UNIVERSITY OF THE DISTRICT OF COLUMBIA
SCHOOL OF ENGINEERING AND APPLIED SCIENCES

Experiential Learning in STEM at UDC Through the Implementation of the Second-Generation Firebird Rover for the NASA Human Exploration Rover Challenge

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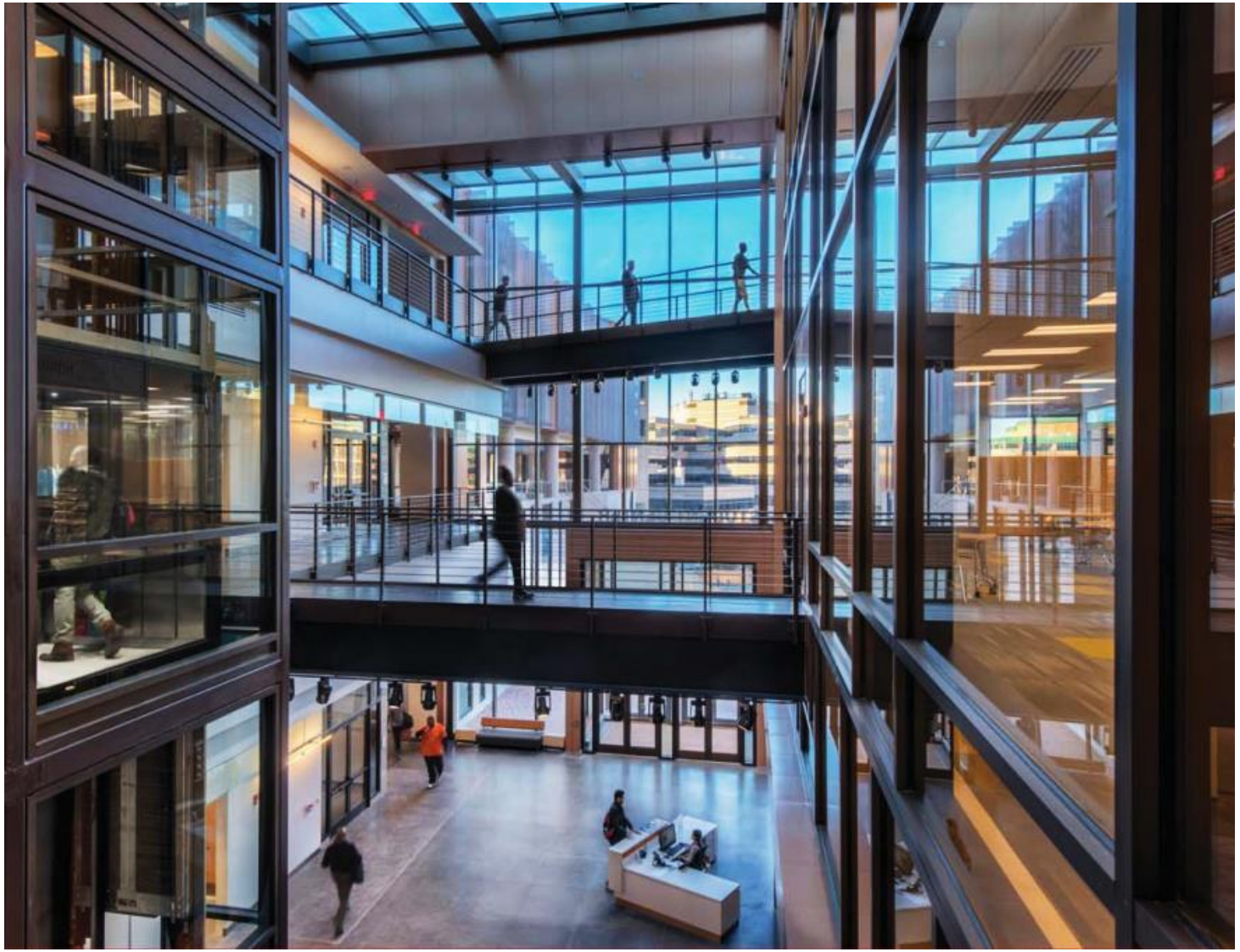


University of the District of Columbia (UDC)

- Historically black college, founded in 1851
- The District of Columbia's only public institution of higher learning
- One of only a few urban land-grant universities
- Supports many underserved populations
- Recipient of NASA MUREP grant of $3 million over the next three years to establish a Center for Advanced Manufacturing in Space Technology & Applied Research (CAM-STAR)

