TO INFINITY

BEYOND PERFORMANCE

2011 NASA Great Moonbuggy

Adam Karges	Leader
Alicia Martin	Recorder
Britta O'Keeffe	Project Engineer
Chris Battisti	Project Engineer
Steve Boyd	Project Engineer

Overview

- Background Information
- Design Specifications
- Final Design
- Economic Analysis
- Competition Results
- Recommendations

Team Photo at the Competition

Background Information

- NASA competition
  - 18th Annual Great Moonbuggy Race
  - U.S. Space & Rocket Center in Huntsville, Alabama
  - Competition for secondary and higher education institutions
  - Design, build and race a human powered vehicle

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

Design Specifications - Dictated by NASA

- Human powered
  - 2 person co-ed team
- Maximum collapsed dimensions of a 4 foot cube
- Maximum assembled width of 4 feet
- Minimum rider clearance of 15 inches from the ground
- Moonbuggy lifted and carried by the riders 20 feet
- Safety
  - Seatbelts
  - Safety Gear
  - Chain clearance

Performance Goals - Dictated by To Infinity

- Weight goal: 120 pounds
- Assembly from collapsed position without additional tools
- Assembly time goal: 5 seconds
- Course Time: 3 minutes
- Top Speed: 20 mph
- Stopping Distance: 27 feet at 16 mph

Design Specifications – Dictated by To Infinity

- Steering
- Hinge
- Transmission
- Frame
- Crank Arm Support
- Axle
- Wheels
- Brakes

