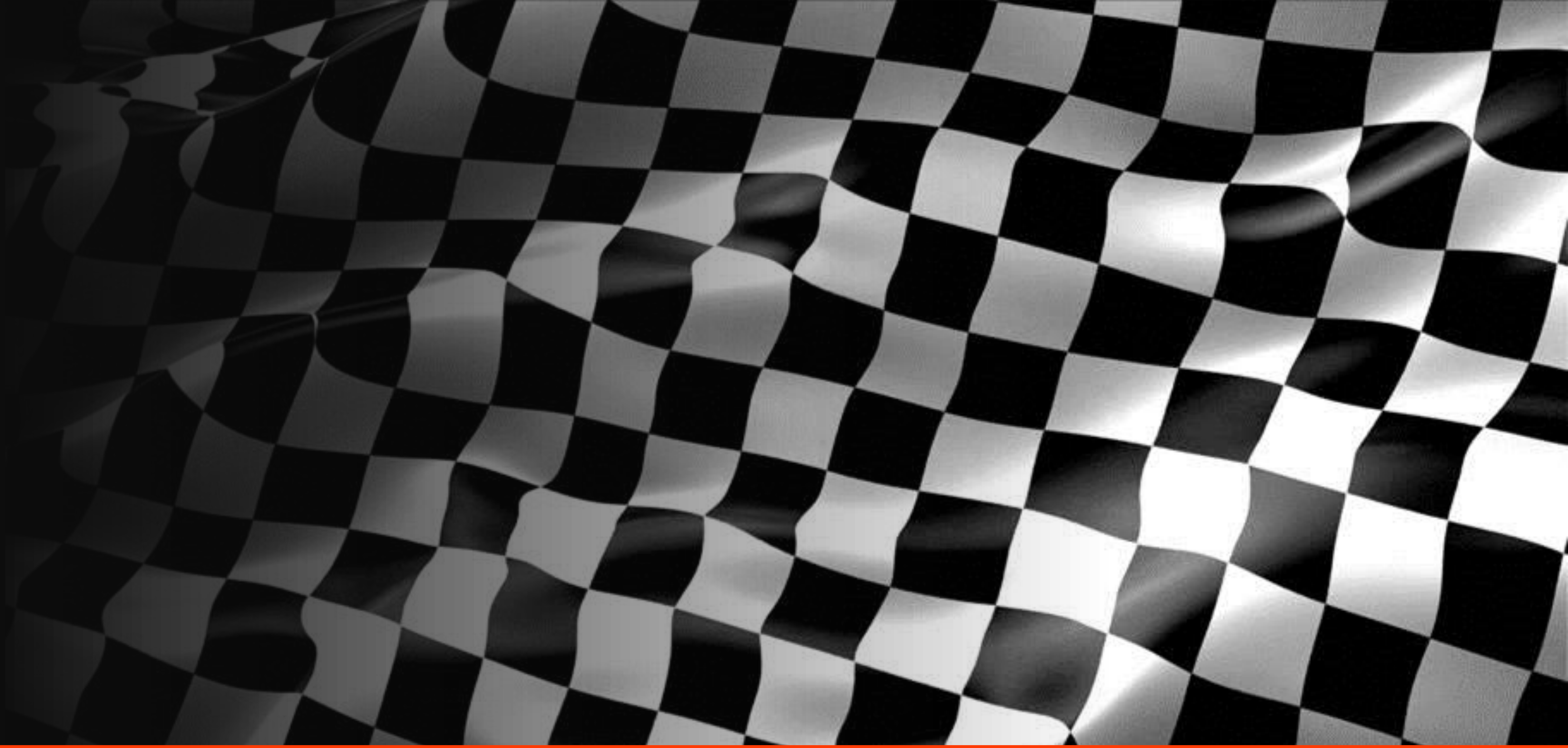
FSGC NASA Human Powered Vehicle



Team 509:

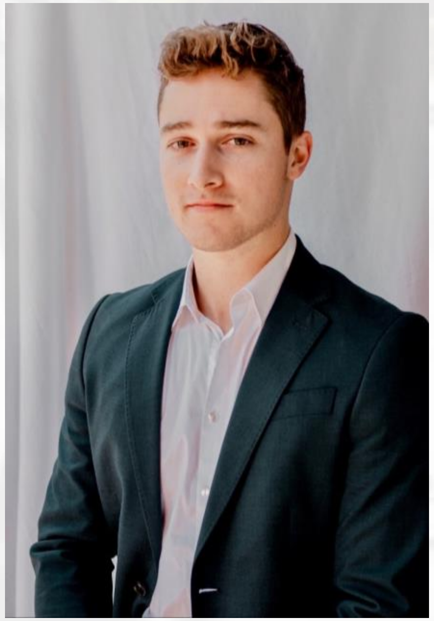
Ryan Floyd, Nicolas Picard,

Ninett Sanchez, Andrew Schlar

Presenters: Ninett Sanchez, Andrew Schlar

Andrew Schlar

NASA Human Powered Vehicle Team 509



Ryan Floyd
Materials Engineer,
Webmaster

Nicolas Picard
Design Engineer

Ninett Sanchez
Design Engineer

Andrew Schlar
Team Leader,
Design Engineer, and
Point of Contact

Andrew Schlar

Sponsor and Advisor

Florida Space Grant Consortium

Dr. Shayne McConomy

Special thanks to Dr. Shayne McConomy for advising and mentoring the team

Andrew Schlar

Project Background

- Apollo 14 lunar mission complications
- Annual NASA Human Exploration Rover Challenge Competition
- Artemis Moon Program
  - Lunar Mission 2024
  - Sustained Settlement 2028

Apollo 14 Flight Crew [1]

Andrew Schlar

Project Summary

Objective

To design and manufacture a human powered vehicle to traverse exoplanetary terrain in a NASA hosted competition

Competition Date(s)

- April 7th virtual competition videos due
- April 16th awards ceremony

Location

- Moved to virtual hosting due to COVID-19

NASA HERC Logo [8]

Ryan Floyd

Competition Targets

Competition Award Targets

- Overall Winner
- Project Review
- STEM Engagement

Competition Requirements

- Operational Readiness Review
- Evidence that volume, size, and clearance restraints are met

Optional Demonstrations

- Video of fully completed rover
- Rover traversing a minimum of 3 excursion obstacles
- 3D-printed liquid sample retrieval tool

NASA HERC Logo [8]

Ryan Floyd

Project Requirements

Dimensions

- Collapse to fit within 125 cubic feet
- 12-inch ground clearance
- 30° approach, departure, and breakover angles
- Overall width ≤ 5 feet

Input/Output

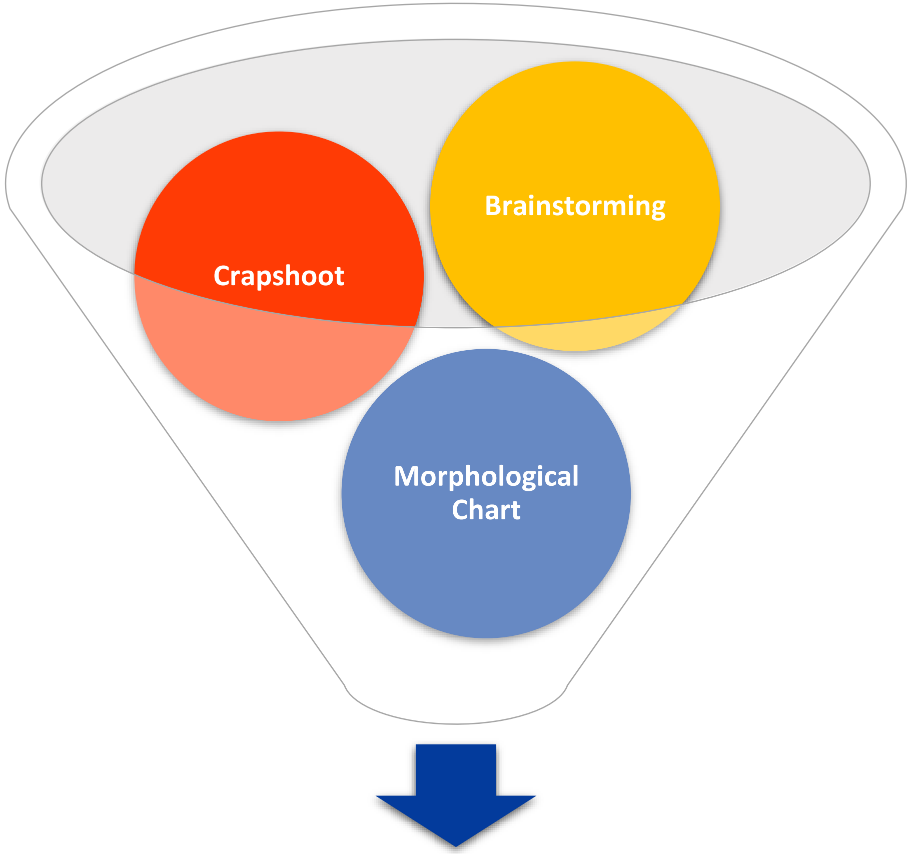
- Proportional Steering
- Maximum turning angle of 20°
- Turning radius ≤ 15 feet
- Pinion sizes: 16, 20 teeth
- Cassette, drive gear sizes: 32, 45 teeth

Safety

- Riders secured to vehicle
- Stopping distance ≤ 8 feet (from 10 mph)

