Project Tiger Launch

2016-2017
Vehicle Dimensions

- Total Length of 93 inches
- Inner Diameter of 6 inches
- Outer Diameter of 6.25 Inches
- Estimated Mass of 28 lbs
Material Selection

- **Fiberglass**
  - Allows Electronics to communicate to outside sources

- **Carbon Fiber**
  - High strength to weight ratio
  - Rated highest in team trade study
Clipped-Delta Fins

- Easy to manufacture
- Proven design
- Performs well in subsonic flight
Ogive Nose Cone

- Low Coefficient of Drag
- Easy to manufacture
- Rated highest by team trade study
- Commonly used in professional and hobby rocketry
NOTE: Gridfins (4x), Fairings (4x), and Fins (4x) are centered at 0°, 90°, 180° and 270°.

NOTE: Gridfins and fairings (3x) not shown for clarity.
Stability Margin

- Static Stability Margin of 2.07 Calibers
- CG located 56.16 inches from nose cone
- CP located 71.37 inches from nose cone
Stability Graphs
Motor Selection and Performance Predictions

- Initial motor selection is a Loki-L930
- Vendor availability
- Thrust-to-weight ratio is 7.2:1
- Provides a rail exit velocity of 58.7 ft/s
Simulated Altitudes

- 5 MPH Wind Speeds: 5298 ft.
- 10 MPH Wind Speeds: 5223 ft.
- 15 MPH Wind Speeds: 5155 ft.
- 20 MPH Wind Speeds: 5039 ft.
Loki-L930 Thrust Curve
# Loki-L930 Motor Specifications

<table>
<thead>
<tr>
<th>Motor Specifications</th>
<th></th>
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<tbody>
<tr>
<td>Manufacturer</td>
<td>Loki</td>
</tr>
<tr>
<td>Motor Designation</td>
<td>Loki-L930</td>
</tr>
<tr>
<td>Diameter</td>
<td>2.99 in</td>
</tr>
<tr>
<td>Length</td>
<td>19.6 in</td>
</tr>
<tr>
<td>Impulse</td>
<td>794.7 lb·sec</td>
</tr>
<tr>
<td>Total Motor Weight</td>
<td>7.81 lb</td>
</tr>
<tr>
<td>Propellant Weight</td>
<td>4 lb</td>
</tr>
<tr>
<td>Average Thrust</td>
<td>201.20 lbf</td>
</tr>
<tr>
<td>Maximum Thrust</td>
<td>252.46 lbf</td>
</tr>
<tr>
<td>Burn Time</td>
<td>3.95 sec</td>
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## Mass Statement

<table>
<thead>
<tr>
<th>Section</th>
<th>Mass (lbs)</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Structure</td>
<td>13</td>
<td>46.43%</td>
</tr>
<tr>
<td>Recovery</td>
<td>4</td>
<td>14.29%</td>
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<tr>
<td>Grid Fins</td>
<td>2</td>
<td>7.14%</td>
</tr>
<tr>
<td>Electronics</td>
<td>1.5</td>
<td>4.25%</td>
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<tr>
<td>Motor</td>
<td>7.81</td>
<td>27.89%</td>
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<tr>
<td>Total</td>
<td>28.31</td>
<td>100%</td>
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Testing Plans

- Full-Scale Flights
- Materials Testing
- Wind Tunnel Testing
Materials Testing

- Three-point bend test
- Compression test
Full Scale Test Flight 1

- Recovery Failure
- Static Grid Fins

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Serial</td>
<td>2251</td>
<td></td>
</tr>
<tr>
<td>Flight</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Date/Time</td>
<td>2017-02-19</td>
<td>18:21:34 UTC</td>
</tr>
<tr>
<td>Maximum height</td>
<td>1396 m</td>
<td>4580 ft</td>
</tr>
<tr>
<td>Maximum GPS height</td>
<td>1427 m</td>
<td>4682 ft</td>
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<tr>
<td>Maximum speed</td>
<td>193 m/s</td>
<td>633 fps</td>
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<tr>
<td></td>
<td></td>
<td>Mach 0.6</td>
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<tr>
<td>Maximum boost acceleration</td>
<td>85 m/s²</td>
<td>279 ft/s²</td>
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<tr>
<td>Average boost acceleration</td>
<td>59 m/s²</td>
<td>194 ft/s²</td>
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<td></td>
<td></td>
<td>6 G</td>
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Full Scale Test Flight 2

- Main Parachute Deployed at Apogee
- Static Grid Fins

<table>
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</thead>
<tbody>
<tr>
<td>Flight</td>
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<tr>
<td>Maximum height</td>
<td>1406 m</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>186 m/s</td>
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<tr>
<td>Maximum boost acceleration</td>
<td>66 m/s²</td>
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<tr>
<td>Average boost acceleration</td>
<td>50 m/s²</td>
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Full Scale Test Flight 3