The Moonbuggy Garage in Huntsville

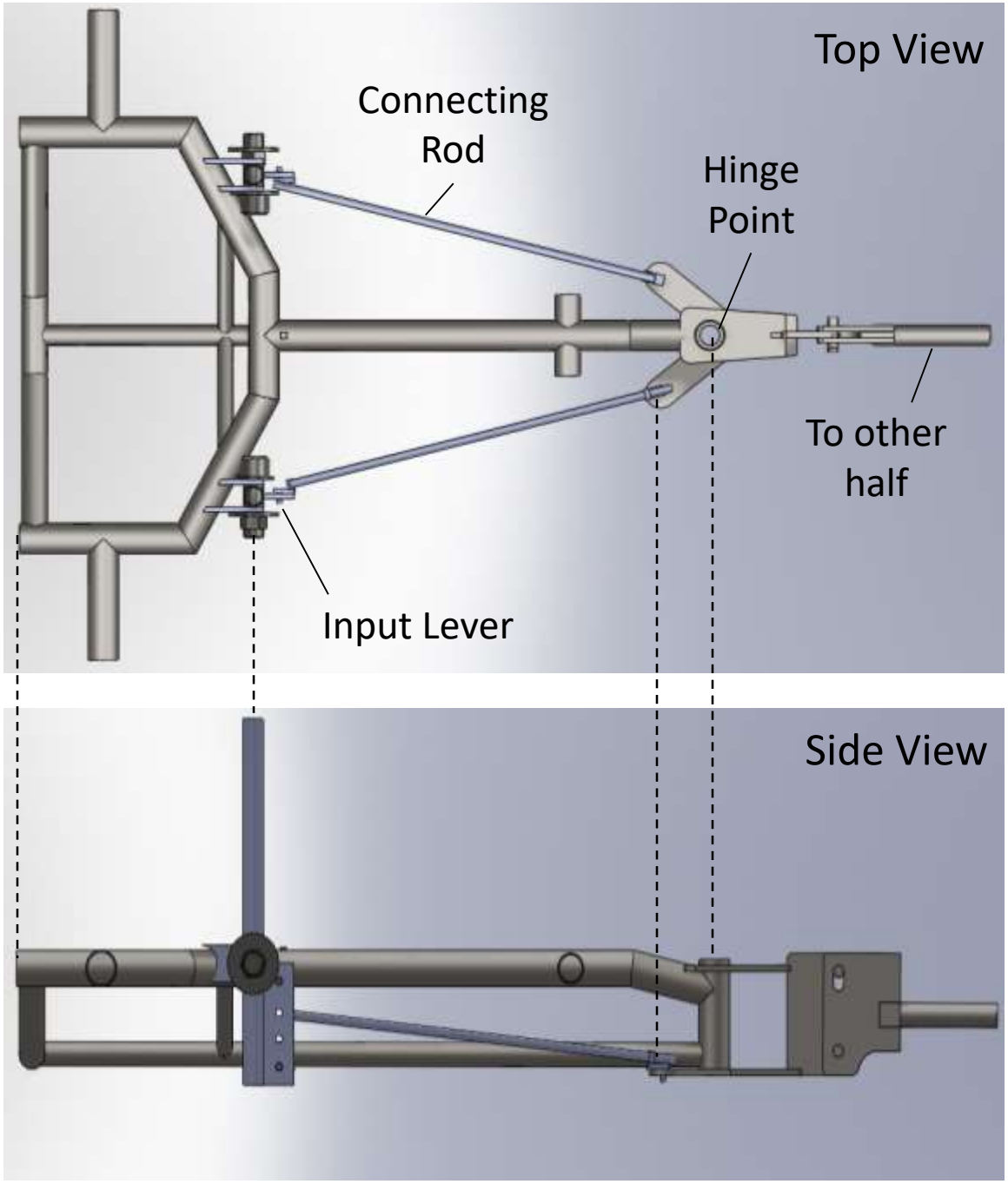
Steering

Design

- Predictable
  - Straight tracking
  - Corner exiting
- Articulated steering
  - Two control levers
  - Hinge pin ten degrees past vertical
  - Adjustable turning radius and sensitivity

Outcome

- Straight tracking
- Difficult corner exiting
  - Short steering levers
- Adjusted to rider feel
  - 14.5 foot turning radius