Nicolas Picard

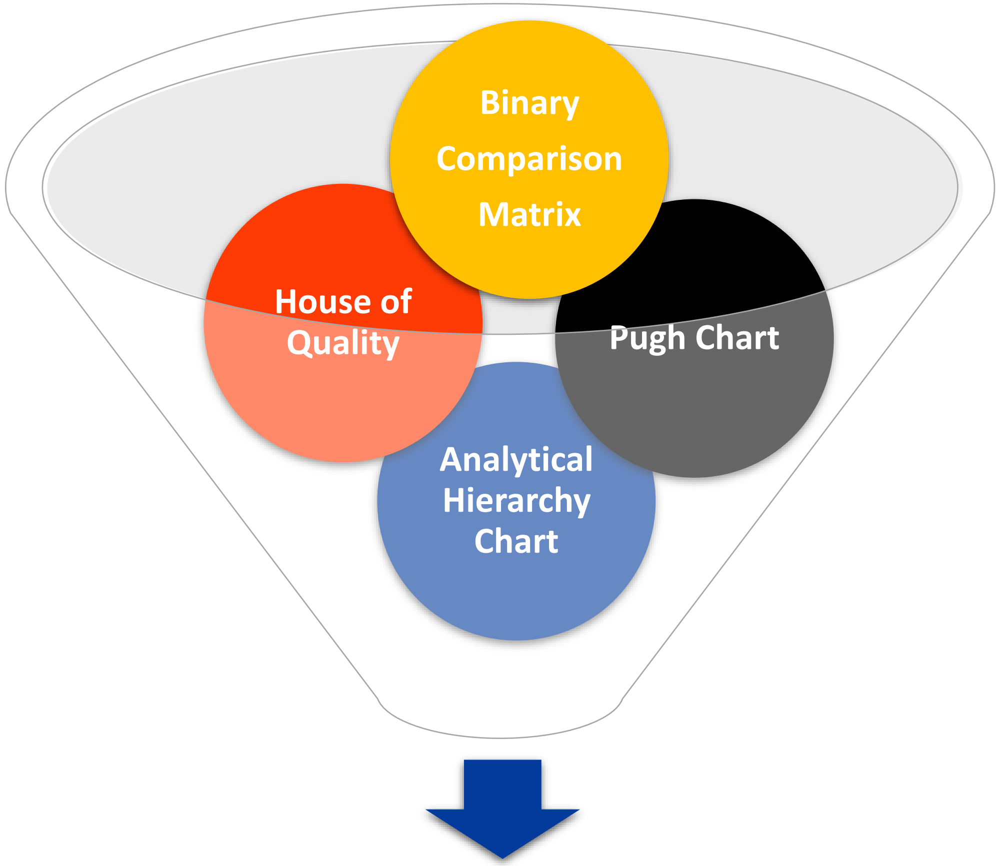
Concept Generation



Medium and High Fidelity

Nicolas Picard

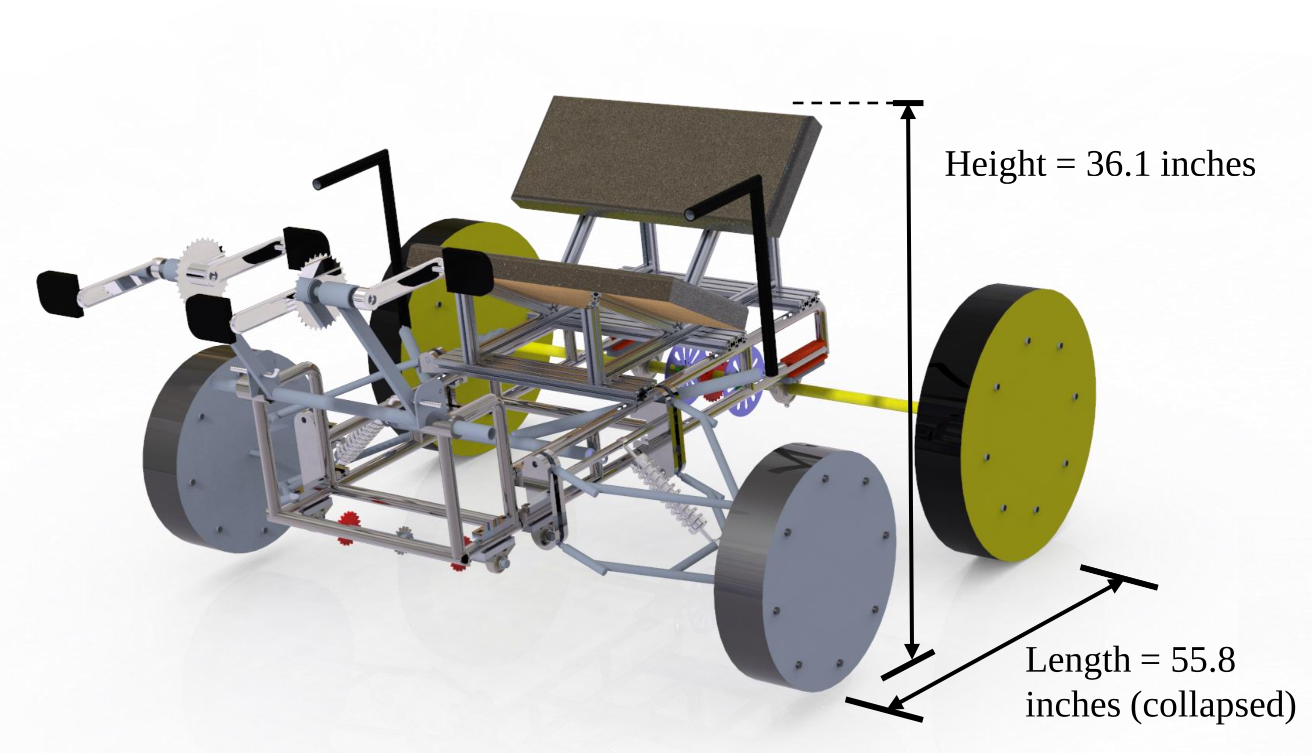
Concept Selection

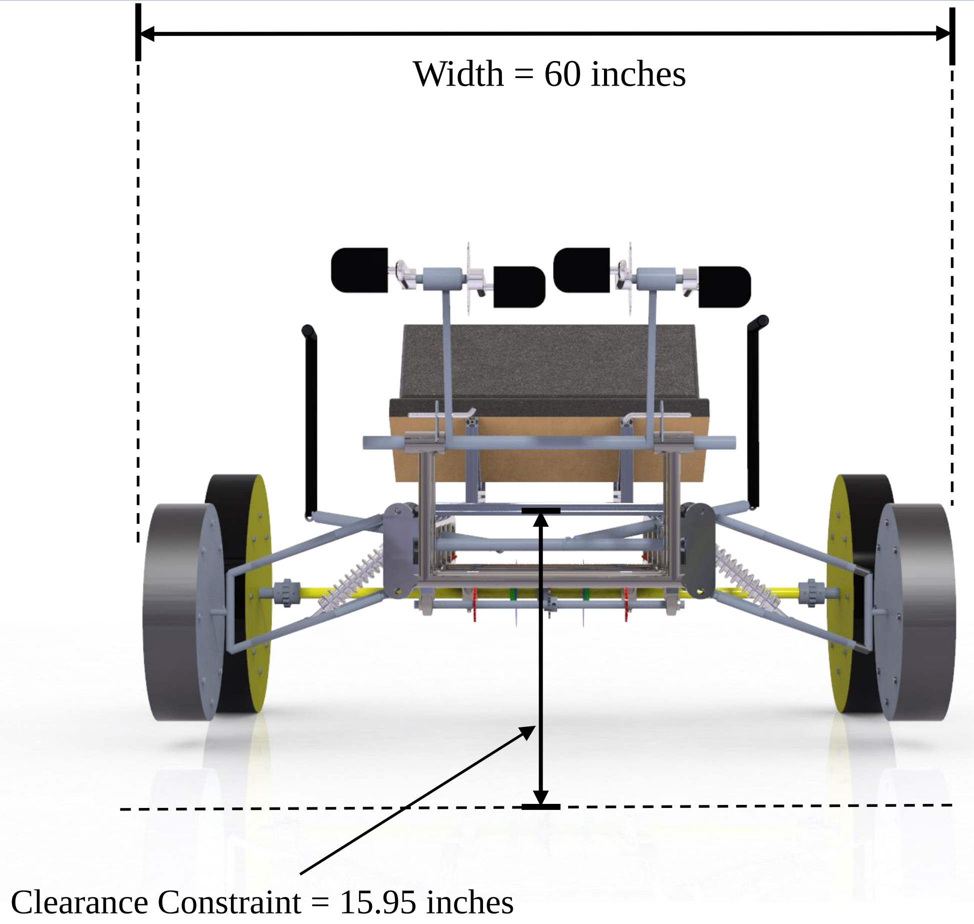


Final Selection

Nicolas Picard

Overall Rover





Ninett Sanchez

Subsystem Development

Tools: Nicolas Picard & Andrew Schlar

Steering: Ninett Sanchez

Drivetrain: Andrew Schlar

Support: Nicolas Picard

Wheels: Ryan Floyd

Ninett Sanchez

Tools

Five Tasks

- Designed specific tools for required tasks
- Concepts made for all tools, however only one will be built
- The liquid sample retrieval tool was redesigned to include a 3D printed aspect
  - Tool built for use in the demonstration video

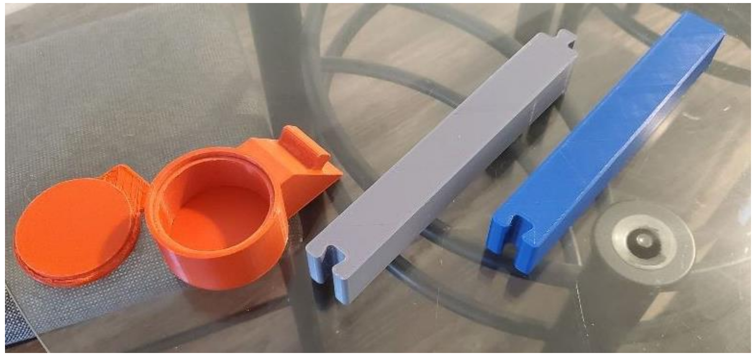
Competitors approach one of the optional tasks in the competition [3]