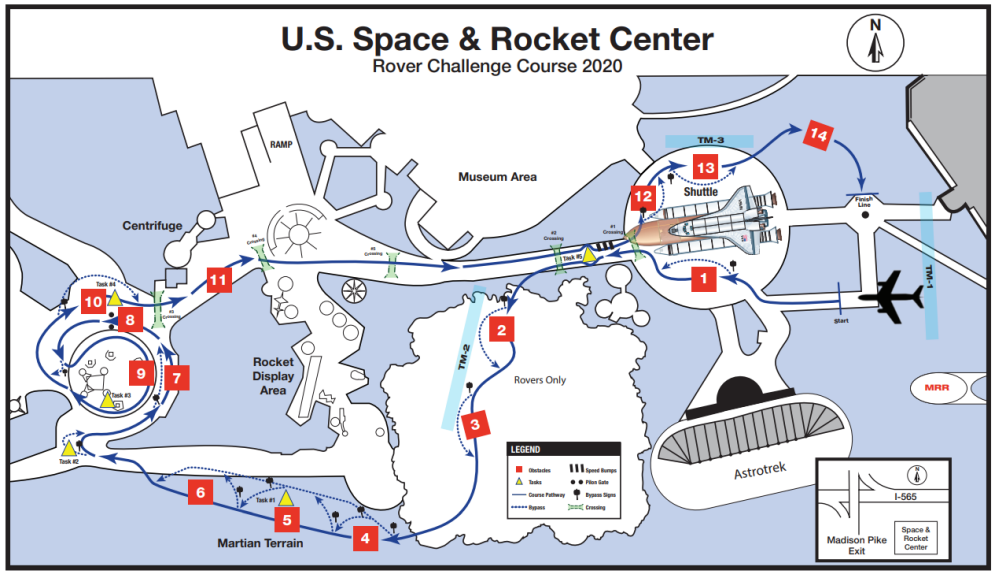
Goals

- **Inspire students to follow a career in STEM**
  - Engage engineering students & foster a drive to continue a STEM career
  - Encourage prospective STEM students to join the field

Goals

- Prepare students for engineering
  - Advanced problem solving
  - Workplace collaboration
- Modernize UDC's undergraduate curricula
  - Increased experiential learning
  - Engage in NASA sponsored projects and challenges
- Enhance in-house fabrication capabilities
  - Additively manufactured parts
  - Carbon composites

NASA HUMAN EXPLORATION ROVER CHALLENGE



The Rover Challenge

- International engineering challenge, consisting of ~100 participants, ~50 each in the university and high school divisions
- Participating teams must develop a human powered rover which can navigate a course & complete various challenges
- Teams compete for points on the basis of number of challenges completed and overall course time
- Rewards robust designs which can complete the course in the allotted time

Challenge Participants

- Open to universities in the US and internationally
  - Range from large schools such as Purdue, Texas A&M, to community colleges, University of Puerto Rico, and international programs from Bangladesh, India, Colombia, and many more
- In previous years, the University of Puerto Rico has been very successful
- Teams pursued highly varied solutions to the problems set out by the challenge

Primary Design Guidelines

- Rover must have two riders, one male and one female
- The rover's wheels must be fabricated in house; existing tires, rims, and the like cannot be used
- Riders must be at least 15" from the ground at the lowest point of contact
- The rover must fit in a 5'x5'x5' cube before deployment for use
- The rover must be deployed in under 2 minutes
- Should be no wider than 5'
- The rover should weigh under 210 lbs without riders