Top View
Connecting Rod
Hinge Point
To other half
Input Lever
Side View

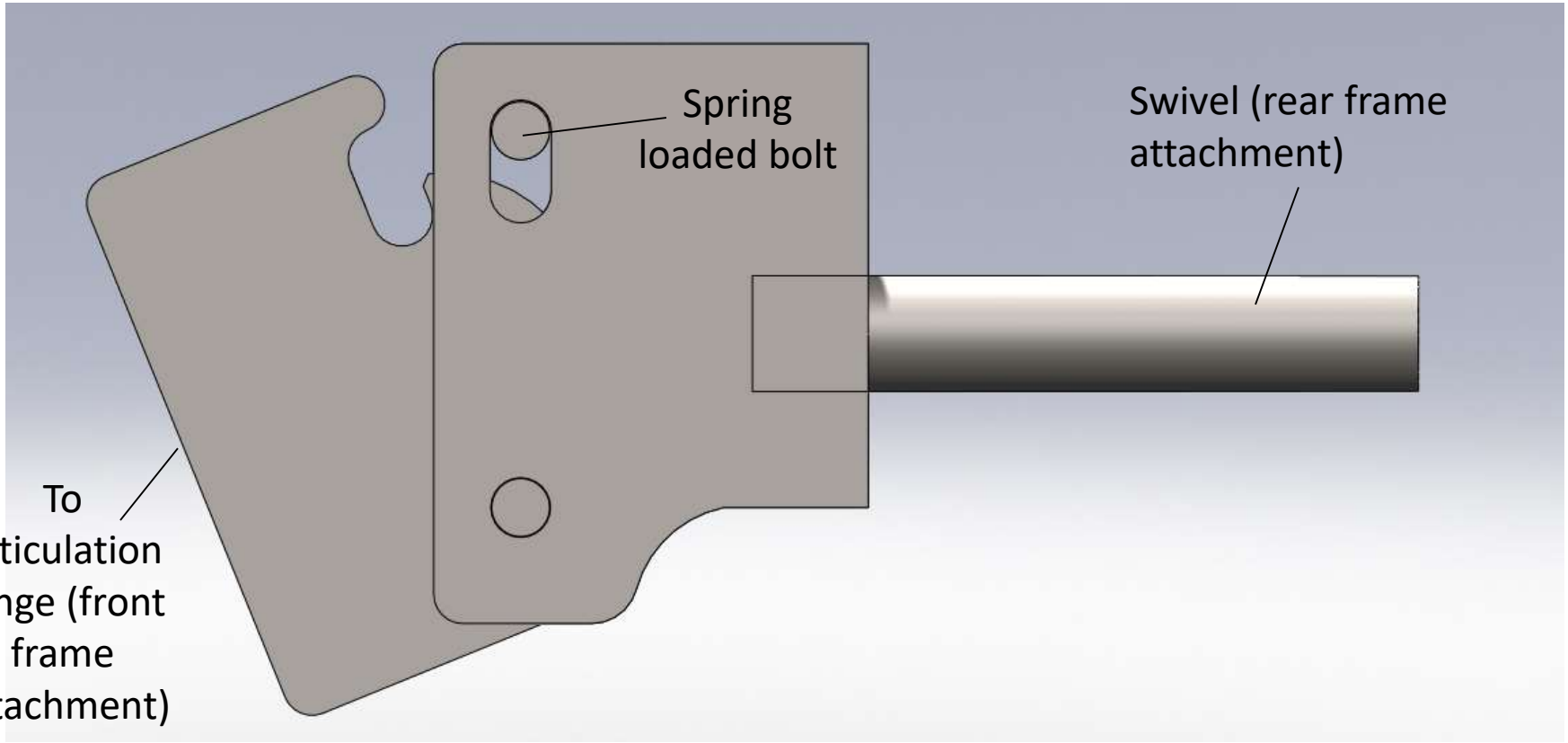
Hinge

Design

- Light weight
  - 3.5 pounds
- Minimal deflection
  - 0.0017 inches
- Allow for fast assembly
  - Minimum assembly time: 7.5 seconds
- Made of three ¼ inch 4130 Chromoly Steel plates

Outcome

- 6 pounds lighter than the 2010 design
- No measured deflection
- No failure or yielding


Spring loaded bolt
Swivel (rear frame attachment)
To articulation hinge (front frame attachment)

Transmission

Design

- High chain security
- Truvativ HammerSchmidt coupled with Single Speed Freewheel Hub

HammerSchmidt AM Crankset

http://www.sram.com/truvativ/products/truvativ-hammerschmidt-am-crankset

Outcome

- Top speed of 16.5 mph
  - Missed design goal of 20 mph
  - Unreasonable pedaling force needed for required gearing
- Saved 6 pounds over 2010 transmission
- Achieved high chain security

