Scaling of the U13A Remote Controlled Helicopter

Project Proposal

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12/9/13
Overview

• Project Description
• Need and Goal
• Objectives
• QFD
• Concept Generation and Selection
• Analysis Overview
• Blade Analysis
Overview Continued

• Landing Gear Analysis
• Final Modeled U13A Helicopter
• New Component Parts
• Cost Analysis
• Gantt Chart
• Summary
• References
Problem Description

- Client is Dr. Kosaraju
- Task of scaling U13A remote controlled helicopter by 1.5
- Capability to have mission specific attachments
Need and Goal

**Need:**
The U13A is too small.

**Goal:**
Successfully upscale a remote controlled helicopter with the ability to add mission specific accessories.
# Objectives

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Measurement Basis</th>
<th>Units</th>
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<tbody>
<tr>
<td>Design and build a RC helicopter</td>
<td>Amount of materials</td>
<td>Dollars</td>
</tr>
<tr>
<td>Attachments</td>
<td>Camera parts</td>
<td>Dollars</td>
</tr>
<tr>
<td>Batteries</td>
<td>Two sets of batteries</td>
<td>Dollars</td>
</tr>
<tr>
<td>Carrying Capabilities</td>
<td>Weight</td>
<td>lbs</td>
</tr>
<tr>
<td>Waterproof Materials</td>
<td>Cost for materials</td>
<td>Dollars</td>
</tr>
<tr>
<td>Lift Capabilities</td>
<td>Height range</td>
<td>Meters</td>
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## Quality Function Deployment

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<tr>
<th>Customer Requirements</th>
<th>Scale</th>
<th>Scale Ratio to 1.5</th>
<th>0</th>
<th>5</th>
<th>0</th>
<th>10</th>
<th>7</th>
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<tr>
<td>Scale</td>
<td>1</td>
<td>Performance</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Durability</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>7</td>
<td>7</td>
<td>Flight Duration</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>0</td>
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<td>10</td>
<td>10</td>
<td>Attachments</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>50</td>
<td>55</td>
<td>99</td>
<td>10</td>
<td>42</td>
</tr>
<tr>
<td><strong>Units</strong></td>
<td></td>
<td></td>
<td>psi</td>
<td>lb</td>
<td>ft-lb/s</td>
<td>in</td>
<td>lbf</td>
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</table>

**Engineering Targets**

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Concept Generation and Selection

• Blades
• Landing Gear
• Battery
Blades

• Problem: Blade Contact

• Solution: Rigid Upper Blade Design

<table>
<thead>
<tr>
<th>Blade Contact:</th>
<th>Column1</th>
<th>Column2</th>
<th>Column3</th>
<th>Column4</th>
<th>Column5</th>
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<tbody>
<tr>
<td>Category</td>
<td>Ease of Design</td>
<td>Safety</td>
<td>Cost</td>
<td>Estimated Life</td>
<td>Total</td>
</tr>
<tr>
<td>Raised Upper Rotor</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>7</td>
<td>5.8</td>
</tr>
<tr>
<td>Durable Blade Material</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>5.5</td>
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<tr>
<td>Rigid Blade Design</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>7.1</td>
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<td>Weight (%)</td>
<td>20</td>
<td>30</td>
<td>20</td>
<td>30</td>
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Landing Gear

- Problem: Helicopter lands on its side

- Solution: Larger Rounded Landing Gear

<table>
<thead>
<tr>
<th>Category</th>
<th>Helicopter Weight</th>
<th>Take-off/Landing</th>
<th>Stability on ground</th>
<th>Landing Impact</th>
<th>Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larger Landing Gear (Flat)</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>6.4</td>
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<tr>
<td>Smaller Landing Gear (Flat)</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>3.2</td>
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<tr>
<td>Smaller Landing Gear (Rounded)</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>7</td>
<td>3.8</td>
</tr>
<tr>
<td>Larger Landing Gear (Rounded)</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>5</td>
<td>7.4</td>
</tr>
<tr>
<td>Weight %</td>
<td>30</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td></td>
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</table>