Course Challenges

Primary

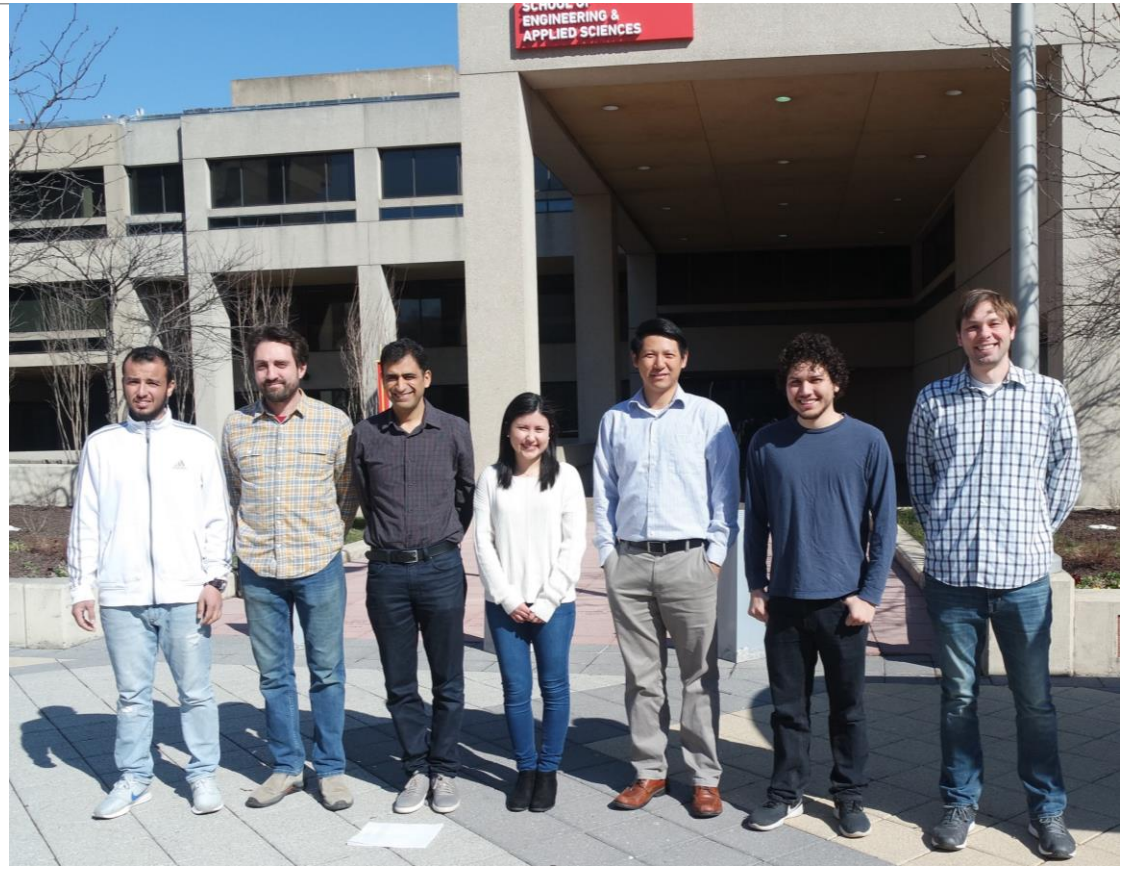
- Complete the ~0.5mi course in under 7 minutes

Secondary

- Liquid and soil sample collection
- RBY filtered camera to document flag planting
- Physical obstacles, such as rolling hills, boulder field, and angled inclines
- Solar energy collecting instrument deployment