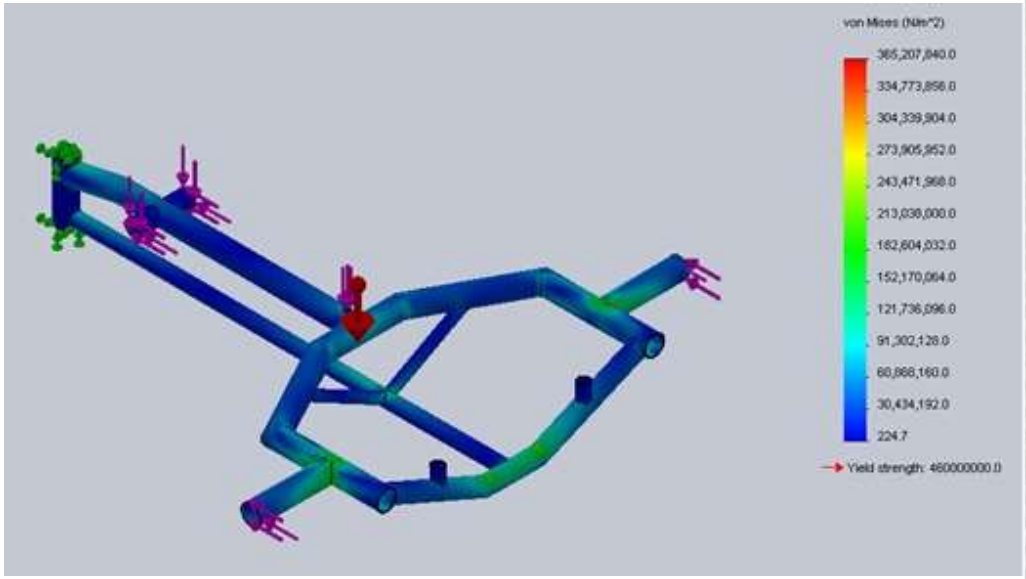
Single Speed Hub

http://www.dmrbikes.com/?Section=HUBRSSD10

Frame

Design

- Strong yet lightweight
  - Chromoly 4130 tubing
  - 1.26 Factor of Safety
- High stiffness
  - Immeasurable Deflection
- Swivel
  - Reused previous swivel design



Outcome

- Total weight: 19.3 pounds
- Frame Deflection: Immeasurable
- No failure or yielding

Crank Arm Support

Design

- Adjustable
  - Adjustable pedal angle
  - Adjustable telescoping length
- Material: 4130 Chromoly Steel Tubing
- Connects to frame via 5/16” grade 5 bolts

Outcome

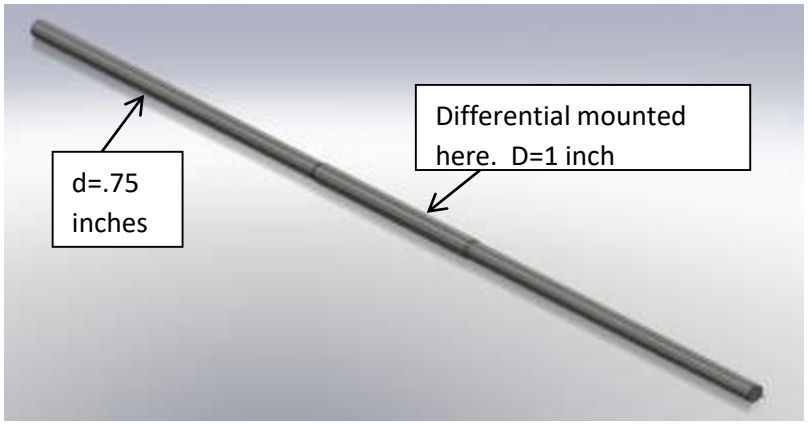
- No failure or yielding
- Weight Reduction: 2 pounds
- Adjustability
- Cable failure

Crank Arm Support

Axle

Design

- Weight Reduction



Stepped Axle Design

Outcome

- Use of the DE Goodman Criteria determined a necessary axle diameter of 1 inch
- Original axle reused

Diameter (in)	FOS	Mass of Axle (lbs)	Fatigue Life (Cycles)
1	0.97	9.74	8.96×10^5
0.75	0.30	6.38	138

Wheels

Design

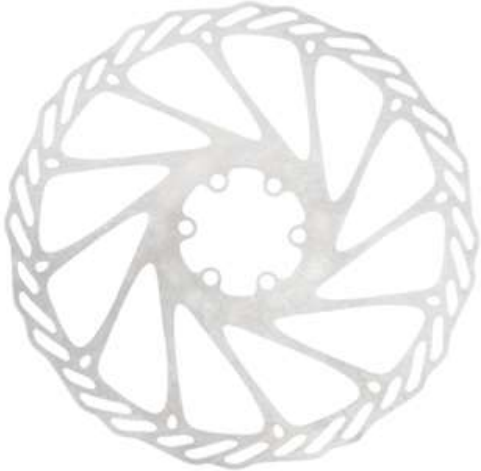
- Designed to withstand high lateral loads
- Brass Nipples
- Custom machined 6061 T6 AL hubs
- Sun Ringle Double Track rims