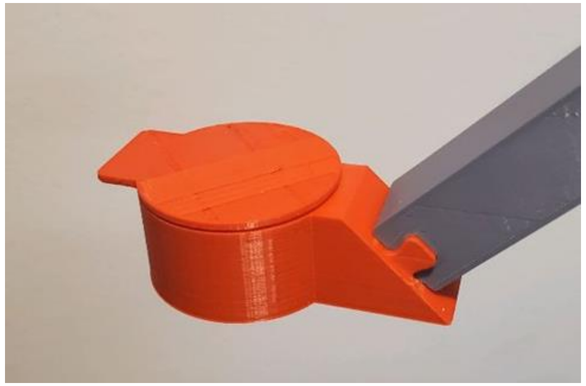
Andrew Schlar

Liquid Sample Retrieval Tool

3D Printed

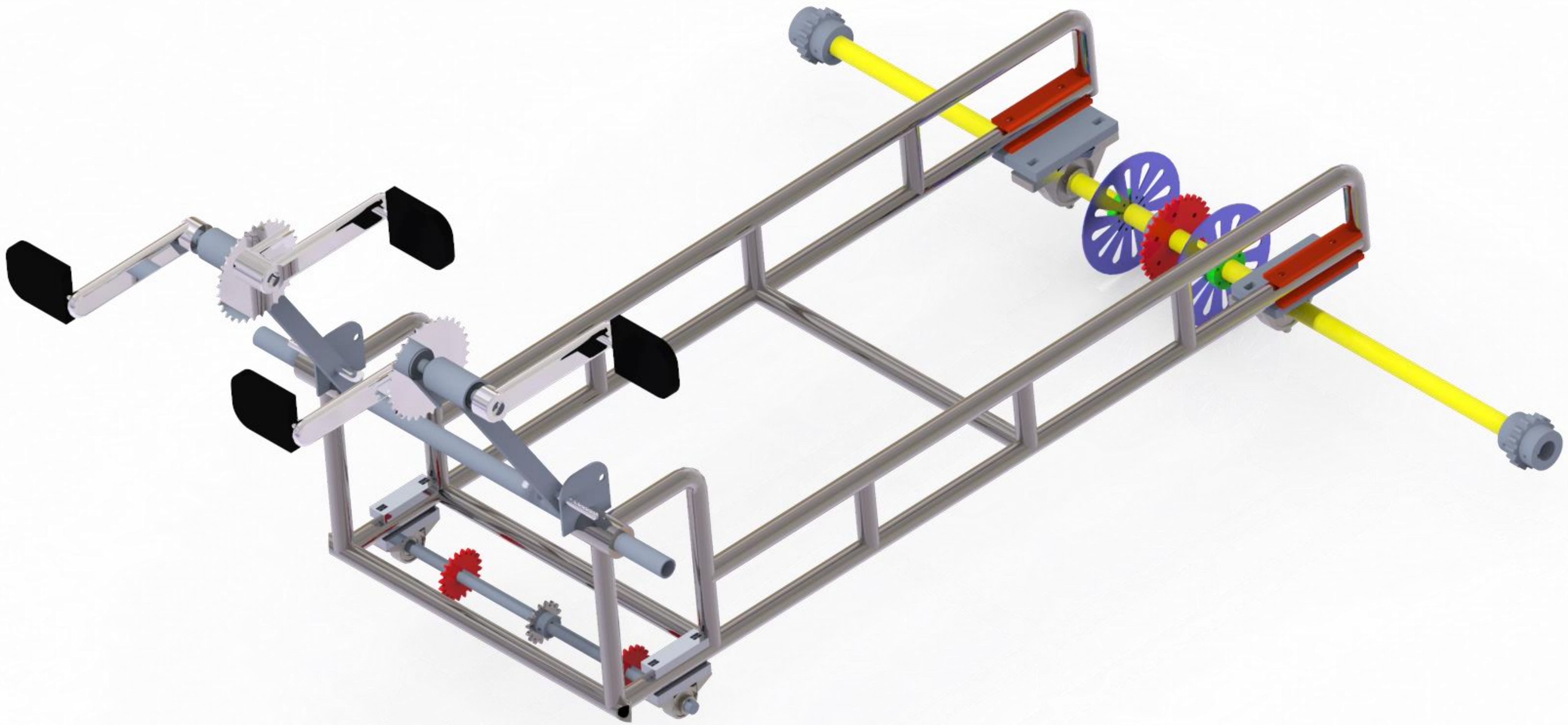
- ⚒ 27'' long pole (3 sections)
- ⚒ Friction dovetail connection to attach the 3 sections
- Flat circular scoop
  - 3 scoops in total (1 for each sample)
  - Holds 88.5 mL
- Silicone sealed lid to prevent spilling and contamination





Andrew Schlar

Rover Drivetrain

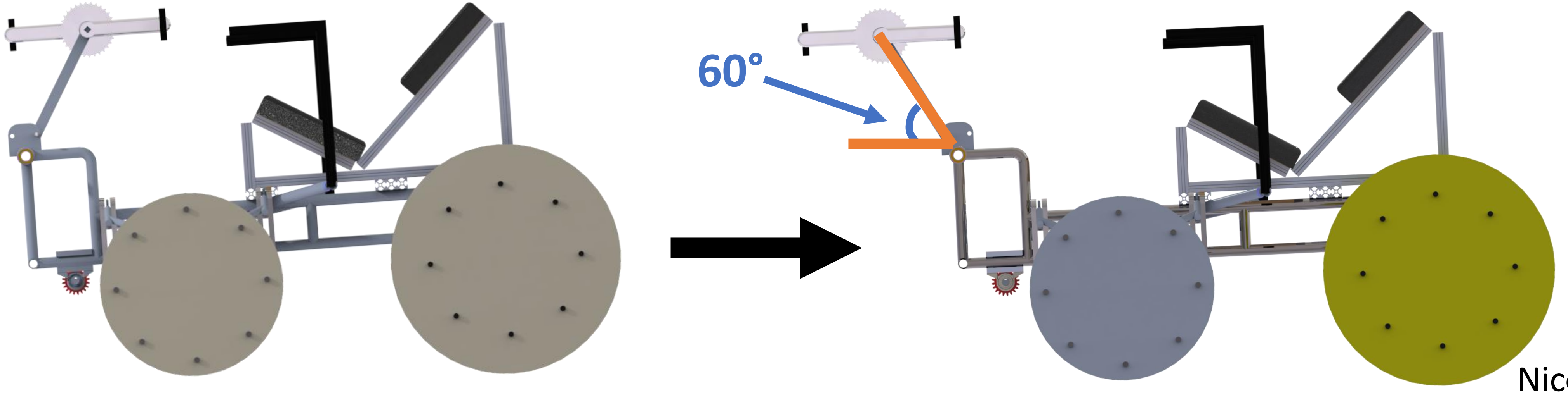


Andrew Schlar

Rover Drivetrain

Pedal System

- Pedal mount extended 12 in. from frame, 60° from horizontal
- Pedal extensions attached to a steel tube
- Steel tube is mounted to frame with brass bearings
    - Allows pedals to be folded back

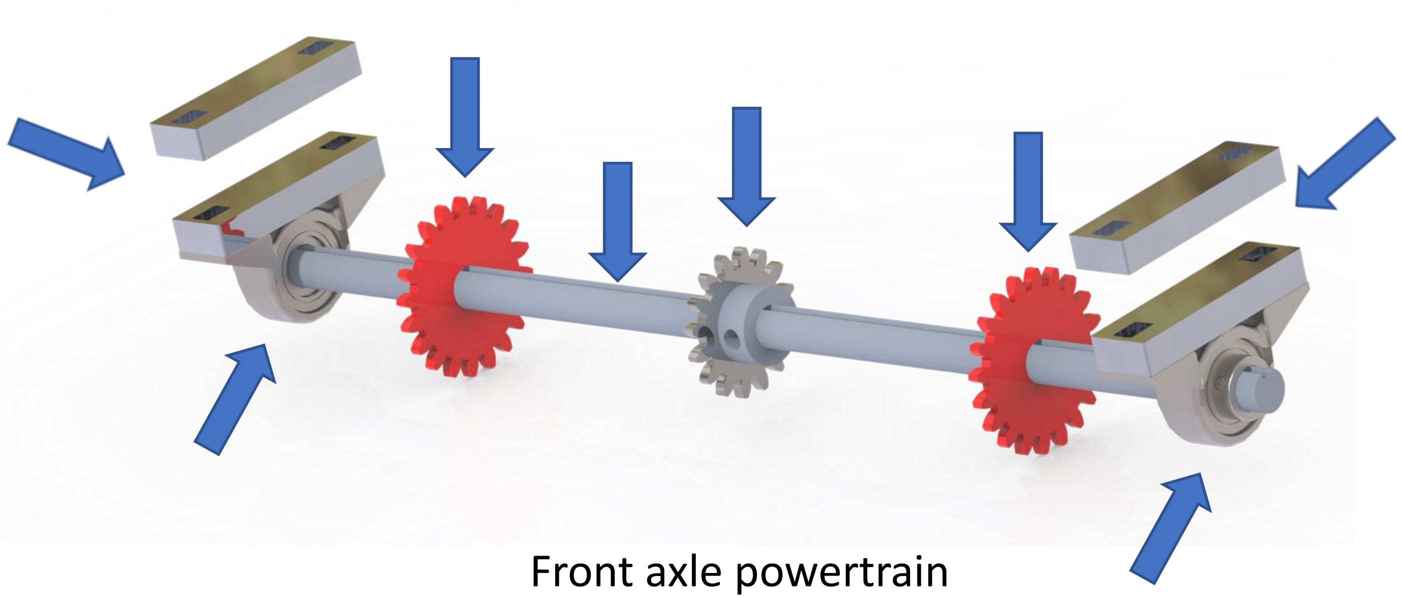


Nicolas Picard

Two-Stage Drivetrain

Front Axle Components

- 5/8” solid steel keyed driveshaft
- 20-tooth free-wheel pinions
- 16-tooth solid ANSI size 35 pinion
- 5/8” ball bearing shaft mounts
- ¼” steel plate mounting brackets



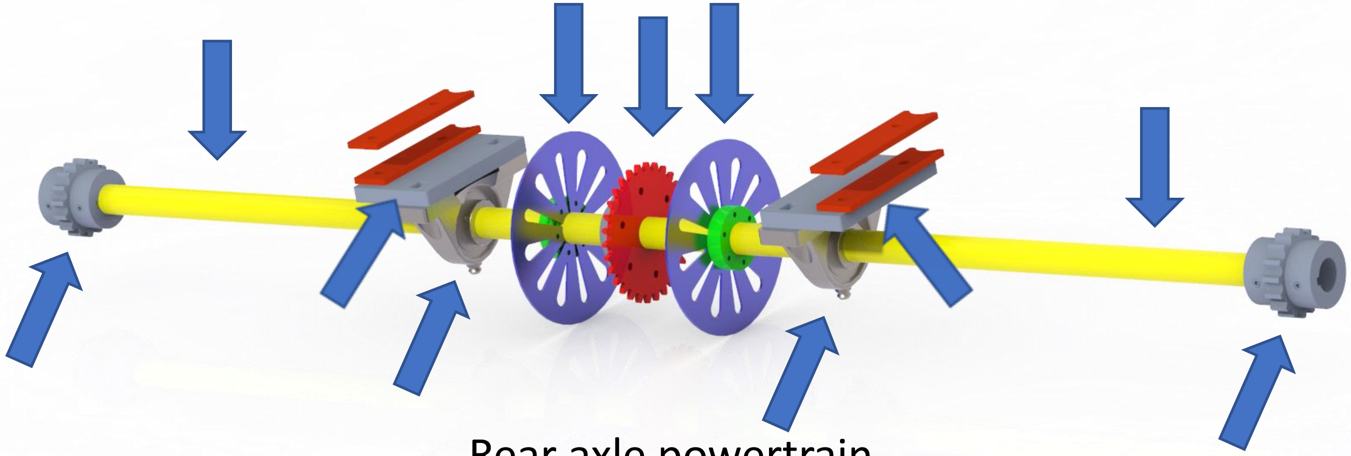
Front axle powertrain

Andrew Schlar

Two-Stage Drivetrain

Rear Axle Components

- 1” hollow steel tubing driveshaft
- 35-tooth ANSI size 35 drive gear
- Disk brake mounts and disks
- Driveshaft flexible shaft coupling
- Cast iron ball bearing housings
- Steel plate bearing adapter mounts



Rear axle powertrain

Andrew Schlar

Wheels

Wheel Objective

Design a non-pneumatic wheel that is light, cheap, and strong.

