</tr>
</tbody>
</table>

## Verification of Functional Requirements

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:** \( \leq 10 \) minutes
- **TALON Endurance:** \( \geq 3 \) hours
- **TALON climb out:**
  - Takeoff radius \( \leq 75 \) ft.
  - Climbout \( \geq 15 \) 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:

<table>
<thead>
<tr>
<th>FR1: The UAS shall provide a continuous overwatch window of 12 hours through the use of one or more UAVs.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 1</strong></td>
</tr>
<tr>
<td>1 hour of overwatch.</td>
</tr>
</tbody>
</table>

| 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. |
|--------------------------------------------------|
| **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. |

<table>
<thead>
<tr>
<th>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.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 1</strong></td>
</tr>
<tr>
<td>Altitude of 10 ft. within 100 ft.</td>
</tr>
</tbody>
</table>

| 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

<table>
<thead>
<tr>
<th>TALON Budget Summary</th>
<th>Sub System</th>
<th>Actual</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Remaining Budget after 1 TALON Replacement</td>
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## Cost Plan - Itemized Budget

### Overview and Updates

<table>
<thead>
<tr>
<th>Item</th>
<th>Vendor</th>
<th>Price</th>
<th>Price Margin</th>
<th>Quantity</th>
<th>Shipping</th>
<th>Shipping Margin</th>
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<tbody>
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</table>

### Schedule

- **Testing: Power and Propulsion**
- **Testing: Full-System**
Questions?
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

<table>
<thead>
<tr>
<th>Structures - Wing Whiffletree Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective</strong></td>
</tr>
<tr>
<td><strong>Description</strong></td>
</tr>
<tr>
<td><strong>Model Comparison</strong></td>
</tr>
<tr>
<td><strong>Key Results</strong></td>
</tr>
<tr>
<td><strong>Validation Against FRs</strong></td>
</tr>
</tbody>
</table>
Design Requirement - Endurance through Aerodynamics

Endurance of Propeller Driven Aircraft

\[ E = \frac{\eta c^{3/2}}{c} \left( \frac{W_1^{-1/2}}{W_0^{-1/2}} \right) \left( \frac{1}{2} \rho \infty s \right)^{1/2} \]

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) 

\( E = f(C_L, C_D^{-1}) \)
Design Requirement - Endurance through Aerodynamics

Wing Tip Stall:
**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

<table>
<thead>
<tr>
<th>Objective</th>
<th>Qualitatively Understand Wing Tip Stall</th>
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<tr>
<td><strong>Description</strong></td>
<td>Extend 2D techniques to 3D, and create high fidelity simulation of wing tips including fine boundary layer resolution.</td>
</tr>
<tr>
<td><strong>Model Comparison</strong></td>
<td>Compare to literature on low $Re$ airfoils.</td>
</tr>
<tr>
<td><strong>Expectation</strong></td>
<td>Understand whether aerodynamic twist effectively mitigates separation and increases efficiency.</td>
</tr>
<tr>
<td><strong>Validation Against FRs</strong></td>
<td>Successfully mitigate wing tip stall increasing efficiency FR1 &amp; increasing maximum lift FR3</td>
</tr>
</tbody>
</table>

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**
Aero - Computational Fluid Dynamics

CL Vs. AOA (2% error bar)

CL Vs. CD (40% error bar)
Aerodynamics - Backup Prior Reynolds Number Analysis
Stanford Model:
- Wetted Area and Flat Plate Skin Friction

\[
C_f = \frac{1.328}{\sqrt{Re_L}} \text{ laminar}
\]

\[
C_f = \frac{0.074}{Re_L^{0.2}} \text{ turbulent}
\]
● CFD: Sensitivity analysis
Aerodynamics Values - Backup

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<th>Max: 11.5° / 22 m/s</th>
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<td>$C_L$ (Max)</td>
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<td>$C_D$ (Cruise)</td>
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<td>Drag (Cruise)</td>
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<td>Drag (Max)</td>
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Objectives: CFD model verification