- Recovery Failure
- Live Fins
- Lighter Nosecone

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Flight</td>
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<tr>
<td>Maximum height</td>
<td>1496 m</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>201 m/s</td>
</tr>
<tr>
<td>Maximum boost acceleration</td>
<td>83 m/s²</td>
</tr>
<tr>
<td>Average boost acceleration</td>
<td>62 m/s²</td>
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</table>
Full Scale Test Flight 4

- Successful Recovery
- Due to first test, did not have a Loki-L930 available on site, instead used a Loki-L840 which gave the vehicle a much higher apogee

<table>
<thead>
<tr>
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<th>Serial</th>
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<tbody>
<tr>
<td>Flight</td>
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<td></td>
</tr>
<tr>
<td>Maximum height</td>
<td>1840 m</td>
<td>6035 ft</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>237 m/s</td>
<td>776 fps</td>
</tr>
<tr>
<td>Maximum boost acceleration</td>
<td>95 m/s²</td>
<td>311 ft/s²</td>
</tr>
<tr>
<td>Average boost acceleration</td>
<td>69 m/s²</td>
<td>227 ft/s²</td>
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</tbody>
</table>
Recovery
Tanner Straker
Recovery Overview

Stage 1: Launch

Stage 2: Apogee - Drogue Deploys

Stage 3: 750 ft - Main Deploys
# Numbers Overview

## Parachute Overview

<table>
<thead>
<tr>
<th>Source</th>
<th>Parachute</th>
<th>Drogue</th>
<th>Main</th>
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<tbody>
<tr>
<td>Diameter (ft)</td>
<td>4.38</td>
<td>7.9</td>
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<tr>
<td>Shape</td>
<td>Hemispherical</td>
<td>Hemispherical</td>
<td></td>
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<tr>
<td>Deployment Altitude</td>
<td>Apogee</td>
<td>800 ft</td>
<td></td>
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<tr>
<td>Descent Velocity</td>
<td>22.2 ft/s</td>
<td>10.75 ft/s</td>
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<tr>
<td>Kinetic Energy</td>
<td>177.09 ft-lb</td>
<td>41.52 ft-lb</td>
<td></td>
</tr>
<tr>
<td>Shock Cord Material</td>
<td>1 inch Tubular Nylon</td>
<td>1 inch Tubular Nylon</td>
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</table>

## Drift Calculations

<table>
<thead>
<tr>
<th>Wind Speed (mph)</th>
<th>Wind Speed (ft/s)</th>
<th>Drift Under Drogue (ft)</th>
<th>Drift Under Main (ft)</th>
<th>Total Drift (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>5</td>
<td>7.33</td>
<td>174.35</td>
<td>3600.22</td>
<td>3774.57</td>
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<tr>
<td>10</td>
<td>14.67</td>
<td>3489.10</td>
<td>7205.36</td>
<td>10694.46</td>
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<td>15</td>
<td>22.00</td>
<td>5232.43</td>
<td>10805.58</td>
<td>16038.01</td>
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<tr>
<td>20</td>
<td>29.33</td>
<td>6975.78</td>
<td>14405.80</td>
<td>21381.58</td>
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</table>

## Main Parachute Stats

<table>
<thead>
<tr>
<th></th>
<th>Drogue</th>
<th>Main</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of Chute</td>
<td>30.17 ft²</td>
<td>98.57 ft²</td>
</tr>
<tr>
<td>Diameter of Chute</td>
<td>52.56 in</td>
<td>95.06 in</td>
</tr>
<tr>
<td>Diameter of Spill Hole</td>
<td>10.56 in</td>
<td>19.01 in</td>
</tr>
<tr>
<td>Circumference of Bottom of Chute</td>
<td>13.67 ft</td>
<td>24.83 ft</td>
</tr>
<tr>
<td>Number of Gores</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Width of Each Gore</td>
<td>20.94 in</td>
<td>38.71 in</td>
</tr>
<tr>
<td>Height of Each Gore</td>
<td>41.3 in</td>
<td>77.42 in</td>
</tr>
</tbody>
</table>
Electronics Overview
Parachutes

• Two parachutes required
  ▫ Drogue – Hemispherical - 4.38 ft diameter
  ▫ Main – Hemispherical – 7.9 ft diameter

• Both parachutes have spill holes
  ▫ ½ in tubular nylon shroud lines
Parachutes

- Construction
  - Gores
- Ripstop nylon
  - Tear resistant weaving
Parachutes

- Main parachute deployed with the two Jolly Logic Chute Releases
  - Series
Recovery Assembly

- Nylon shear pins
- Drogue
- Main parachute
- Chute Releases (series)
- Black powder charges
- Barometric Avionics Enclosure
Attachment Hardware

- Nylon Slotted Pan Head Machine Screws
- Steel U-Bolts
- Quick Links
- Carbon Fiber Altimeter Board
Shock Cord

- 1 inch tubular nylon
- Excellent tensile strength
- Low weight
Electronics - Altimeters