Material Selection Process

Set dimensional and performance constraints

↓

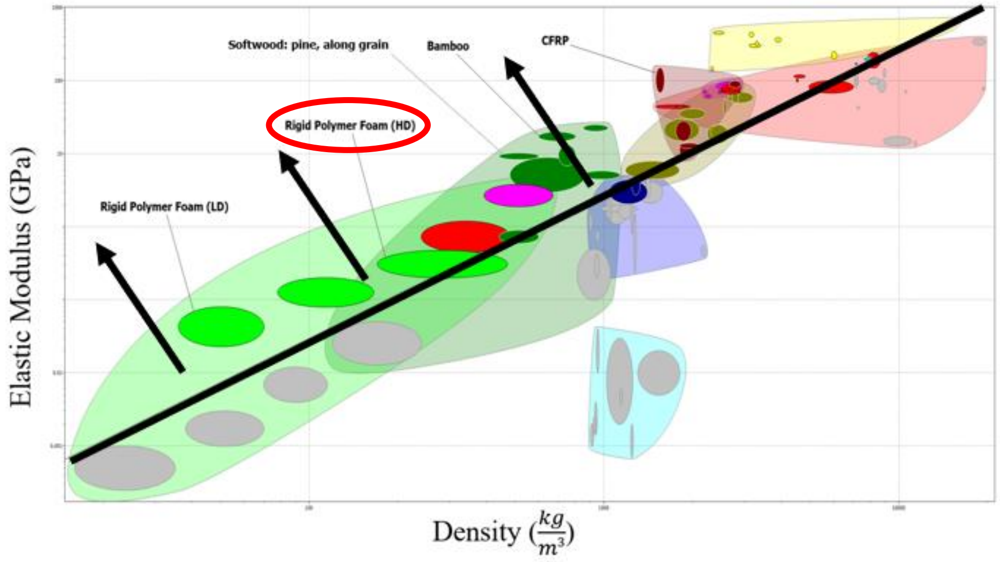
Come up with material index to satisfy objectives

↓

Pick a set of materials that score high on the index

↓

Quantitatively compare materials against each other



Ryan Floyd

Wheels

Fabrication Material: Polyurethane 2-Part Expanding Foam

Cheap

- $100 for enough material to make 4 wheels

Impressive mechanical properties

- Compressive Strength: 580 psi
- Flexural Strength: 750 psi

Easy Fabrication

- 2 Female molds from MDF and polycarbonate
  - 1 mold for front wheels, 1 mold for back wheels
- Pouring hole at the top of each mold

Polyurethane 2-Part Expanding Foam, 2lb density [5]

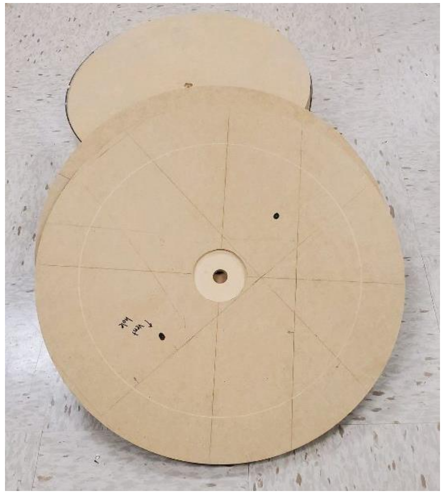
*** We will be using 8lb density*

Ryan Floyd

Wheel Fabrication

Fabrication:

- Trial wheel has been molded
- Dimensions will be finished with hot wire and sander
  - Cuts along cross-section with hot wire
  - Diameter shaping with sander
- Lightweight and rigid results

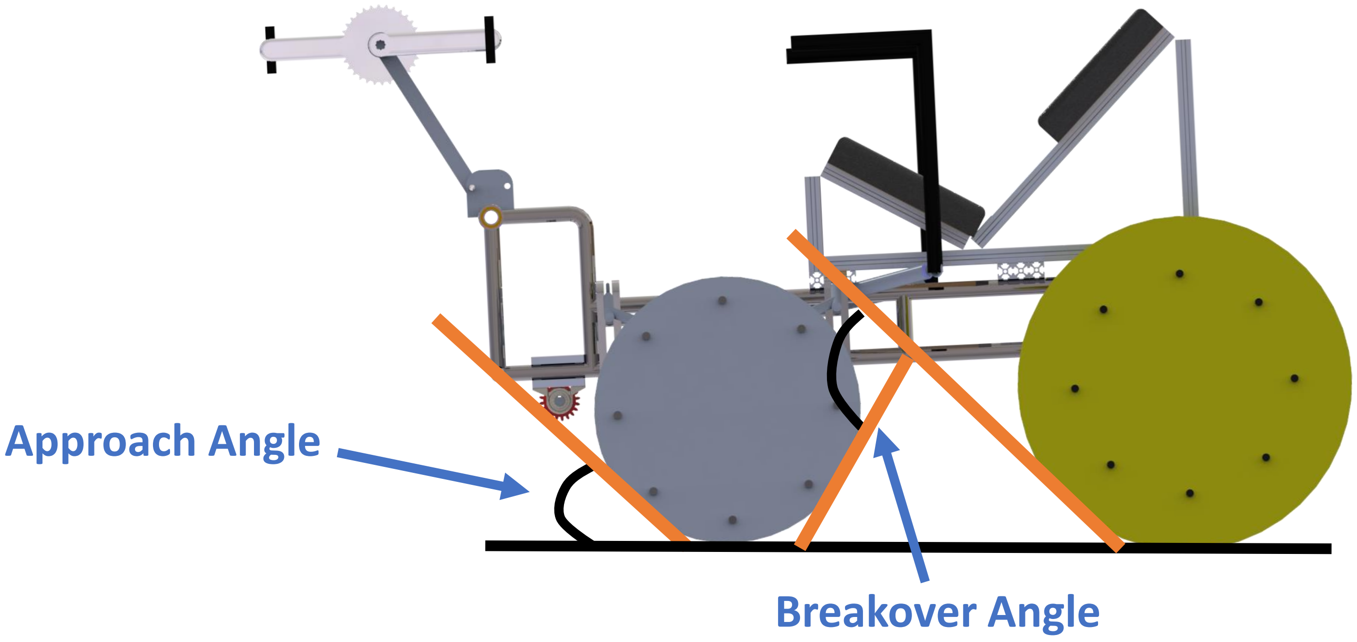


Ryan Floyd

Support

Frame

- Chromoly steel tubing frame
- Short wheelbase
  - 77° breakover angle
  - 44° approach angle
  - No departure angle



Nicolas Picard

Support

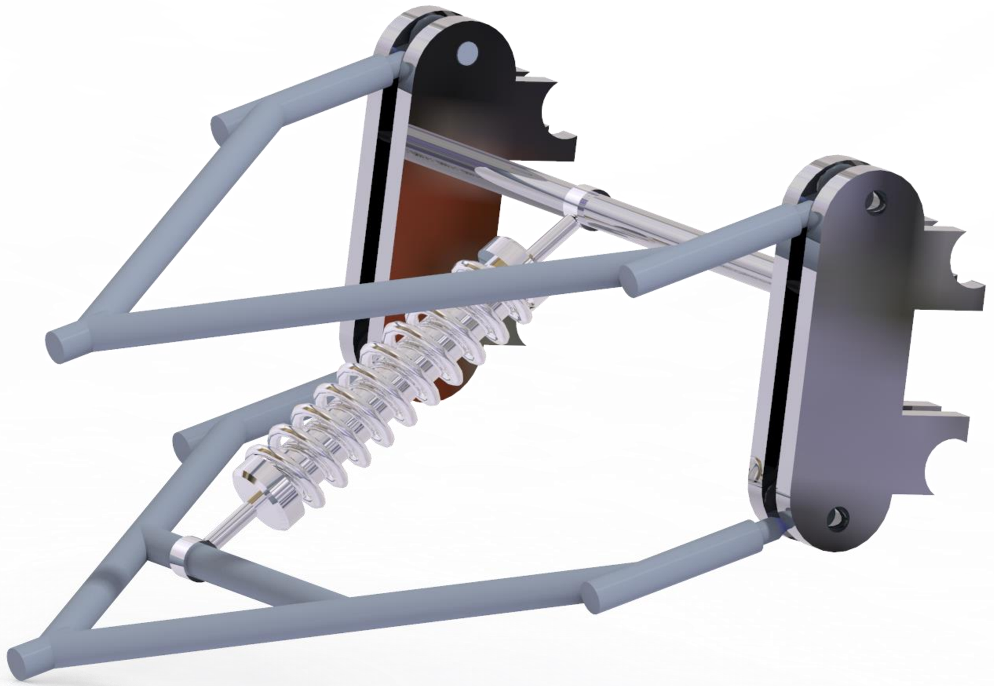
Suspension

Front:

- Double wishbone from previous team
- Utilizes mountain bike struts with spring constant of 650 lb/in
- Equal length wishbones help maintain large contact patch

Rear:

- No rear suspension → easy drivetrain implementation



Nicolas Picard

Support

Seating

- Side-by-side bench seat
- Two-point seatbelts for safety
- Mounted using 8020 aluminum
  - Allows for adjustments
- Recumbent style position
  - Seat bottom angled 30° from horizontal
  - Provides riders with optimal leg extension angle of 25°

Nicolas Picard

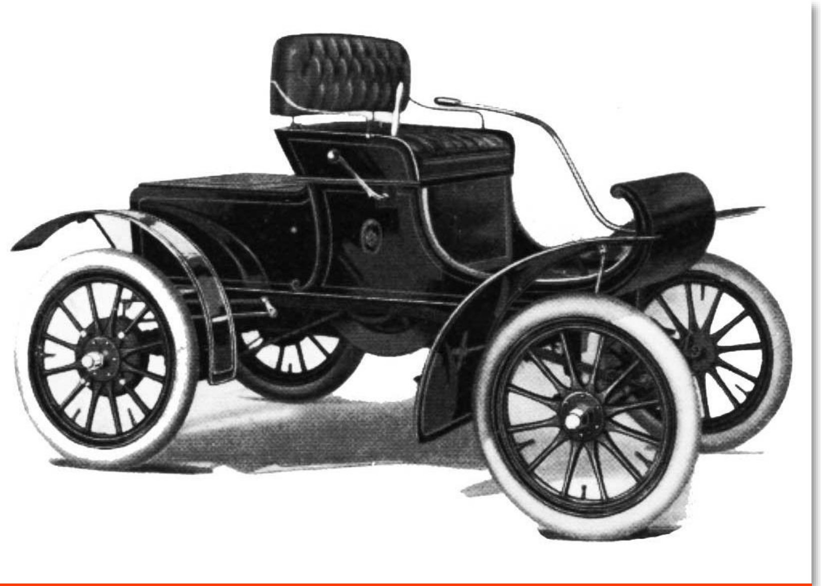
Steering

Dual Tiller Steering

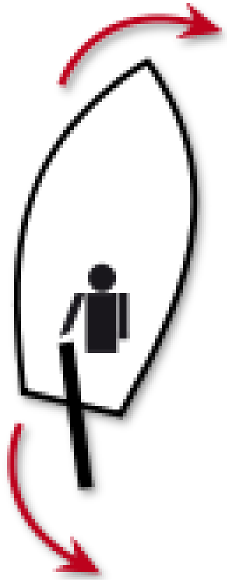
- Steering input is out of the way
- Synchronize turning of front wheels with rider communication

Important factors

- No pedal interference
- 2-person driver
- Direct steering
- Provides quick response time
- Provides leverage in the form of torque to turn