Wheel Hubs

Outcome

- Manufacturing Error
  - Aluminum nipples installed opposed to specified Brass nipples leading to wheel failure in Day 1 run
- Wheel was rebuilt with brass nipples, and did not fail in Day 2 run

Brakes

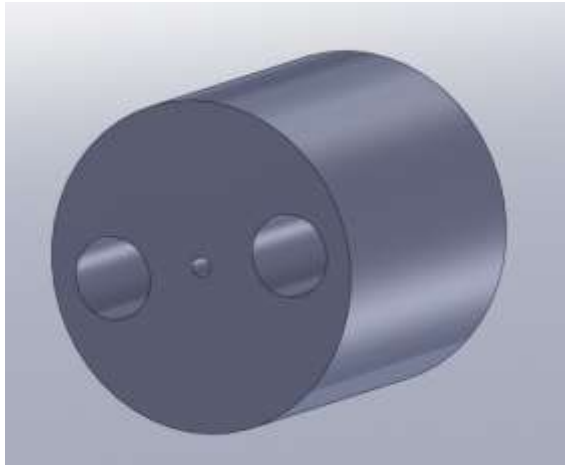


Brake Rotor

http://www.sram.com/avid/products/g3-cleansweep

Design

- Stopping Distance: 27 feet at 16 mph
- Calipers mechanically activated:
  - Avid mechanical disk brakes
  - Rotor radius: 3.64 inches
- Front Rider Control
  - Splitter beneath front rider's seat



Brake Cable Splitter

Outcome

- Stopping distance: 37 feet at 16 mph
  - Missed design goal due to mechanical losses in the splitter

Economic Analysis

EXPENSE	QTY	TOTAL COST
Student Engineering (varying rate)	911.25 hours	$43,381.63
Engineering Shop ($60/hr)	103 hours	$6,180
Purchased Materials	-	$1,390.25
Competition (Travel)	-	$3,033.50
TOTAL COST	-	**$53,985.38**
Production Cost/Unit	1	**$2,500**
Retail Price	1	**$3,750**