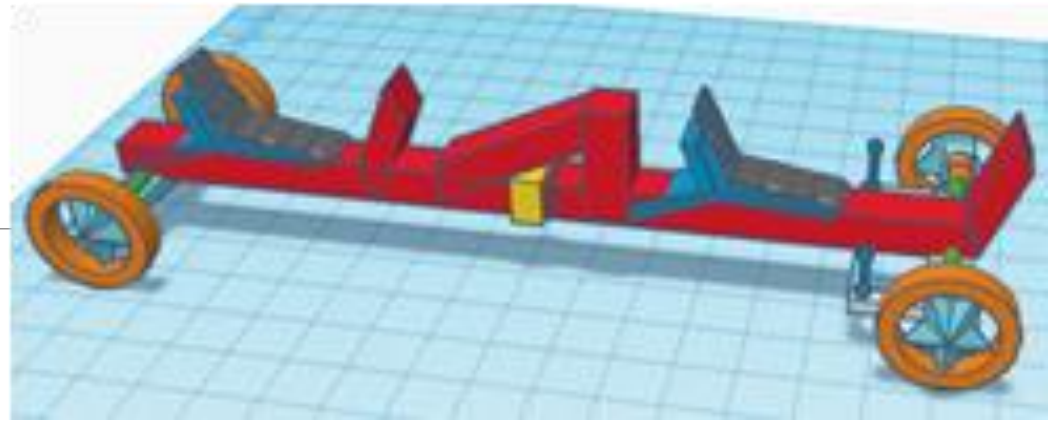
The Team

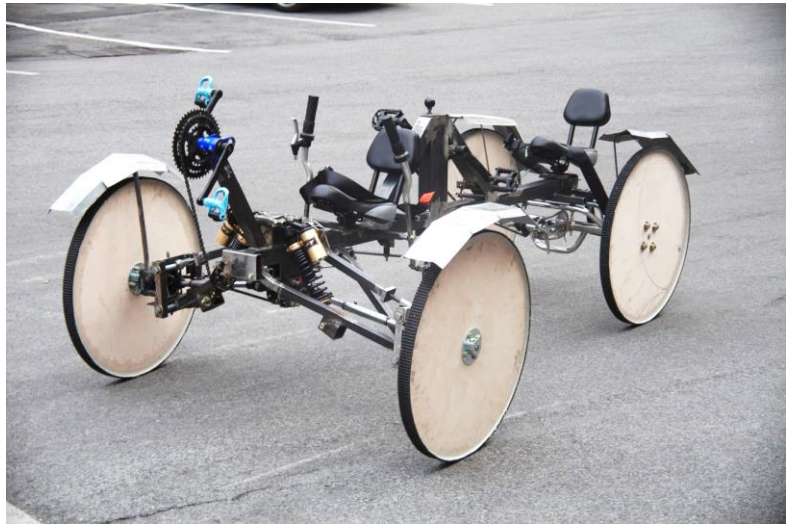
- Composed of engineering students from the Mechanical & Biomedical, Electrical, and Civil Engineering departments
- Students come from a variety of backgrounds
  - DC residents
  - International students
  - Second degree seeking students



Design Challenges

- Taking the design from paper to steel
  - Adjust to the reality of actual fabrication ability
  - Designing for available parts
- Team had to learn fabrication techniques such as:
  - MIG Welding
  - TIG Welding
  - Milling
  - Lathe machining





Design Challenges

- Initial 2018 design had tandem configuration with riders pedaling back to back
- Redesign with riders pedaling in the same direction due to size constraints
  - Required substantial modifications
- Numerous parts broke with testing as weak links were discovered, including
  - Front driveshaft spline sheared
  - Rear guide sprocket sheared off frame
  - Steering linkages failed

2018 Design

- 3-wheel drive (2 rear drive wheels, one front drive wheel)
- Fixed gear drive train
- Solid plywood 24” wheels
- Lacked rear differential
- Originally planned for an aluminum frame, but switched to steel due to fabrication issues

2018 Results: 7th Place Overall, 3rd Place for Rookie Teams

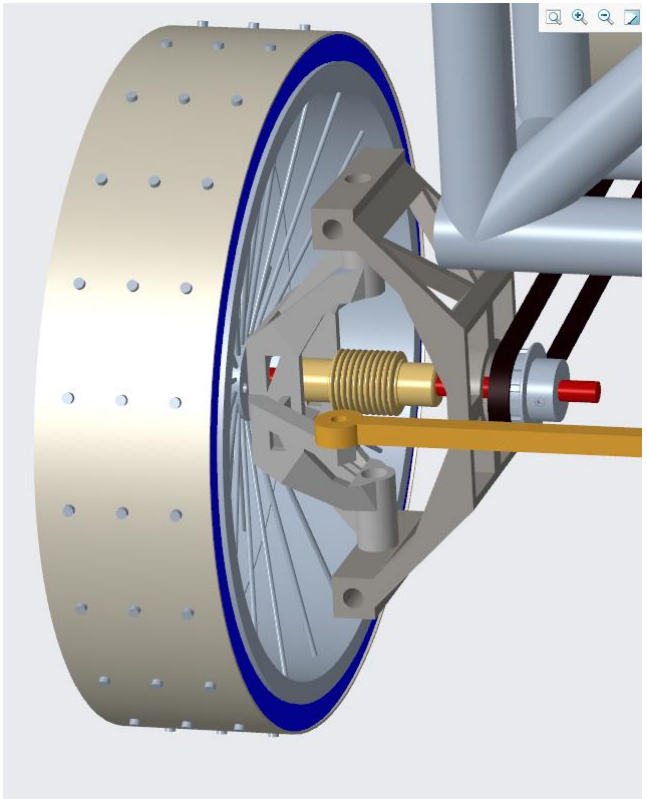
Completed the course in 6:29, accruing 30 points