1904 Cyklonette [3]



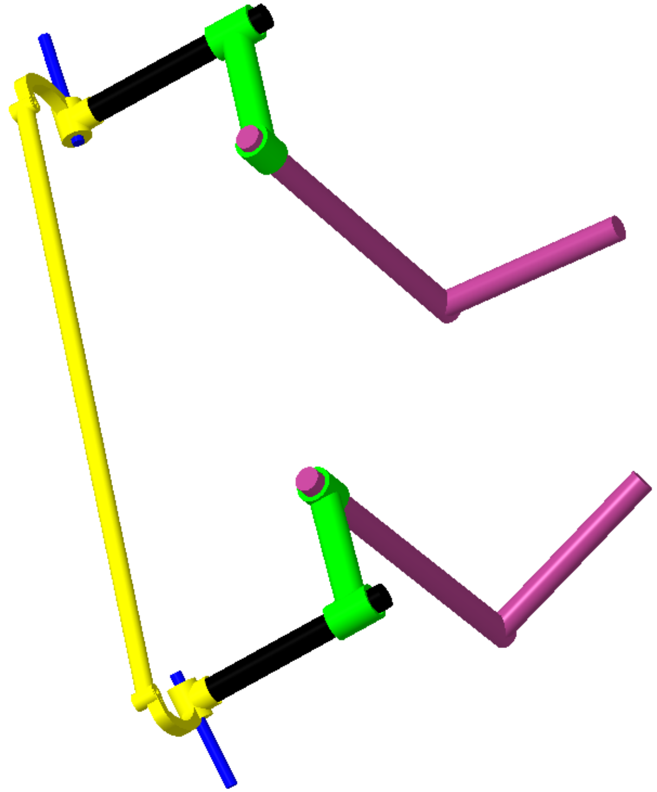
Small Boat [3]

Ninett Sanchez

Steering

Components (15 lbs)

- Aluminum handlebars
  - Outside of rider's hip
  - L- shaped handle
- 2 bolted clamps
- Kingpin axis
  - stems, spacer, headset, and steering knuckle
- Alloy steel tie rod
  - low carbon content, 70,000-psi yield strength

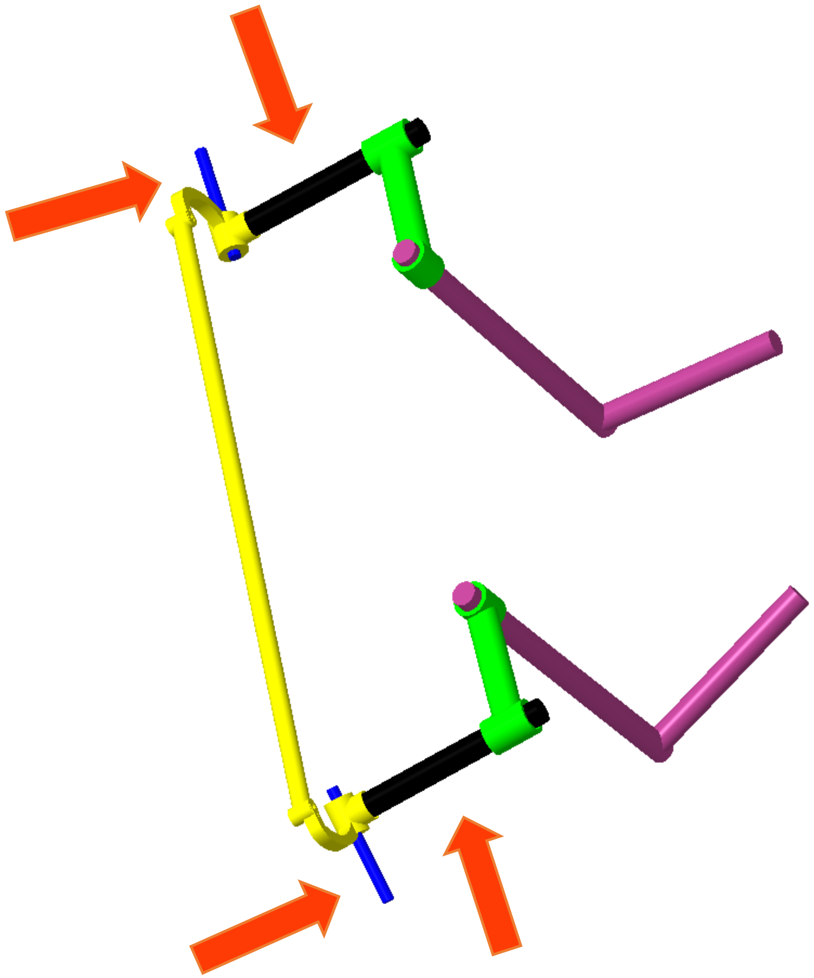


Ninett Sanchez

Steering

Wheel Integration

- Pivot points on the frame
- Steering knuckle for direct wheel to steer contact



Ninett Sanchez

Rover Dynamics

Torque & Speed Calculations

- Input torque 40.56 ft-lb per rider
  - 60 rpm input pedaling
- Output torque 110.9 ft-lb combined
- Vehicle top speed 3.5 mph
  - 75 rpm input pedaling

Andrew Schlar

Testing and Validation

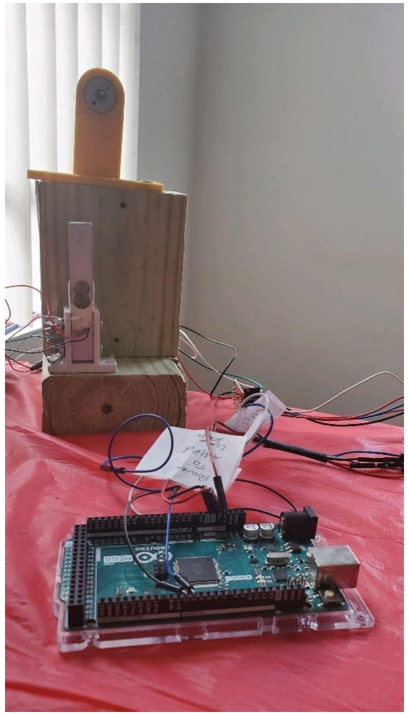
Spring constant (650 lbs/in)

- 2’’ diameter PVC pipe
- 1’’ diameter PVC pipe
- Measured deform and undeformed spring state

Wheel Torque

- Arduino based Torque Meter
- Utilizes a load sensor in conjunction with signal amplifier
- Testing speed compared to wheels
- Accurate to 0.1 Nm

Spring constant tester



Wheel torque tester

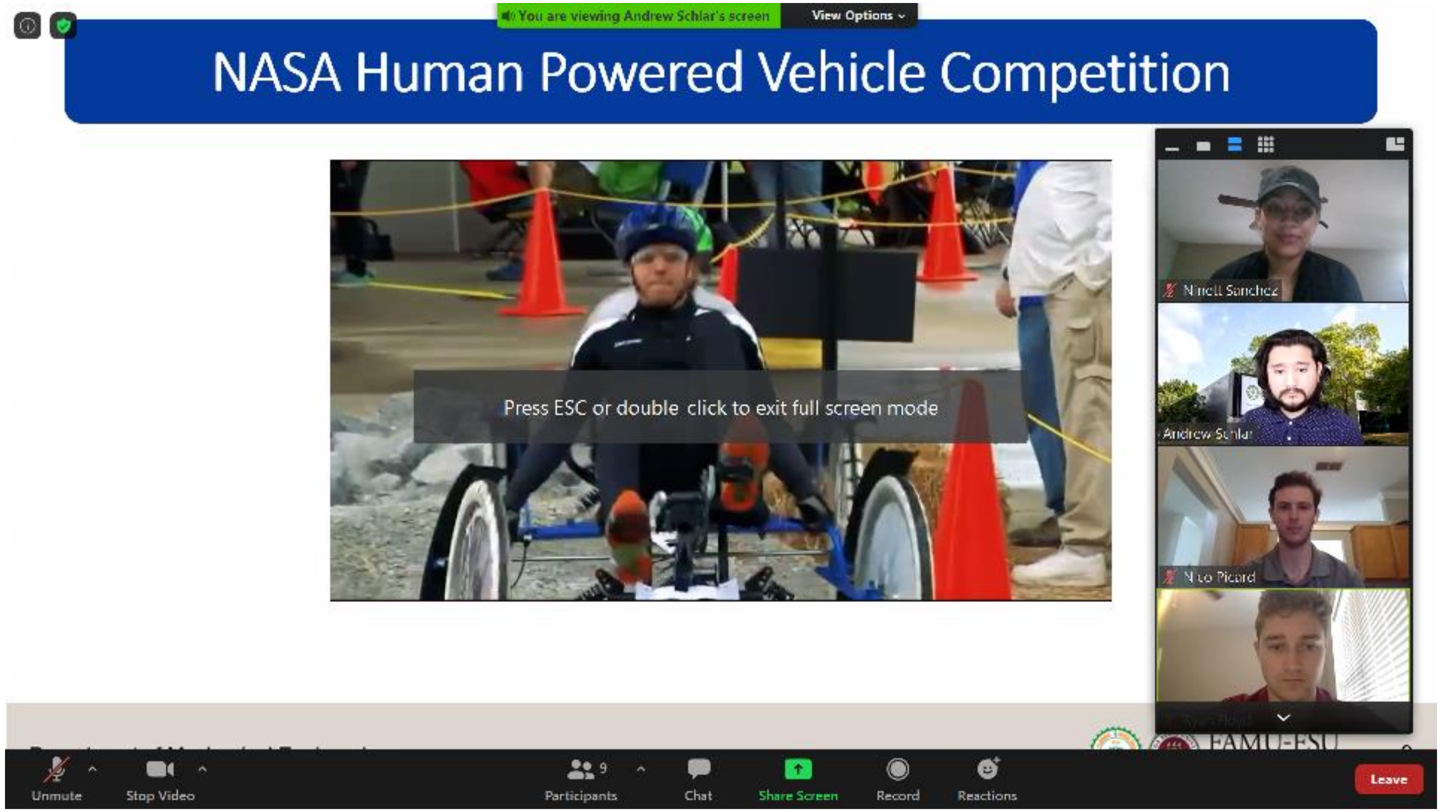
Ryan Floyd

NSBE Outreach

National Society of Black Engineers

FAMU-FSU NSBE JR. [6]

- Saturday, March 13th



Ninett Sanchez

Incomplete Work

Machining

- Many parts are currently being worked on in the machine shop

Assembly

- We will be working on assembly as we receive back our machined parts
- Plan to finish assembly by March 30^{th}

Testing

- Rover will be tested over a variety of terrain to ensure it is fully functional