Non Technical Considerations

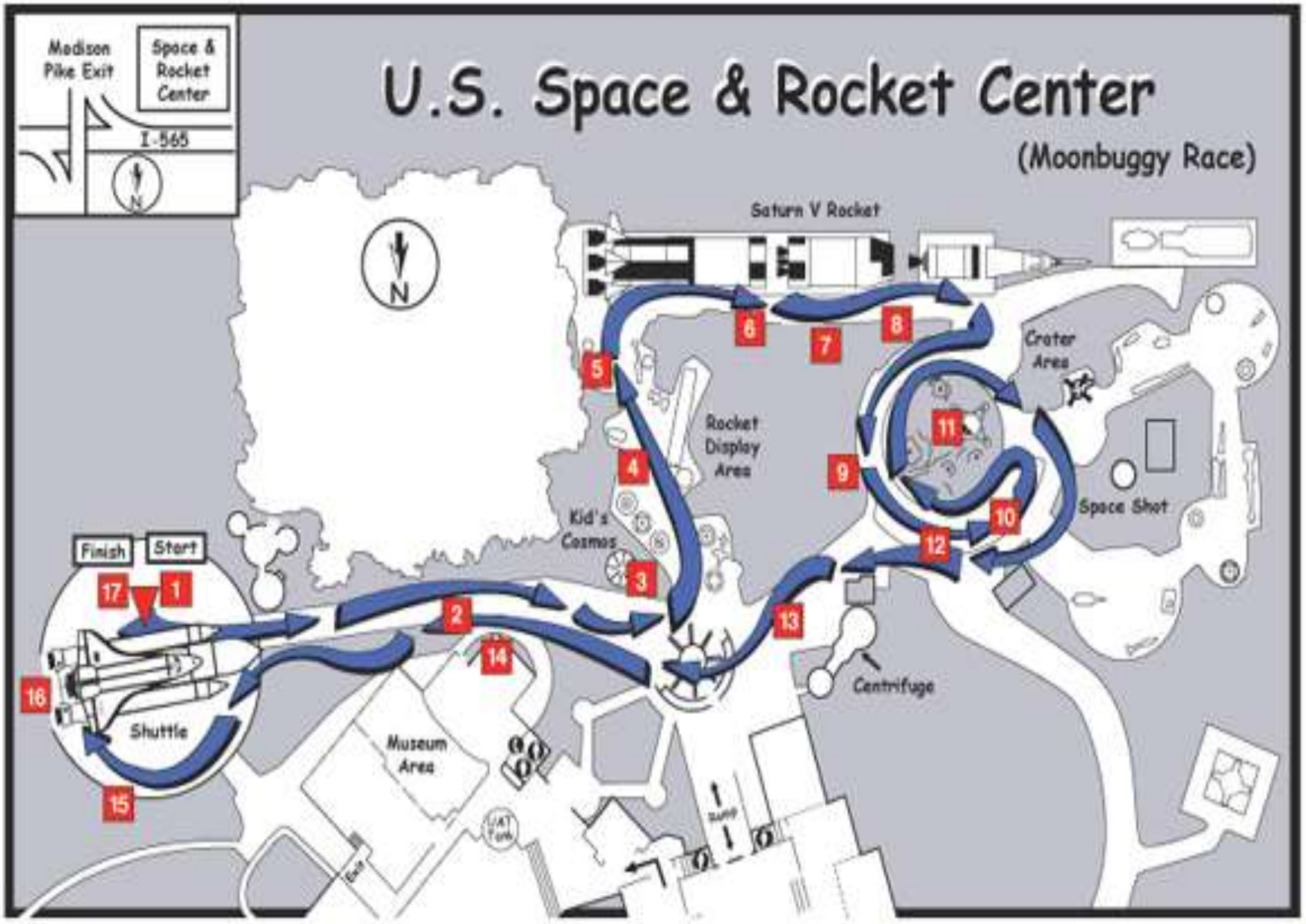
- Aesthetics
  - New Seat Covers
  - Painted white
  - Gold brake and shift housing
  - Updated fenders
- Safety
  - New helmets were purchased
  - No sharp edges

Competition

Pre Race Tasks:

- Volume Requirement - 4 foot cube
- Weight Requirement
  - Carried 20 feet by the riders
  - Final weight -146 lbs
- Timed assembly – 10.5 seconds
  - Goal assembly time – 5 seconds

The Course



http://moonbuggy.msfc.nasa.gov/course_map.html

Competition

Day One:

- Front half roll-over
- Front Right Wheel Nipple Failure
- No serious injuries!