- Total Elements = 45,000
Objectives: CFD model verification

- Standard sea level atmospheric conditions applied
Objectives: CFD model verification
Objectives: CFD model verification
Objectives: CFD model verification

- Mesh refinement can be seen
- Total number of cells now 45,735
Objectives: CFD model verification

- Resulting Y+ and Coefficient of Pressure distribution
Aero - Wind Tunnel

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

<table>
<thead>
<tr>
<th>Objective</th>
<th>Verify Aerodynamic Characteristics of Wing and Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Quantify Lift and Drag</td>
</tr>
<tr>
<td>Model Comparison</td>
<td>Potential Flow Estimates of Lift and Drag</td>
</tr>
<tr>
<td>Expectation</td>
<td>Increase in Predicted Drag</td>
</tr>
<tr>
<td>Validation Against FRs</td>
<td>Aerodynamic surfaces optimize lift and minimize drag to meet FR1 &amp; FR3</td>
</tr>
</tbody>
</table>
Propulsion - Backup
Propulsion - Backup

Motor Selection

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

<table>
<thead>
<tr>
<th>Target Climbout Power</th>
<th>950-1050 W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Climbout Thrust</td>
<td>8.2-8.8 lbf</td>
</tr>
</tbody>
</table>
Endurance Maximizing Velocity (Minimum \( P_{\text{req}} \)) [1]

\[
C_D = \frac{1}{3} k C_L^2 \quad v_{\text{end}} = \sqrt{\frac{2W}{\rho S \left( \frac{k}{3C_D} \right)}} \quad \text{where} \quad k = \frac{1}{\pi \cdot e \cdot AR}
\]

Coefficient of Lift (Lift = Weight) [2]

\[
C_L = \frac{W}{\frac{1}{2} \rho \cdot v_{\text{end}}^2 \cdot S}
\]

Thrust (Thrust = Drag) [1]

\[
T = D = q \cdot S \cdot \left( C_D + (k \cdot C_L^2) \right) \quad \text{where} \quad q = \frac{1}{2} \cdot \rho \cdot v_{\text{end}}^2
\]

Power [2]

\[
P_R = T V_{\text{end}} = q_\infty S C_D v_{\text{end}} + q_\infty S V_{\text{end}} \frac{C_L^2}{\pi e AR} \quad P_{\text{req}} = \frac{P_A}{\eta_{\text{prop}}}
\]

Endurance Flight satisfies FR1 

<table>
<thead>
<tr>
<th>Results</th>
<th>IMP</th>
<th>SI</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_{\text{req}} ) Endurance</td>
<td>.901 lbf</td>
<td>4.00 N</td>
</tr>
<tr>
<td>( P_{\text{req}} ) Endurance</td>
<td>.109 hp</td>
<td>81.6 W</td>
</tr>
<tr>
<td>( V_{\text{req}} ) Endurance</td>
<td>27.3 mph</td>
<td>12.2 m/s</td>
</tr>
<tr>
<td>( C_{L_{\text{req}}} ) Endurance</td>
<td>1.42</td>
<td>1.42</td>
</tr>
<tr>
<td>( T_{\text{req}} ) Climbout</td>
<td>8.20 lbf</td>
<td>36.5 N</td>
</tr>
<tr>
<td>( P_{\text{req}} ) Climbout</td>
<td>1.28 hp</td>
<td>957 W</td>
</tr>
<tr>
<td>( C_{L_{\text{req}}} ) Climbout</td>
<td>.975</td>
<td>.975</td>
</tr>
<tr>
<td>( V_{\text{req}} ) Climbout</td>
<td>35.1 mph</td>
<td>15.7 m/s</td>
</tr>
<tr>
<td>( T_{\text{req}} ) Headwind</td>
<td>0.78 lbf</td>
<td>3.47 N</td>
</tr>
<tr>
<td>( P_{\text{req}} ) Headwind</td>
<td>0.121 hp</td>
<td>90.4 W</td>
</tr>
<tr>
<td>( C_{L_{\text{req}}} ) Headwind</td>
<td>.871</td>
<td>.871</td>
</tr>
<tr>
<td>( V_{\text{req}} ) Headwind</td>
<td>35 mph</td>
<td>15.6 m/s</td>
</tr>
</tbody>
</table>
Design Requirement - Propulsion System Optimization