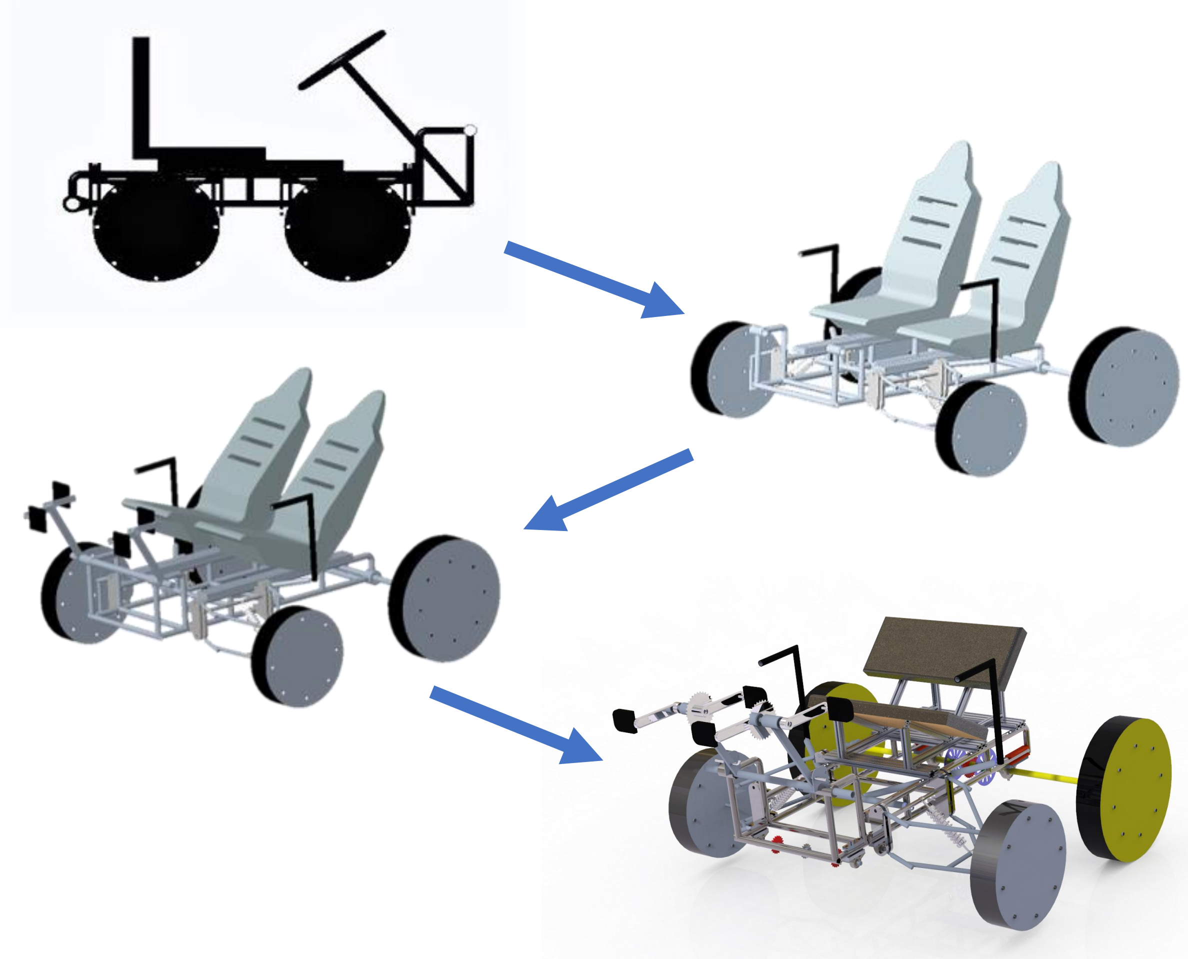
Validation

- We will be constructing 3 obstacles that resemble obstacles in the original competition
- Our rover will be validated by successfully traversing these obstacles

Nicolas Picard

Lessons Learned

- Importance of detailed CAD models
- Importance of team communication
- Level of detail required to go from theoretical ideas to physical prototypes
- Contact machine shop for design verification

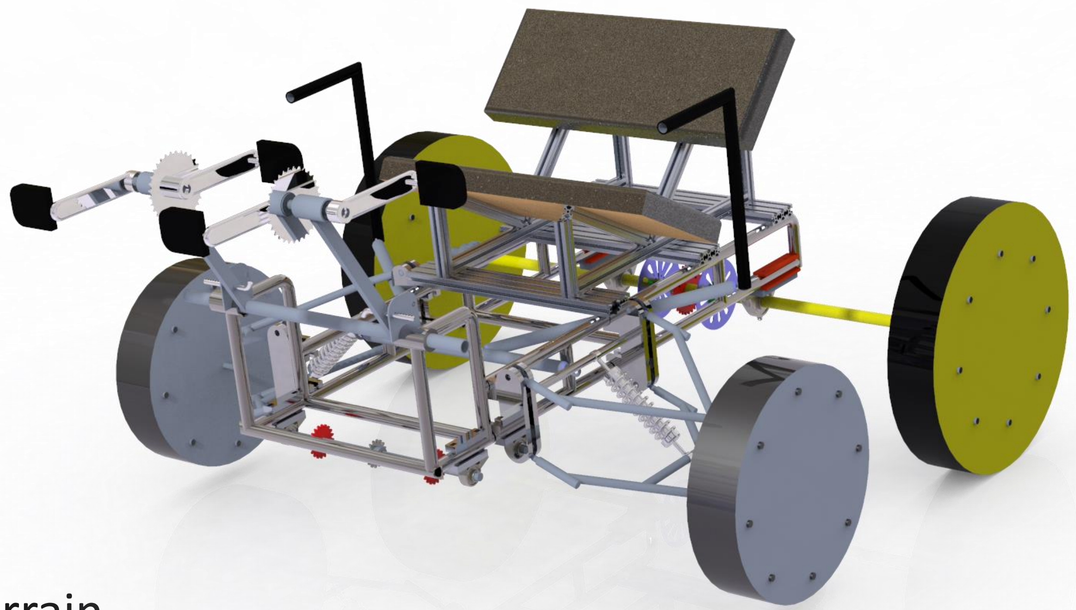


Nicolas Picard

Summary

Rover

- Two-stage drivetrain with rear wheel drive
- Wheels made of polyurethane foam
- Steel tubing frame
- Double wishbone suspension
- Recumbent bench seating
- Dual tiller steering



Validation

- Driven through obstacles simulating lunar terrain
- Video submitted to NASA Competition

Nicolas Picard

Acknowledgement

- Florida Space Grant Consortium
- Special Thanks to Dr. Shayne McConomy
- Dr. Patrick Hollis
- Jessica Meeker
- Dr. Renee Gordon
- FAMU-FSU NSBE
- Justin Pogge

Andrew Schlar

Questions?

FSGC NASA Human Powered Vehicle

Our job is to design and manufacture a human powered vehicle to traverse exoplanetary terrain in a NASA hosted competition.

Feel free to ask us any questions.

Andrew Schlar

Section Links

Project Background

Competition

Project Requirements

Concept Generation

Concept Selection

Project Progress

Acknowledgements

References

Team 509

References

[1] Apollo 14 Crew Portrait. (2016, February 5). NASA. https://www.nasa.gov/image-feature/apollo-14-crew-portrait/

[2] Archive, N. (2019, May 15). NASA Celebrates 25th Anniversary Human Exploration Rover Challenge. Retrieved October 15, 2020, from https://www.flickr.com/photos/nasamarshallphotos/40890053883/in/album-72157705115914232/

[3] Nasa. (2020, January 13). The rover doctor is in: The Anatomy of a NASA human Exploration Rover Challenge Rover. Retrieved February 16, 2021, from https://nasa.tumblr.com/post/190237928704/the-rover-doctor-is-in-the-anatomy-of-a-nasa

[4] Uttley, C. (2009, October 05). How off-roading works. Retrieved February 16, 2021, from https://adventure.howstuffworks.com/outdoor-activities/off-roading/off-roading1.htm

[5] Top 10 most popular RoadBikeReview articles of 2015. (n.d.). Retrieved February 16, 2021, from https://www.roadbikereview.com/threads/top-10-most-popular-roadbikereview-articles-of-2015.380765/

[6] NSBE Logo. https://www.nsbe.org/Downloads/Official-Downloads/NSBE-Logo-Downloads.aspx#.YCyid2hKg2w

[7] TCC Logo. https://www.tcc.fl.edu/academics/academic-divisions/science-and-mathematics/tallahassee-science-festival/gmstem/

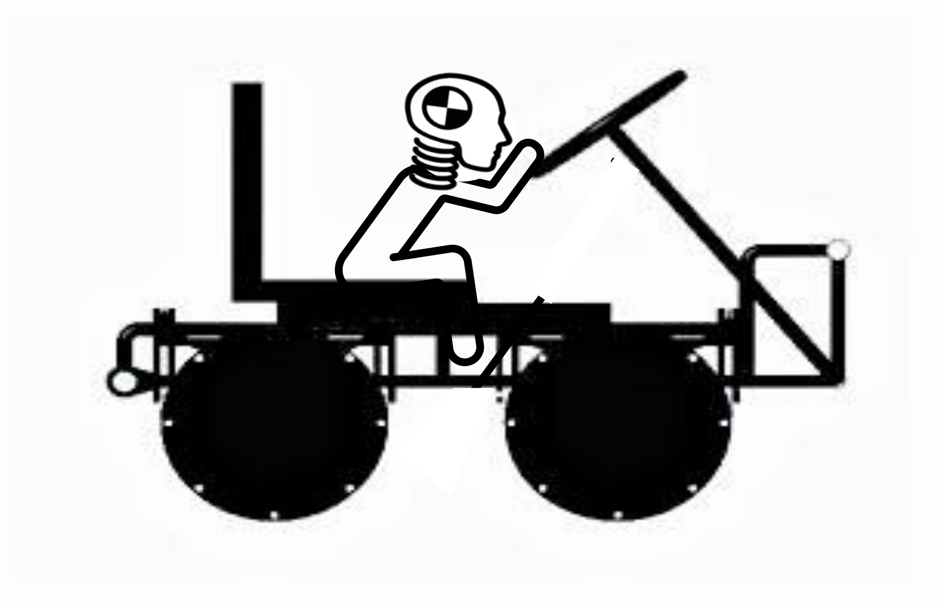
[8] Rover Competition Logo. file://HERC%20Feb%20Email%201%20.pdf

Backup Slides

Team 509

Validation

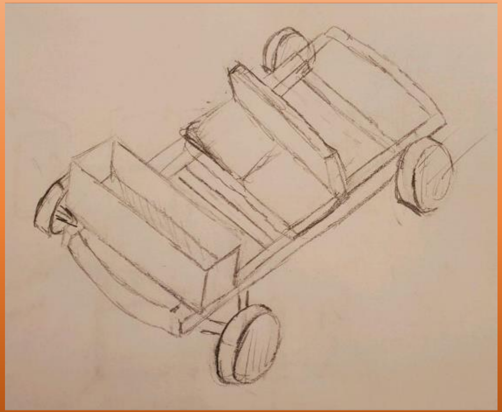
- ✓ Subsystems and components will be tested individually for their performance prior to competition
- ✓ Design will be fully validated in the field during the competition



Nicolas Picard

Medium Fidelity

Disk Brakes



Fronk Design

[7]