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Battery

• Problem: Short Battery Life

• Solution: Set batteries in series

<table>
<thead>
<tr>
<th></th>
<th>Voltage</th>
<th>Capacity</th>
<th>Weight</th>
<th>Durability</th>
<th>Cost</th>
<th>Total</th>
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<tbody>
<tr>
<td>Single LiPo</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>4</td>
<td>9</td>
<td>6.15</td>
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<tr>
<td>LiPos in Parallel</td>
<td>5</td>
<td>10</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>7.1</td>
</tr>
<tr>
<td>LiPos in Series</td>
<td>10</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>7.45</td>
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<tr>
<td>Parallel+Series</td>
<td>10</td>
<td>10</td>
<td>6</td>
<td>8</td>
<td>3</td>
<td>7.9</td>
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</table>

Weight (%)

- 25
- 30
- 25
- 5
- 15
Analysis Overview

• Areas for engineering analysis
• Blades
• Landing gear
Blade Analysis

• Goal of analysis:
  – Find approximate lift force to be generated by the scaled helicopter.
  – Calculate the max stresses occurring in the blades.
  – Choose a suitable blade material.
Blade Dimensions & Assumptions

• Length = 7.5 inches.
• Width = 1.2 inches.
• Thickness = 0.10 inches.
• Coefficient of drag = 0.1.
• Angular velocity = 1600 RPM.
• Coefficient of lift = 0.4.
Forces on Rotor in Flight
Force Analysis

• Lift greater than drag and will result in bending upward.
• Power = 0.268 hp
• Power loading = 0.2184 hp/ft\(^2\)
• Thrust loading = 13.94 lbs/hp
• Lift = 3.74 lbs/rotor (1.87 lbs/blade)
• Drag = 0.1417 lbs per rotor
Blade Strength Analysis

• Treat as a simple cantilever of constant width and thickness along the length with a point load at its tip.

• Maximum moment = 14.025 in-lbs
• Maximum stress = 7012.5 psi
Common RC Blade Materials

• Polypropylene cheapest, great impact resistance, but cannot handle stresses.
• Wood second cheapest, handles all stresses, not great impact resistance.
• Carbon fiber and fiber glass expensive, lightweight, poor impact resistance.
• No great choice \(\rightarrow\) rapid prototyping provides additional options.
Rapid Prototyping the Blades

• 3D printing allows for easily reproducible custom blades.

• Two options for blade material: ABS & Ultem
  – Can handle necessary stresses
  – Great impact resistance

• Either material will work for this application
  – 1st choice is Ultem, however, availability is not 100% guaranteed.
Landing Gear Analysis

• Material is Ethylene Vinyl Acetate (EVA)
• Material has a compressive strength of 1450 PSI and tensile strength of 2000 PSI
• Excellent shock absorbing properties
• We want it to simply deform and spring back for short or non energetic landings but to break for high energy landings.
Landing Gear Analysis

- Landing gear needs to survive a 6 ft drop with abrupt stop
- Impact force equation $F_I = \frac{Wxh}{s}$
- Total force is 172.8 lbs
Landing Gear Analysis

- Total compressive force on leg is 40.6 lbs
- Compare stress in leg to the UCS
- Stress is \( \sigma = \frac{F}{A} \)
- Using \( A = 0.15 \text{ in}^2 \) the stress is 270.6 PSI
- 270.6 PSI < 1450 PSI so the landing gear will survive 6 ft fall
Modeled U13A

• Tasks over the last three weeks
  – Final Model
  – Material Selection

• Things to do in upcoming weeks
  – Order Parts
  – 3D Printing
Modeled U13A
Exploded View of Model
New Components
## Cost Analysis

