Rapid Prototyping and Additive Manufacturing for the Functional Implementation of Expanding Wheel Suspension

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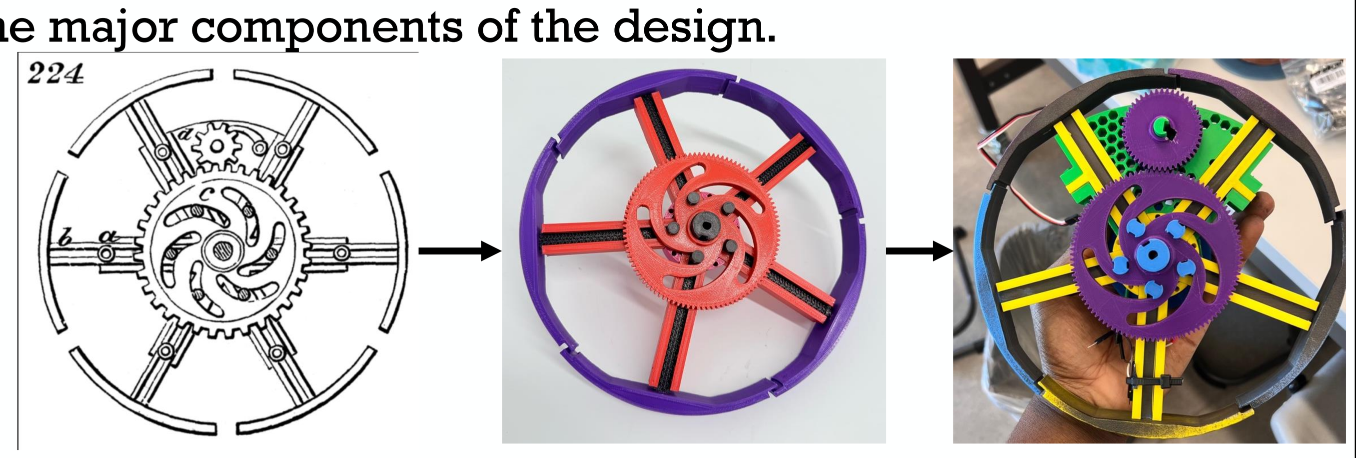
ABSTRACT

The Foxy Robotics team developed a novel form of locomotion inspired by the expanding pulley design featured in Henry T. Brown's 507 Mechanical Movements. Modernizing the design to enable stable and safe motion and navigation across various terrains.
The final rover featured a set of four mechanically expanding wheels, enabling an active suspension system that supported stable locomotion and the safety of the cargo within.
The rover used a gyro meter combined with dead reckoning and PID algorithms to account for imperfections in the ground, indentations, and bumps, individually expanding or reducing the wheel diameter to maintain the stability of the main rover body and reduce vibrations throughout the body.

MECHANISMS

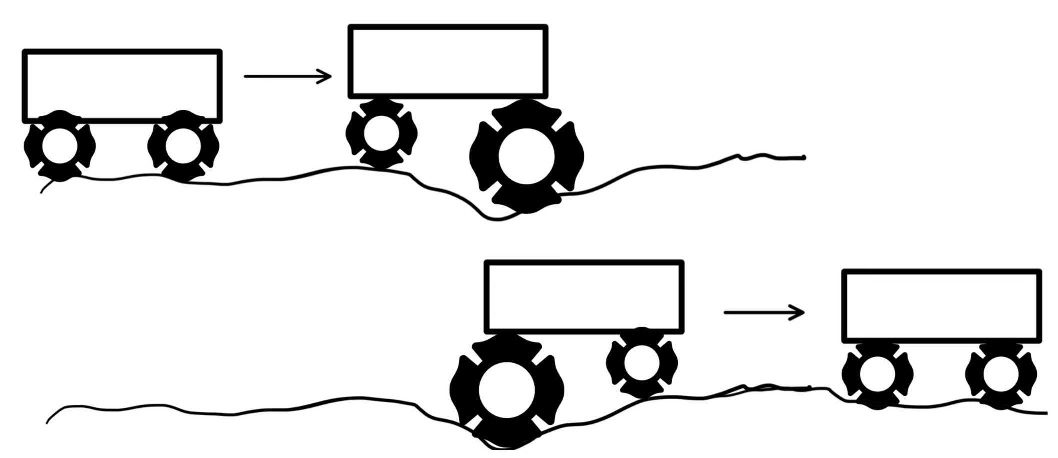
After NASA-COSGC Program invited student teams to build and test their unique, autonomous rover design. The Foxy robotics team rapidly prototyped a proof-of-concept wheel with additive manufacturing. This allowed us to break down the major components of the design.