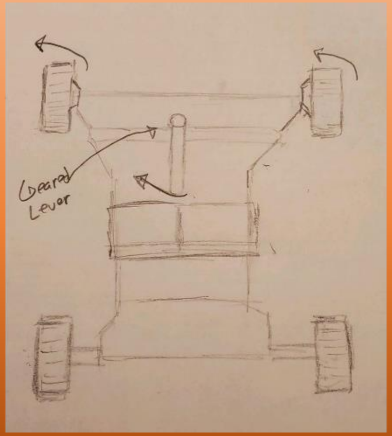
3-Point Seatbelt

Ninett Sanchez

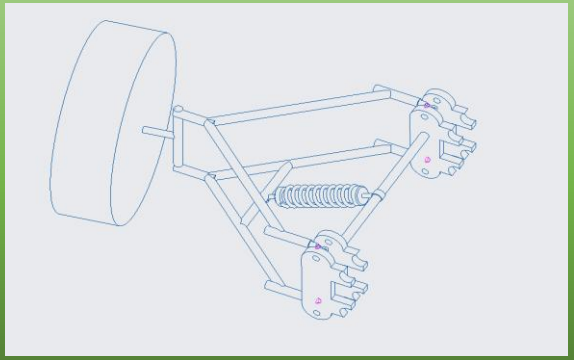
Medium Fidelity

[8]

Sample Gathering Tool



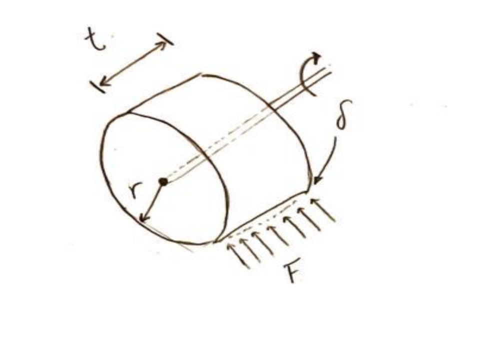
Tiller Steering Mechanism



Double Wishbone Suspension (Front and Rear)

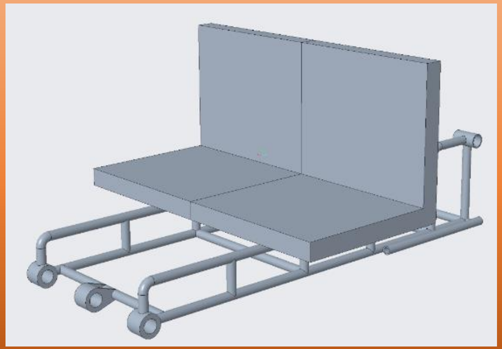
Ninett Sanchez

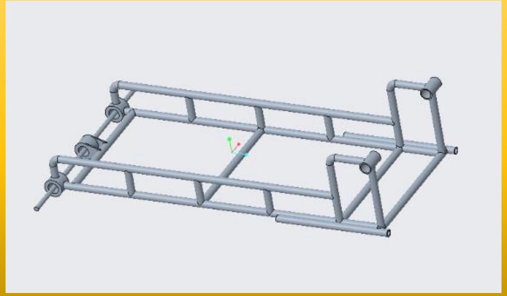
High Fidelity



High Density Rigid Polymer Foam Wheels

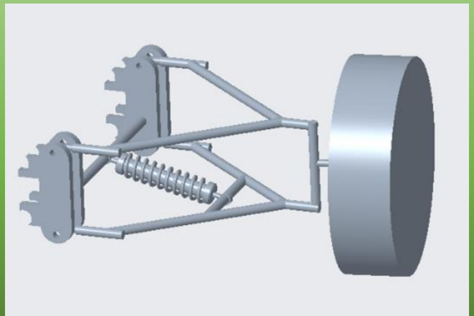
Side-by-Side Seating





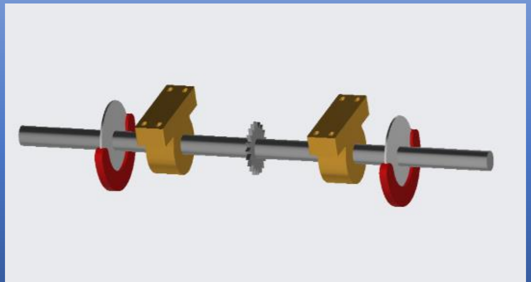
Frame from Previous Year's Team 514

Double Wishbone Suspension (Front only)

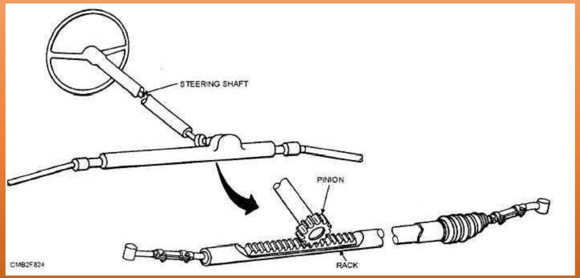


Ninett Sanchez

High Fidelity



Rear Axle Powertrain and Disk Brakes



[9]

Rack and Pinion Steering

[10]

2-Point Seatbelt

Ninett Sanchez

Binary Comparison

Binary Comparison Matrix

House of Quality

Pugh Chart

Analytical Hierarchy Chart

Customer Requirements	Importance Weight Factor
Maintain Functionality	7
Cost Effective	6
Maintain Operator Safety	5
Ease of Production	4
Handle Rough Terrain	2
Rider Size Accommodation	2
Ease of Assembly	2

Nicolas Picard

House of Quality

Binary Comparison Matrix

House of Quality

Pugh Chart

Analytical Hierarchy Chart

		Engineering Characteristics						
Improvement Direction	↑	↑	↓	↑	↑	↑	↑	↑
Units		N/A	inches	Number of seats	inches	inches*lbf	in	in^3 N/A
Customer Requirements	Importance Weight Factor	Stability	Turning Radius	Seating Accommodation	Ground Clearance	Rover Torque	Stopping Distance	Storage
Handle rough terrain	2	8	4	0	8	4	2	0
Maintain operator safety	5	4	2	8	2	0	2	0
Maintain functionality	7	2	2	0	2	8	8	4
Ease of production	4	0	0	4	4	4	2	2
Rider size accommodation	2	4	0	8	2	2	2	4
Cost effective	6	4	2	2	2	4	0	2
Ease of assembly	2	2	2	4	2	2	0	0
Raw Score (552)		86	48	92	76	112	82	56
Relative Weight (%)		15.58	8.70	16.67	13.76	20.29	14.86	10.14
Rank Order		3	7	2	6	1	4	5

Nicolas Picard

House of Quality

Binary Comparison Matrix

House of Quality

Pugh Chart

Analytical Hierarchy Chart

		Engineering Characteristics						
Improvement Direction	↑	↑	↓	↑	↑	↑	↑	↑
Units		N/A	inches	Number of seats	inches	inches*lbf	in	in^3 N/A
Customer Requirements	Importance Weight Factor	Stability	Turning Radius	Seating Accommodation	Ground Clearance	Rover Torque	Stopping Distance	Storage
Handle rough terrain	2	8	4	0	8	4	2	0
Maintain operator safety	5	4	2	8	2	0	2	0
Maintain functionality	7	2	2	0	2	8	8	4
Ease of production	4	0	0	4	4	4	2	2
Rider size accommodation	2	4	0	8	2	2	2	4
Cost effective	6	4	2	2	2	4	0	2
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Nicolas Picard

House of Quality

Binary Comparison Matrix

House of Quality

Pugh Chart

Analytical Hierarchy Chart

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Raw Score (552)		86	48	92	76	112	82	56
Relative Weight (%)		15.58	8.70	16.67	13.76	20.29	14.86	10.14
Rank Order		3	7	2	6	1	4	5

Nicolas Picard

Steering Pugh Chart

Binary Comparison Matrix

House of Quality

Pugh Chart

Analytical Hierarchy Chart

Steering				
	Concepts			
Engineering Characteristics	Rack and pinion Steering from previous year	Tiller Steering Mechanism	Double Wheel Steering	Rear Wheel Steering
Stability	Datum	S	-	-
Turning Radius		-	-	-
Seating Accommodation		S	S	S
Ground Clearance		+	S	S
Drivetrain Torque		S	S	S
Stopping Distance		S	S	S
Storage		S	S	S
# pluses		1	0	0
# minuses		1	2	2

Ninett Sanchez

Suspension Pugh Chart

Binary Comparison Matrix

House of Quality

Pugh Chart

Analytical Hierarchy Chart

Suspension				
	Concepts			
Engineering Characteristics	Double wishbone suspension (front)	No suspension	Double wishbone suspension (front and rear)	MacPherson Strut (front)
Stability	Datum	-	+	-
Turning Radius		S	S	S
Seating Accommodation		S	S	S
Ground Clearance		+	-	S
Rover Torque		-	+	S
Stopping Distance		-	-	S
Storage		S	S	S
# pluses		1	2	0
# minuses		3	2	1

Ninett Sanchez

Frame Pugh Chart

Binary Comparison Matrix

House of Quality

Pugh Chart

Analytical Hierarchy Chart

Frame				
	Concepts			
Engineering Characteristics	Frame from previous year	Elongated and segmented frame from previous year	Single beam, segmented frame	Wooden frame with center fold joint
Stability	Datum	-	-	-
Turning Radius		-	-	-
Seating Accommodation		S	S	S
Ground Clearance		S	S	S
Rover Torque		S	S	S
Stopping Distance		S	S	S
Storage		+	+	-
# pluses		1	1	0
# minuses		2	2	3

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Wheels Pugh Chart

Binary Comparison Matrix

House of Quality

Pugh Chart

Analytical Hierarchy Chart

Wheels				
	Concepts			
Engineering Characteristics	Cork wheels, solid throughout	High density rigid polymer foam wheels	Wooden wheels	Patterned aluminum wheels
Stability	Datum	+	-	-
Turning Radius		S	S	S
Seating Accommodation		S	S	S
Ground Clearance		+	+	+
Rover Torque		S	-	-
Stopping Distance		S	S	S
Storage		S	S	S
# pluses		2	1	1
# minuses		0	1	2

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Analytical Hierarchy Process

- Binary Comparison Matrix
- House of Quality
- Pugh Chart
- **Analytical Hierarchy Chart**

Evaluation Criteria

Final Concepts

Evaluated Comparison

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Final Selection

- Double wishbone front suspension
- Side-by-side forward facing seating
- Rack and pinion steering
- Rear-axle drive train
- Rear-axle disk brakes

Nicolas Picard

Binary Comparison

Binary Comparison Matrix

House of Quality

Pugh Chart

Analytical Hierarchy Chart

	1	2	3	4	5	6	7	8	Total
1. Handle rough terrain	-	0	0	0	0	0	1	1	2
2. Maintain operator safety	1	-	0	1	1	0	1	1	5
3. Maintain functionality	1	1	-	1	1	1	1	1	7
4. Ease of production	1	0	0	-	1	0	1	1	4
5. Rider size accommodation	1	0	0	0	-	0	0	1	2
6. Cost effective	1	1	0	1	1	-	1	1	6
7. Ease of assembly	0	0	0	0	1	0	-	1	2
Total	5	2	0	3	5	1	5	7	-

Team 509

Driveshaft Calculations

Torsion of Shaft Calculator:

Shaft style	○Solid Shaft ◉Hollow Shaft	
INPUT PARAMETERS		
Parameter	**Value**	
Torque [T]	166	lbf*ft
Rotation speed [w]	82	rpm
Shaft outer radius [c_2]	1	inch
Shaft inner radius [c_1]	0.188	inch
Shaft length [L]	48	inch
Modulus of rigidity [G]	11.12	psi*10^6
Calculate		