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Part</th>
<th>Name</th>
<th>Price Per Part</th>
<th>Price</th>
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<tbody>
<tr>
<td>2</td>
<td>Main 250 Motors</td>
<td>Hobbymate HB2622-5000kv Brushless Motor</td>
<td>$24.80</td>
<td>$49.60</td>
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<tr>
<td>2</td>
<td>Main Rotor ESC</td>
<td>New HobbyWing Flyfun ESC 30A</td>
<td>$17.49</td>
<td>$34.98</td>
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<tr>
<td>1</td>
<td>Tail ESC</td>
<td>New HobbyWing Flyfun ESC 10A</td>
<td>$11.99</td>
<td>$11.99</td>
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<tr>
<td>3</td>
<td>Batteries</td>
<td>HYPERION G3 EX 1600 MAH 2S 7.4V 45C/90C LIPOLY PACK</td>
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<td>$77.85</td>
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<tr>
<td>1</td>
<td>Top Shaft</td>
<td>HP Heli's Inner Main Shaft for the X-2 helicopter</td>
<td>$10.99</td>
<td>$10.99</td>
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<tr>
<td>1</td>
<td>Lower Shaft</td>
<td>HP Heli's Outer Main Shaft w/Gear for the X-2 helicopter</td>
<td>$10.99</td>
<td>$10.99</td>
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<tr>
<td>1</td>
<td>Transmitter-Receiver</td>
<td>Fly Sky CT6B OEM Version Exceed RC 6-Ch 2.4Ghz Transmitter w/ Receiver</td>
<td>$44.70</td>
<td>$44.70</td>
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<tr>
<td>2</td>
<td>Small Gears</td>
<td>Mod 0.5, 10 Tooth, 2.3 mm ID Pinion</td>
<td>$1.99</td>
<td>$3.98</td>
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<tr>
<td>2</td>
<td>Large Gears</td>
<td>Mod 0.5, 80 Tooth, 6 mm ID Gear</td>
<td>$2.00</td>
<td>$4.00</td>
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<tr>
<td>1</td>
<td>Screws</td>
<td>LPPM3006 - M3 x 6mm - Thread forming screws For Plastic (100)</td>
<td>$2.40</td>
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<td>10</td>
<td>Pins</td>
<td>M2 - 8mm Roll Pins</td>
<td>$0.11</td>
<td>$1.10</td>
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<tr>
<td>1</td>
<td>Camera</td>
<td>Wholesale - New mini Wireless Spy Camera Hidden cam Security kit</td>
<td>$30.43</td>
<td>$30.43</td>
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<tr>
<td>1</td>
<td>3D Printer Material</td>
<td>ABS Polymer for Rapid Prototyping</td>
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<td><strong>Total</strong></td>
<td><strong>#</strong></td>
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<td></td>
<td><strong>$798.00</strong></td>
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</table>
Cost Analysis Continued

• Biggest expense is polymer material but is being paid for by student fees
• This material will be used for almost every structural material in helicopter
• Electronic components are second most expensive
• No manufacturing costs to consider
Gantt Chart

- **Reverse Engineering**: 9/30/13 - 11/4/13
- **Testing Helicopter Properties**: 9/30/13 - 10/11/13
- **Deconstruction**: 10/11/13 - 10/18/13
- **Analyze Helicopter Parts**: 10/11/13 - 11/1/13
- **Design Scaled Up Helicopter**: 11/1/13 - 12/12/13
- **Brainstorm Design Improvements**: 11/1/13 - 11/8/13
- **Individual Part Design**: 11/8/13 - 12/5/13
- **Part/Material Sourcing**: 11/29/13 - 12/12/13

- **Helicopter Test Flight**: 10/4
- **Reassembly Test Flight**: 11/4
- **Final Design Due**: 12/5

- **Month Indicators**: Sep, Oct, Nov, Dec

- **Year**: 2013
Summary

• Our task is to upscale a U13A helicopter by 1.5.
• The need is that we have a small helicopter and our goal is to upscale the helicopter by 1.5.
• Stated what our objectives were.
• Calculated the requirements on the QFD table.
• The concept and generation that our team chose to analyze were the blades, landing gear, and battery.
Summary Continued

• During the process of selection, there were three main problems: chips in the blades, helicopter landing on its side, and short battery life.

• Our team then decided that the blades and landing gear needed the most engineering analysis due to their importance towards helicopter.

• During the blade analysis, we found the forces on the rotors in flight, and calculated the maximum moment to be 14.025 in-lbs and maximum stress = 7012.5 psi.
Summary Continued

• Rapid prototyping was chosen based on the material selection. Our team decided to 3D print the blades because it can be easily reproduced if a blade fails. ABS & Ultem was the material that can handle the stress load.

• Using the material ethylene vinyl acetate, we found that the scaled landing gear will easily survive a 6 foot fall.
Summary Continued

• We showed the current model of the U13A helicopter in both assembled and exploded views and highlighted what the main parts were going to be used in rapid prototype.
• Performed a cost analysis on the number of parts to order.
• Gave an update on where our team is currently at and provided a spring project plan.
References

• Seddon, J., 1990, Basic Helicopter Aerodynamics, Mackays of Chatham, Chatham, Kent.
References Continued


Questions?