Levels of Success for Climbout: (measured from ground)

Success:
- Level 1: \( \gamma_1 = 5.71^\circ \)
- Level 2: \( \gamma_2 = 11.3^\circ \)
- Level 3: \( \gamma_3 = 21.8^\circ ** \)

**outside Small Angle Approx

Rate of Climb (RoC):

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

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

\[
L = \frac{1}{2} \rho V^2 SC_L = W \cos \theta \rightarrow V = \sqrt{\frac{W \cos \theta \rho SC_L}{2}} \text{ where } \theta = \gamma + \alpha
\]

\[
T_{\text{climbout}} = D + W \sin \theta = \frac{1}{2} \rho V^2 SC_D + W \sin \theta \text{ where } C_D = C_{\text{D0}} + kC_L^2
\]

\[
P_{\text{req}} = \frac{T_{\text{climbout}} V_{\text{climbout}}}{\eta_{\text{prop}}}
\]

<table>
<thead>
<tr>
<th>Results</th>
<th>IMP</th>
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<td>1.42</td>
</tr>
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</tr>
<tr>
<td>( V_{\text{req}} ) Headwind</td>
<td>35 mph</td>
<td>15.6 m/s</td>
</tr>
</tbody>
</table>
Propulsion: Headwind

Requirement for Headwind: 30 mph Headwind

\[ C_L = \frac{W}{\frac{1}{2}\rho \cdot \text{vel}_{wind}^2 \cdot S} \]

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

\[ q = \frac{1}{2} \rho \cdot V_{wind}^2 \cdot S \]

\[ P_{req} = \frac{T_{wind} \cdot V_{wind}}{\eta_{prop}} \]

<table>
<thead>
<tr>
<th>Results</th>
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<th>SI</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.901 lbf</td>
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</tr>
<tr>
<td>( C_L_{req} ) Endurance</td>
<td>1.42</td>
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<td>( V_{req} ) Headwind</td>
<td>35 mph</td>
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</tr>
</tbody>
</table>
**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
Scorpion SII 520KV with 15x8E APC Propeller

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Motor Specification</th>
<th>Target Specification (climbout)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power [W]</td>
<td>925.9</td>
<td>950</td>
</tr>
<tr>
<td>Thrust [grams]</td>
<td>3970</td>
<td>3950</td>
</tr>
<tr>
<td>Current [amps]</td>
<td>50</td>
<td>Lower is Better</td>
</tr>
<tr>
<td>Weight [grams]</td>
<td>353</td>
<td>Lower is Better</td>
</tr>
<tr>
<td>Cost [$]</td>
<td>150</td>
<td>Lower is Better</td>
</tr>
<tr>
<td>Compatible Battery</td>
<td>6s 3500-5000mah</td>
<td>Smaller is Better</td>
</tr>
</tbody>
</table>
Goal: Obtain quantitative data for thrust dependent on current draw and percent throttle as a means to validate motor specs and pick ideal propeller size.
Static Testing

520Kv Scorpion III w/ 17x7E

470Kv E-flite w/ 17x7E
Static Testing

520Kv Scorpion III w/ 18x8E with 14.5V 5000mAh Battery

520Kv Scorpion III w/ 15x8E with 14.5V 5000mAh Battery
Thrust Vs. Amps Metrics
Electronics - Backup
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 ($\rho_{SL} = 1.225 \text{ kg/m}^3$).
- Control surface with largest area will drive calculations:
  - $A_{Wing} = 2 \text{ in.} \times 48 \text{ in.}$ (modeled after Tempest Aircraft).
Appended Assumptions:

- Aircraft will experience Incompressible Flow
- Reynolds Number = $1 \times 10^5$
- Wing geometry of NACA 4412 airfoil
- Airfoil experiences total velocity of $V_{\text{total}} = 25.144 \text{ m/s}$
- Average chord length, $\bar{c} = 8 \text{ in} = 0.2032 \text{ m}$
  - Control surface is hinged at 75% of wing chord
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°C + 85°C
- **Cost Effective**: $40 per radio
Hinge Moment/Span:

- \[ M_{hinge} = -0.01455 \cdot \left( \frac{1}{2} \cdot \rho_{SL} \cdot V_{SL}^2 \cdot c^2 \right) \]
- -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
- \( V_{\text{cruise}} = 16.4 \text{ m/s} \)
- Max Gust Speed = 9.144 m/s

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

**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
- **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

Battery Size vs Endurance - Colormap

Battery Size vs Endurance - Colormapped Against Mass
CAD Model - Backup
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
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
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
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
**Objective:** Maintain controllability and establish inherent stability to reduce flightpath deviation and energy draw for correction.

![Horizontal Tail Design Space](image)
Objective: Maintain controllability and establish inherent stability to reduce flightpath deviation and energy draw for correction

<table>
<thead>
<tr>
<th></th>
<th>Volume coefficient</th>
<th>Surface Area [ft^2]</th>
<th>Span [ft]</th>
<th>Weight [lbs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Tail</td>
<td>0.40</td>
<td>0.85</td>
<td>1.69</td>
<td>0.35</td>
</tr>
<tr>
<td>Estimates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical Tail</td>
<td>0.02</td>
<td>0.36</td>
<td>0.73</td>
<td>0.15</td>
</tr>
<tr>
<td>Estimates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Objective: Maintain controllability and establish inherent stability to reduce flightpath deviation and energy draw for correction

- $C_m_{\alpha} = -1.9849$
- Neutral Point = 51.1% Chord
- $SM = 0.3377 \% \text{ chord} = 4.05 \text{ inches}$
Modular Design - Backup

Carbon Fiber Bar
Carbon Fiber Rod
Clevis Pin
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 ⅛ of one tube of epoxy into a mixing cup and mix
## Predicted Aerodynamic Characteristics - Potential Flow Theory

<table>
<thead>
<tr>
<th></th>
<th>Cruise: 4.8° AOA / 16.4 m/s</th>
<th>Max: 11.5° / 22 m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_L$ (Cruise)</td>
<td>0.7991</td>
<td>$C_L$ (Max)</td>
</tr>
<tr>
<td>$C_D$ (Cruise)</td>
<td>0.0319</td>
<td>$C_D$ (Max)</td>
</tr>
<tr>
<td>$C_L/C_D$ (Cruise)</td>
<td>25.06</td>
<td>$C_L/C_D$ (Max)</td>
</tr>
<tr>
<td>Lift (Cruise)</td>
<td>72.1 (N)</td>
<td>Lift (Max)</td>
</tr>
<tr>
<td>Drag (Cruise)</td>
<td>5.9 (N)</td>
<td>Drag (Max)</td>
</tr>
</tbody>
</table>

### Predicted Endurance through Aerodynamics

- **Albatross (Bird):**
  - 20:1

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

- **Rutan Voyager**
  - 27:1 (216 Hrs)
Structures - Backup
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
  - $\rho = 48 \text{ kg/m}^3$
  - $E = 80.12 \text{ MPa}$
- 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]

<table>
<thead>
<tr>
<th>Wing Landing Simulation</th>
<th>Wing Results</th>
<th>XPS Wing Allowed</th>
<th>ABS Harness Results</th>
<th>Harness Allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Tensile Bending Stress</td>
<td>340 kPa</td>
<td>234 kPa</td>
<td>1.058 MPa</td>
<td>14.85 MPa</td>
</tr>
<tr>
<td>Max. Compressive Bending Stress</td>
<td>347 kPa</td>
<td>234 kPa</td>
<td>0.984 MPa</td>
<td>14.85 MPa</td>
</tr>
<tr>
<td>Total Tip Deflection</td>
<td>0.165 m</td>
<td>0.08 - 0.2 m</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