RESULTS		
Parameter	**Value**	
Maximum shear stress [τ_{max}]	1269.733	psi
Angle of twist [θ]	0.005	Radian
Power requirement [P]	2.592	hp
Polar moment of inertia [J]	0	ft^4

Source: https://amesweb.info/Torsion/torsion-of-shaft-calculator.aspx

Team 509

Rover Dynamics Calculations

Powertrain

35 tooth drive gear, 16 tooth intermediate

Assumy 55 Nm input
65 rpm

max rpm
input = 75 rpm

1st Stage

$$T_{out} = \frac{20}{32}\left(2\left(40.5659\right)\right) = 50.707 \text{ ft-lb}$$

2nd Stage

$$T_{out} = \frac{35}{16}\left(50.707\right) \text{ ft-lb} = 110.9223828 \text{ ft-lb}$$

rear wheel radius
10.675

$$\tau_1 \omega_1 = \tau_2 \omega_2$$

@ 65 rpm
input
55 Nm

$$81.1318(65) = 50.707\,\omega_2$$

intermediate axle $\rightarrow$ $\omega_2 = 104.000$ rpm

rear axle

$$50.707(104) = 110\,\omega_3$$

$$\omega_3 = 47.941 \text{ rpm}$$

Linear vel = r x RPM x $\underbrace{0.10472}_{\text{unit conversion}}$

$V = 3.04$ mph @ 65 rpm
Avg speed

Powertrain continued

35 tooth rear drive, 16 tooth intermediate

@ 75 rpm
55 Nm

input max torque $\rightarrow$ $81.1318(75) = \tau_2 \omega_2 = 50.707\,\omega_2$

$$\omega_2 = 120 \text{ rpm}$$

$$50.707(120) = 110.922(\omega_3)$$

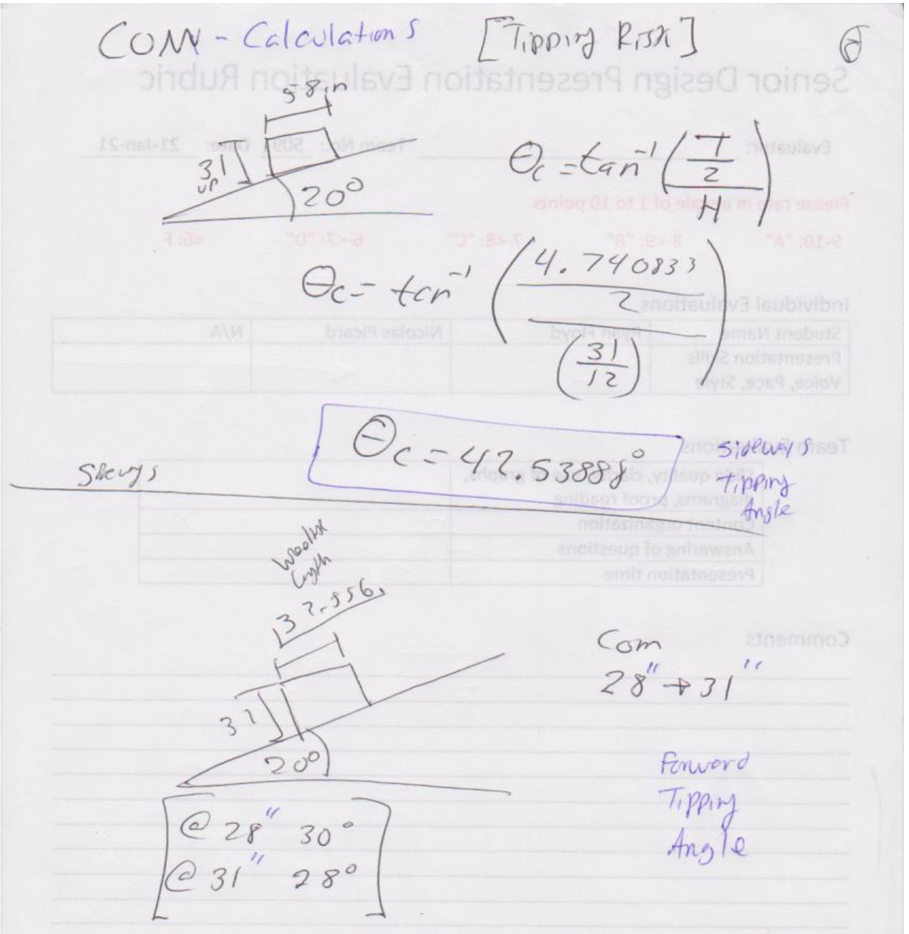
$$\omega_3 = 54.8569 \text{ rpm}$$

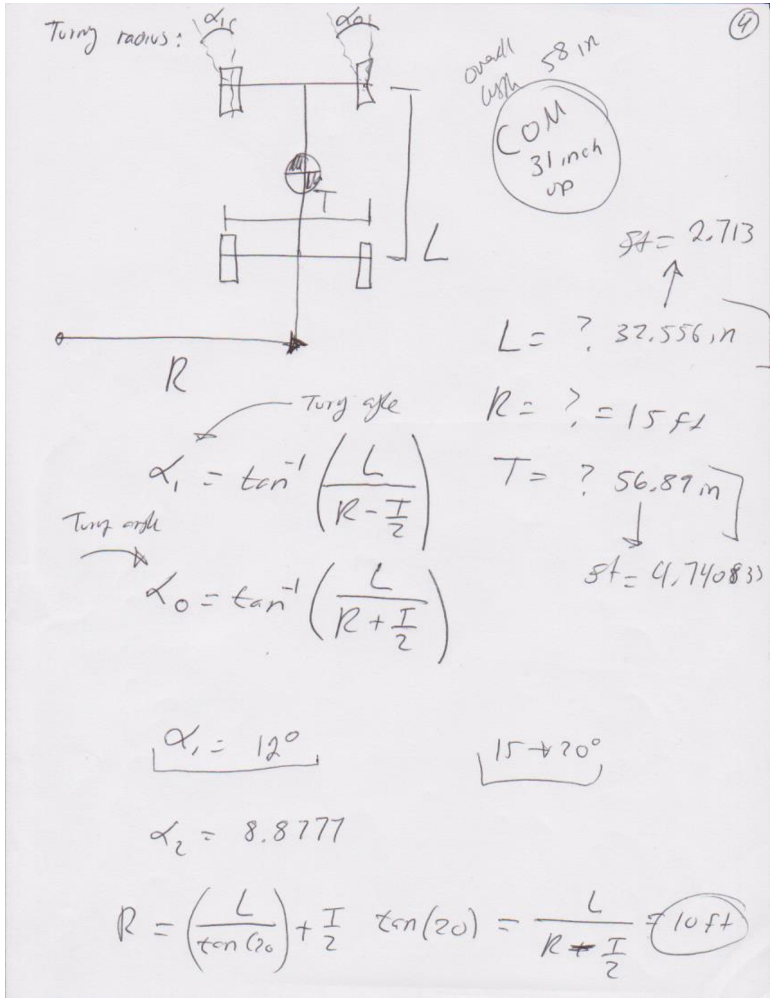
$V = 3.48$ mph max speed

Assumy 94% efficiency chain drive

Team 509

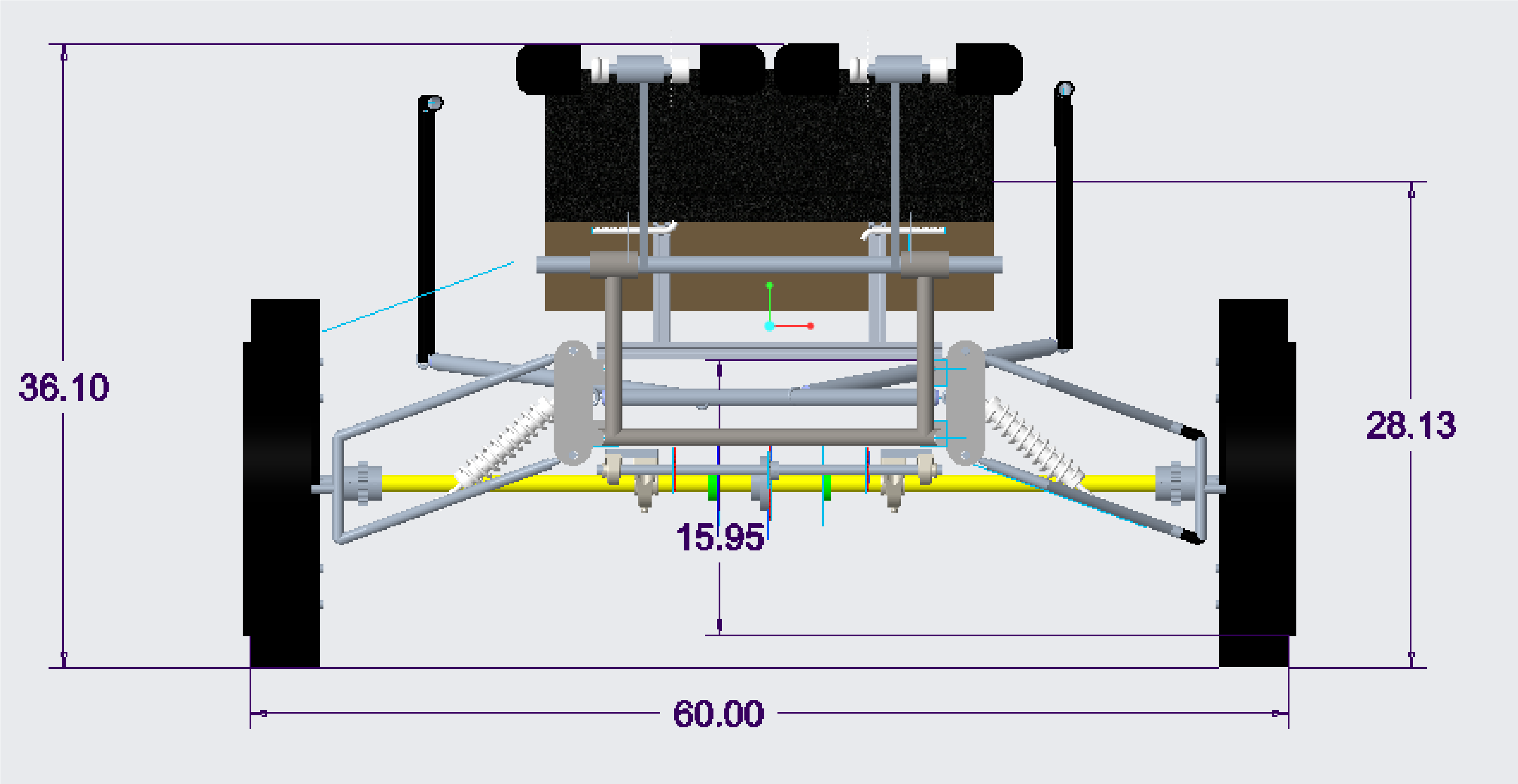
Rover Dynamics Calculations





Team 509

Rover Clearance Constraints



Team 509