Before the Crash

Front Roll-Over

Source: Moonbuggy Race Facebook Page

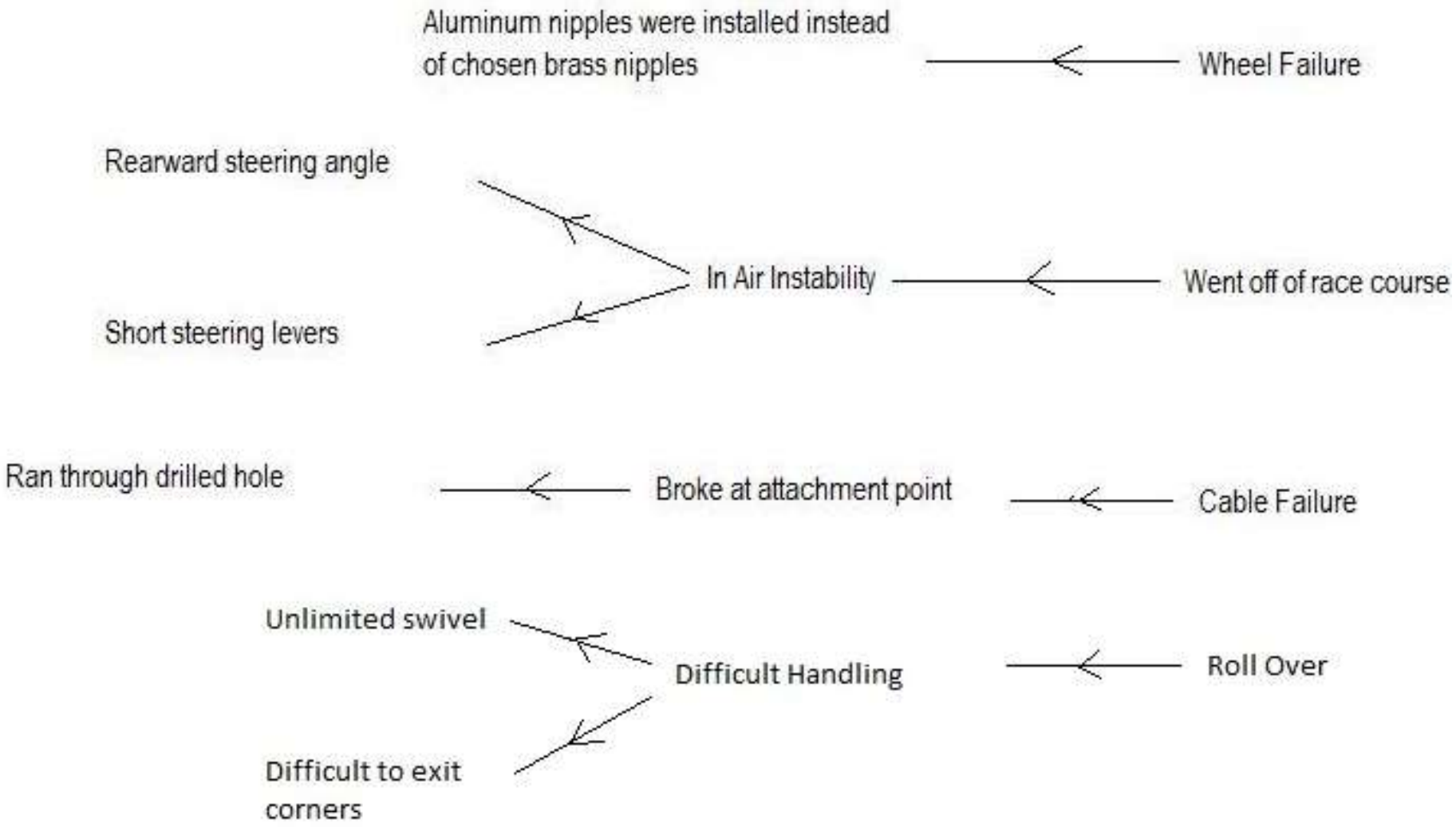
Competition

Day Two:

- Successful cornering in day one problem-area
- In-air instability
- Crank arm cable failure
- Completed race time: 6:58
- 18th place

Day One Crash Location

Root Cause Analysis



Recommendation: Practice

Problems

- Not enough practice time
- Poor terrain simulations

Solutions

- Early approval for construction
- Communicate with past teams
- Replicate race obstacles

Back Alley Practice

Recommendation: Steering

Problem

- In Air Instability

Solutions

- Reverse hinge angle
- Lengthen steering levers

Recommendation: Swivel

Problem

- Unlimited rotation

- Solution
  - Limit rotation using springs or stops

Design Summary

- Design Positives
  - Gearing
    - Optimal Low and High Gearing for Course Terrain
  - Adjustable Crank Arm
    - 5 inches of Length Adjustability
  - Weight Reduction
    - 22 pounds Lighter than 2010 Moonbuggy
  - Hinge
    - 6 pounds Lighter than 2010 Moonbuggy
    - No Yielding or Failure
  - Tire Choice
    - Low Rolling Resistance and High Volume
  - Frame
    - No Yielding or Failure

To Infinity Owes a Debt of Gratitude To:

- Wyoming NASA Space Grant Consortium
- Dr. Dennis Coon
- College of Engineering shop personnel
- Mr. Scott Morton
- Dr. Matt Bundle

Questions?