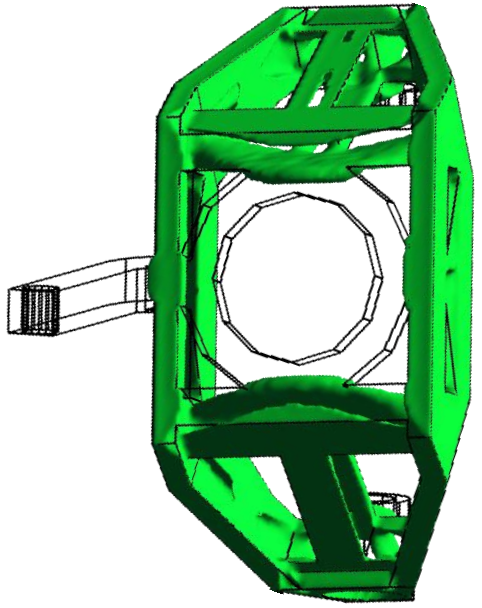
2018 Outcomes

- Successful 2018 competition enables the school to pursue a 2019 team
- Increased institutional knowledge allows UDC to more readily compete in this and other design challenges
- Outreach to additional students via workshops on topics such as 3D CAD design and simulation
- Collaboration with McKinley Technology High School students to develop their own rover for the high school competition
- Continue to work to meet DC Space Consortium guidelines to predominantly include women and underserved populations

Changes for 2019

- Knowledge of the course and competition allows the team to learn from past mistakes
  - Iterate & refine design ideas that worked
  - Improve or abandon design ideas that did not work
- Fully featured 3D CAD modelling and simulation before construction
- Topology optimization of 3D models to reduce weight and complexity





Changes for 2019

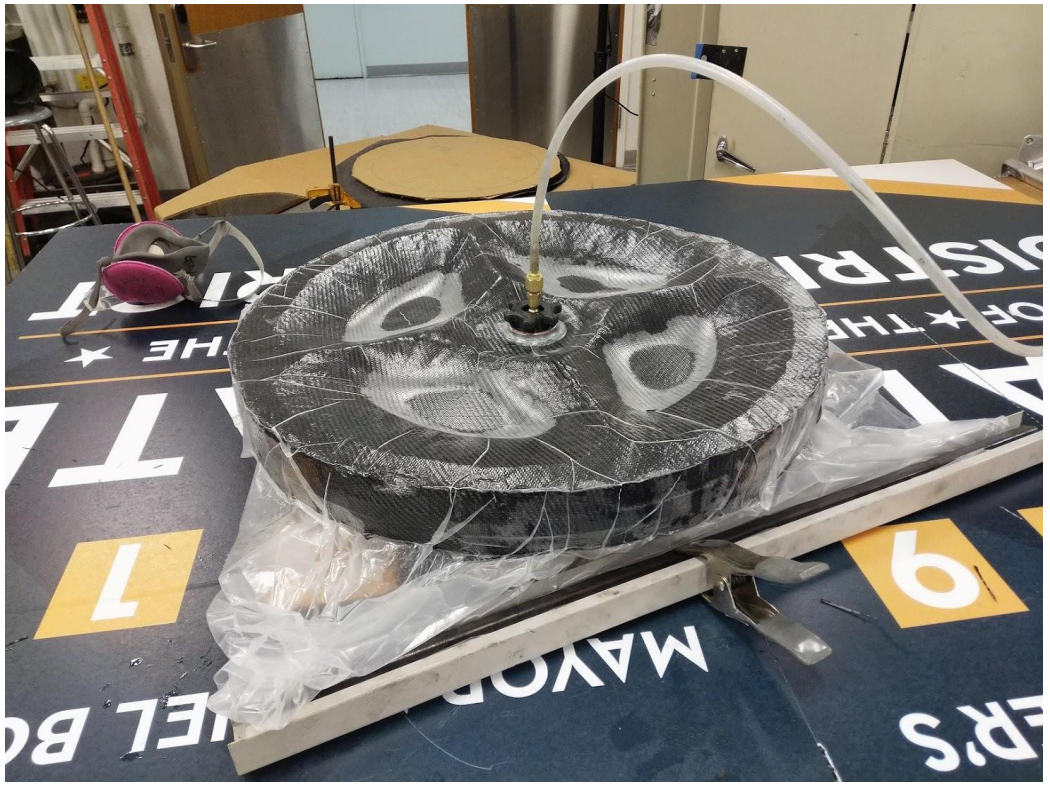
- Weight-reduced 2018 frame
  - ~24lb weight reduction
- Enhanced front suspension and new parallelogram steering
- Carbon fiber composite wheels with larger 4-inch footprint, from 1-inch footprint in 2018
- Rear differential

