NASA Great Moonbuggy Race
2012

SpacePokes Design

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Overview

- Competition Information
- Design Specifications
- Competition Results
- Design Improvements
- Cost Analysis
- Future considerations
- Recommendations
NASA Great Moonbuggy Race

• U.S. Space and Rocket Center, Huntsville, Alabama
• 19th Annual competition
• Design, Fabricate, and Race Human Powered Vehicle
• 87 Teams
  – 44 College
  – 43 High School
Competition

- 2 Days
- 18 Obstacles
  - Simulated Moon Terrain
  - Gravel
  - 15” high
- .7 Miles

http://moonbuggy.msfc.nasa.gov
Pre-Race Qualifications

- Weight: 165 lbs
  - Over goal of 150 lbs
- Volume Requirement
  - Fit in 4 ft cube
- Assembly Time: 30 Seconds
  - Additional Penalty: 30 Seconds

Collapsed Dimension Testing

Pre-Race Safety Check
Overall Results

- 6th Place
- Best Race Time - 5:23
- Best Adjusted Time - 6:23
- Most Improved Award

Competition Awards Ceremony
Design Specifications

• NASA Requirements
  – Human powered
  – Two riders
    • male & female
  – Collapsible- 4’ cube
  – Width- 4’ maximum
  – 15” ground clearance
  – Portable
  – Safety

http://moonbuggy.msfc.nasa.gov
Design Specifications

- SpacePokes’ Specifications
  - 15 MPH maximum speed
  - Vehicle weight < 150 lbs
  - Assembly < 10 seconds
  - 15 ft radius curve at 10 MPH
  - Stop from 15 MPH < 30 ft

Davis and Lesley at Competition
Continuing Concepts

- Rider Configuration
- Transmission System
- Articulation
- Fold Scheme
- Brake System
- Frame

Ready to Race
Design Improvements

Recommendations

- Stability
- Mid-air Control
- Steering
- Ergonomics

Solutions

- Assisted Centering Hinge
- Bearing Plates
- Longer Steering Arms
- Suspended Seat Webbing
Stability Model

• Calculated Stability during a Turn
• Sum of the Moments about a “Tip Line”
  – Tip Line $AB$
  – Assume Central Forces on All Masses:
    $$F_i = m_i \frac{v^2}{\rho}$$
  – Determine Perpendicular Vectors $R_i$
  – Vector Multiplication:
    $$M_{tip} = \det \begin{bmatrix} AB_X & AB_Y & AB_Z \\ R_X & R_Y & R_Z \\ F_X & F_Y & F_Z \end{bmatrix}$$
• If $\Sigma M_{tip} = 0$, Moonbuggy Overturns
Bearing Plates

• Design
  – 3/8 in aluminum plates
  – Resist lateral forces
  – Increase ease of assembly

• Results
  – Factor of safety of 1.8
  – Lightening holes greatly reduced factor of safety

Front Bearing Plate
Steering

• Design
  – Extended Steering Arms
  – Adjustable
    • Sensitivity
    • Turning radius

• Results
  – Exceed goal of 15 ft turning radius
  – Improved sensitivity and stability
Hinge

- Turning Compresses Spring
  - Collar Rotates About Pin
  - Spring Force Assists Hinge Return

- Provides Restoring Force
  - Facilitates Course Correction
  - Improves Mid-Air Control
  - Prevents “Snaking”
Hinge

\[ F_S = k(X_0 + \frac{\alpha}{180} D \tan \theta) \]

- Theoretical Torque: 290 in-lbs
- Experimental Torque: 305 in-lbs
- Theoretical Return Force: 28 lbs
- Experimental Return Force: 29 lbs

Return Force Testing
Non-Technical Design Considerations

• Safety
  – Covered Sharp Edges
  – Seatbelts
  – Personal Protective Equipment
  – Seat Webbing

• Aesthetics
  – Painted Brown and Gold
  – New Seat Covers

Front Seat
## Cost Analysis

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<tr>
<th>Expense</th>
<th>QTY</th>
<th>Total Cost</th>
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<td>Student Engineering</td>
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<td>Engineering Shop</td>
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Future Considerations

- Day 1: Eye-Bolt Failure
- Day 2: Power Link Chain Failure
Recommendations

• Simulate Obstacles
• Increase Factor of Safety
• Alternate Drive System

Turn Radius Testing
Special Thanks

• Wyoming NASA Space Grant Consortium
• The College of Engineering Machine Shop
• Lyle Lack: Honorary Team Member
• To Infinity Design
• Pedal House
• Karen Wisseman
Questions?
Effect of Seat Height on Tipping Moment

- **Stable**
- **Unstable**

Tipping Moment (lbf*ft) vs. Seat Height Relative to Axle (ft)
Effect of Rider Position on Tipping Moment

Stable

Unstable

Distance from Hinge to Driver's CG (ft)
Frame

- Deflection
  - Two halves articulated by center hinge
  - Welded 4130 Steel Tubing
  - Suspended from Axle
    - Lower center of gravity
  - Theoretical Deflection: 0.086 in

- Results
  - Actual Deflection: 0.065 in
Day 2

- Chain Failure
  - Failed at Power Link
- 3 Touch Penalties
- Race Time: 8:54
- Adjusted Time: 12:54
Brakes

• Design
  – Avid BB7 Mechanical Disk Brakes
  – Brake Rotor Radius 3.64 in
  – Problem Solvers Cable Splitter

• Results
  – Even Braking Through Splitter
  – 23 ft Stopping Distance
    • Exceeded Goal of 30 ft
Transmission

- Design
  - Truvativ HammerSchmidt Crank Set
    - Two gears
  - Shimano Single Speed Freewheel Hub
  - Chain Tensioners
    - Reduced risk of slipping chain
- Results
  - Top Speed 15 MPH
  - Chain Broke At Power Link
Wheels

- 26” Bontrager Bike Tires
- Custom Aluminum Hubs
- Collapsible Rear Wheels
- New Brass Nipples