- Two altimeters
  - Altus Metrum Telemega
  - Altus Metrum Telemetrum
- No patch antennae
  - Fiberglass coupler
Electronics - Altimeters
Black Powder Ejection System

- Effective
- Reliable
- Tested
- Low volume
Black Powder Ejection System

- Ideal Gas Law
  - $PV = nRT$
  - $P = \text{pins} \times \frac{F}{A}$
  - $N = 0.00052 \times F \times L$
- Charge cups
- Tests
  - 5 grams, 5.5 grams, 7 grams
Testing - Ejection

- Successful trials
  - Aided in sizing of shock cord
  - Confirmed dual deploy system
Testing - Wind Tunnels

- Obtained drag data
  - Similar to expected flight conditions
  - More accurate coefficient of drag
  - Spill hole stabilized test
Testing - Materials

• Analyzed performance of materials
  ▫ Jolly Logics Chute Release
    • Shake and Release tests
  ▫ Shear pins
  ▫ Black powder charge size
Launch Day Procedures

• **E-match / Altimeter Set up**
  - Twist the altimeter lead wires that are located on the bay around each other
  - Assemble the e-matches by placing them through the bottom charge cup holes
  - Twist e-matches around twisted wires
  - Twist electrical tape around the twisted wires / e-matches
  - Test altimeters for response
  - Wrap the lead wires around the quick link on the bay

• **Attaching Parachutes**
  - Place bay into upper body section temporarily
  - Test tension on shock cords
  - Attach more shock cords connecting the drogue and main parachute
  - Attach nose cone to upper body section

• **Charge Cups**
  - Tape e-match to charge cup
  - Fill up charge cups with seven grams of black powder per cup with a funnel
  - Cover the top of the charge cups with painters tape

• **Jolly Logic Setup**
  - Place barf into the bottom of the upper section leaving enough room for nose cone
  - Attach bay to upper body
  - Set Jolly Logic to deploy parachute at 800 feet

• **Parachute Packing**
  - Pack main parachute cord and then the main parachute into the upper body section vertically
  - Place the drogue cord and then the drogue into the upper body section vertically
  - Attach nose cone to upper body section
  - Screw shear pins in-between the upper section and nose cone
  - Attach coupler to bay and screw it in
Launch 1

- Circular drogue only
  - 80 ft/s
Launch 2

- Main release at apogee
  - 21 ft/s
Launch 3

- Hemispherical drogue only
  - Tangled
Launch 4

• Success!
  ▫ 30 ft/s, 12 ft/s
  ▫ 2100 ft drift vs 5344 ft estimated
    • 5 mph winds
Design (Fins)

- Similar to last year
- Increase width
- Include Roll
Design (Fins)

- 3.5”x5.176”x1.25”
Design (Fairings)

- 3.5”x1.25”
- 13.5” curvature
- Lengthened to prevent local shock
Design (Actuation)

- 2 separate systems
- Pitch only
- Pitch and roll
Testing

• Water and wind Tunnel Testing
Electronics

- Arduino Uno
- IMU Breakout
- SC-1258TG
Safety

- Need to Make Sure
  - Grid fins deploy simultaneously
  - Grid Fins do not deploy before burnout
  - Rocket is stable
Fail Safety
Fail Safety

Servo Burnout Test

- 10 days
- 1 degree every 0.01 seconds
- 100 degrees/second
- 6,000 degrees/minute
- 360,000 degrees/hour
- 8,640,000 degrees/day
- 86,400,000 degrees in total
Safety

- Hazard Analyses Updated & Modified
- Checklists Developing
  - Grid fin testing checklist supplied
  - Wiring checklist in the future
- Continuous Training via ORM
  - OSHA Workshop Course scheduled
  - Online courses
    - Laser Safety
    - Hand and Power Tool
    - Lab Safety

- MSDS, Inventory Sheets, NAR/TRA Safety Codes all available through team website
- Additional briefings are held prior to launch opportunities
- Desired modifications to checklists, communication, and safety procedures discussed in general meetings after launches.

### Risk Assessment Matrix

<table>
<thead>
<tr>
<th>Probability</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 - Minor</td>
</tr>
<tr>
<td>1 - Extremely unlikely</td>
<td>1</td>
</tr>
<tr>
<td>2 - Remote</td>
<td>2</td>
</tr>
<tr>
<td>3 - Reasonably possible</td>
<td>3</td>
</tr>
<tr>
<td>4 - Frequent</td>
<td>4</td>
</tr>
<tr>
<td>5 - Almost guaranteed</td>
<td>5</td>
</tr>
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Education

Bryce Gardner
Educational Outreach Events

• Drake Middle School 7th Grade Rocket Week - February 27th, 28th and March 3rd, 2017
• Samuel Ginn College Engineering Day - February 24, 2017
• Boy Scout Outreach November 12, 2016
• Girl Scout Outreach - Spring 2017
• Auburn High School Junior E-day – November 17 2016