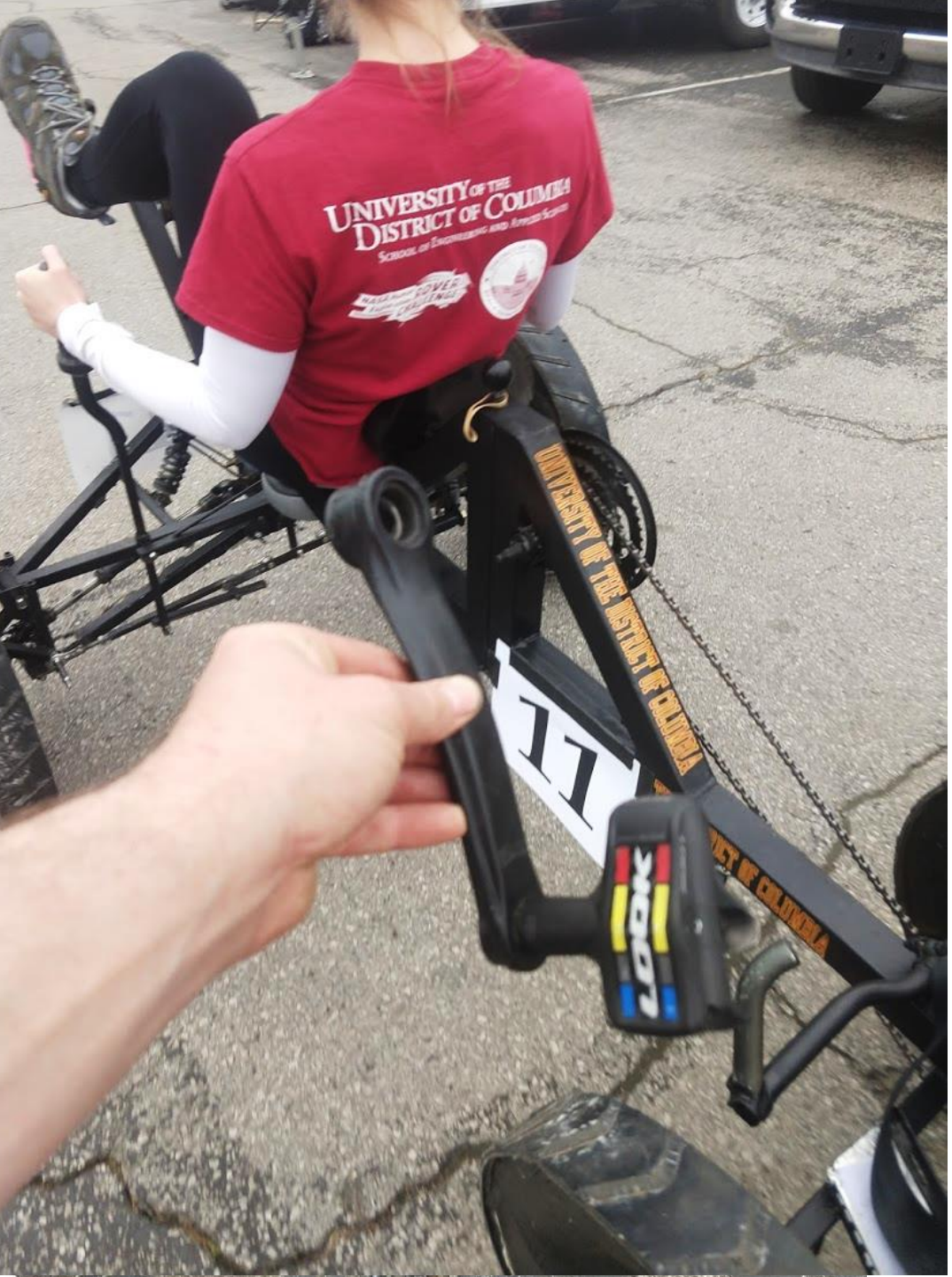
2019 Design

- Tandem seating, front wheel steering
- 3-wheel-drive: 2 rear, 1 front
- Folding design with central hinge
- <30 second deployment time
- 171lb competition weight