- **Max. Tensile Bending Stress**
  - Simulation: 340 kPa
  - Results: 234 kPa
  - XPS Wing Allowed: 1.058 MPa
  - ABS Harness Results: 14.85 MPa
  - Harness Allowed: N/A

- **Max. Compressive Bending Stress**
  - Simulation: 347 kPa
  - Results: 234 kPa
  - XPS Wing Allowed: 0.984 MPa
  - ABS Harness Results: 14.85 MPa
  - Harness Allowed: N/A

- **Total Tip Deflection**
  - Simulation: 0.165 m
  - Results: 0.08 - 0.2 m
  - XPS Wing Allowed: N/A
  - ABS Harness Results: N/A
  - Harness Allowed: N/A

---

**Wing Launch Simulation**

- Total Deformation [Top]
- Wing Bending Stress [Bottom]
- Harness Bending Stress [Bottom-Right]
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
  - $\rho = 1.3 \text{ g/cm}^3$
  - $E = 3 \text{ MPa}$
  - 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

<table>
<thead>
<tr>
<th>Fuselage Landing Simulation</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Tail Connector Deflection</td>
<td>0.6 in</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th><strong>Objective</strong></th>
<th>Confirm that XPS foam reinforced with carbon fiber rods satisfies our aircraft structural requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Perform tensile testing on a sample of XPS with carbon fiber rods and strips inserted</td>
</tr>
<tr>
<td><strong>Model Comparison</strong></td>
<td>Confirm that tensile testing results are consistent with previously found flexure testing results.</td>
</tr>
<tr>
<td><strong>Expectation</strong></td>
<td>Yield Strength greater than 298 kPa with an acceptable factor of safety of 1.5</td>
</tr>
<tr>
<td><strong>Validation Against FRs</strong></td>
<td>Wing able to support the takeoff loads imparted by level 3 success of FR3</td>
</tr>
</tbody>
</table>
Rectangular Wing Lift Distribution: \( W(x) = w_0(1 - \frac{x^2}{L^2}) \)

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

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

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

Bending Stiffness: \( K = \frac{\text{Applied Force}}{\text{Displacement}} \)
V_{climbout} = 16.4\,\text{m/s}
Time to 50\,\text{feet} = 3.05\,\text{s}
Upwards acceleration to 20\,\text{ft}: 1.31\,\text{m/s}^2
L = m(g + a_z) = 6.4\,\text{kg}(9.81\,\text{m/s}^2 + 1.31\,\text{m/s}) = 75.6\,\text{N} = 37.8\,\text{N/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
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
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 Scoring Matrix

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Minimal</th>
<th>Minor</th>
<th>Major</th>
<th>Serious</th>
<th>Catastrophic</th>
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<tr>
<td>Near Certain</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
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<tr>
<td>Highly Likely</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>20</td>
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<tr>
<td>Likely</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
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<tr>
<td>Low Likelihood</td>
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<tr>
<td>Improbable</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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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

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

Overview and Updates
Schedule
Testing: Electronics
Testing: Structures
Testing: Power and Propulsion
Testing: Full-System
Risk Management
Budget
<table>
<thead>
<tr>
<th>Source</th>
<th>Items</th>
<th>Shipping Lead-times</th>
<th>Shipping Location</th>
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<tr>
<td>Mohr Composites</td>
<td>Foam Wings</td>
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<td>Plastic Anvil Workshop</td>
<td>3D printed materials</td>
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<td>Carbon fiber, Misc. hardware</td>
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<td>Hobbytown</td>
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<td>Resin for 3D printing</td>
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<tr>
<td>Fleer Auto Reconditioning</td>
<td>Painting and Monokote</td>
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<td>Horizon Hobby</td>
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<tr>
<td>Task</td>
<td>Time Required</td>
<td>Reliance on prior task completion</td>
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