2019 Design

- Wheels were particularly difficult
  - Design guidelines force teams to spend time to come up with unique solutions
  - Effectively ask teams to ignore commercial solutions and focus on in-house design and testing
  - For 2019, plywood core wheels with foam and carbon fiber overwrap was used to yield a 24” wheel at 4” wide





2019 Results – Day 1

- Bearing Failure – course completion in 11:38, more than the allotted 7 minutes due to front bearings cracking
- Team found new bearings in Huntsville, replaced the broken parts and prepared the rover for race day 2
- Rear driver pedal detached after testing the new bearing, retaining nut lost, subsequently welded in place
- Final repairs affected by the end of Race Day 1

2019 Results – Day 2

Placed 14th overall

Course competition time of 5:10

48 total points

Improved on point total due to obstacles attempted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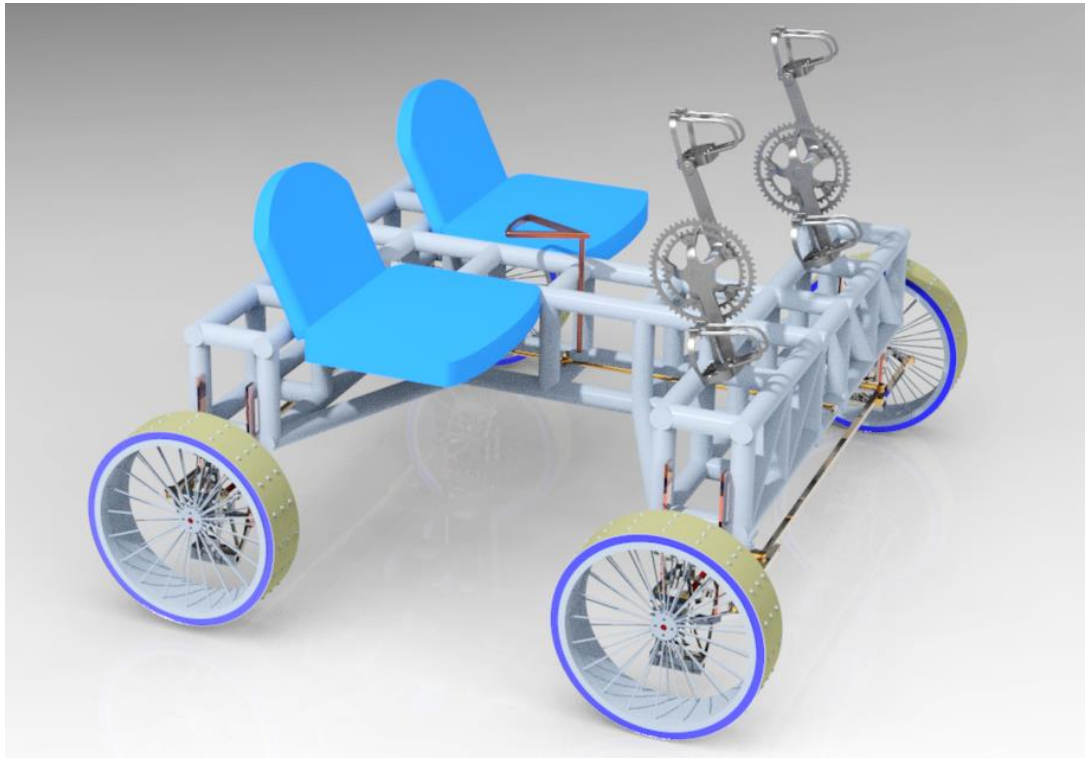
2020 and Beyond

Design:

- Short wheelbase design fits in 5’x5’x5’ volume without folding
- Lightweight tube frame reduces planned mass to <150lbs
- AM limited slip differential
  - Electropolished/chempolished AM 316L steel
- Carbon composite driveshaft for **chain-free** drivetrain
- Rover telemetry data and rider biometrics



2020 and Beyond

Recruitment efforts for the 2020 team:

- Team is majority female
- Majority minority
- Most current members are underclassmen (~75% of team)

STEM Outreach

- Work with local high schools to assist in the development of their own rover
- Consulting with nearby colleges to assist with the development of their own rover program