Original Concept , Initial Design Of Expanding Wheel And Final Design

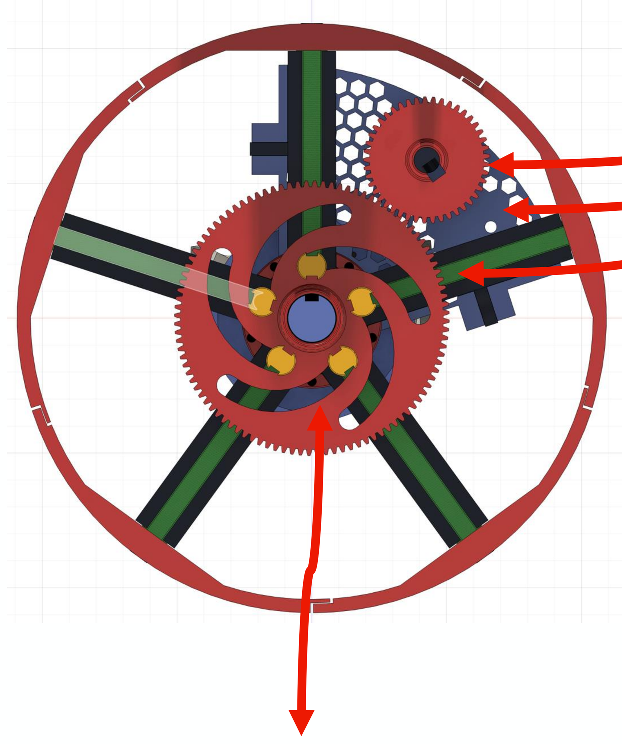
The wheel works by turning the smaller gear, which in turn imparts a torque to main wheel gear which, by means of curved slots cut therein, thrusts the studs fastened to arms of pulley outward or inward, thus augmenting or diminishing the size of the pulley. This creates two dynamics :

The small gear has to provide the torque difference between the expanded and contracted forms and the main focus of the project the expanding wheel would act as another form of suspension to balance the rover while traversing rough and uneven terrain.

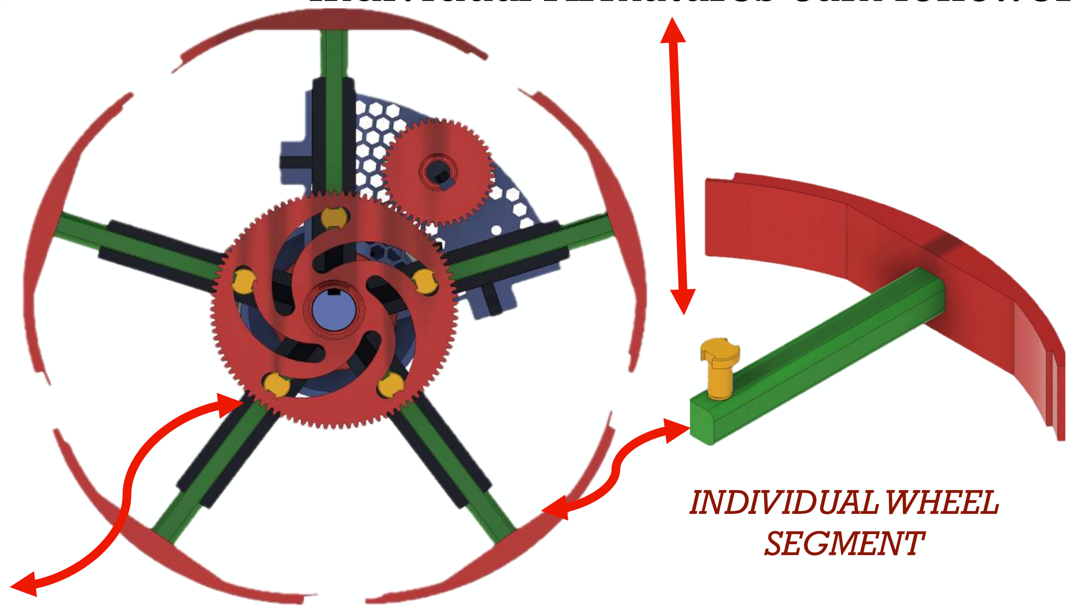


Representation of Active suspension with the Expanding Wheel

FINAL WHEEL DESIGN



- Servo motor Assembly
  - Servo motor gear
  - Servo motor bracket
- Main Gear with cam slots
- Individual Armatures cam followers

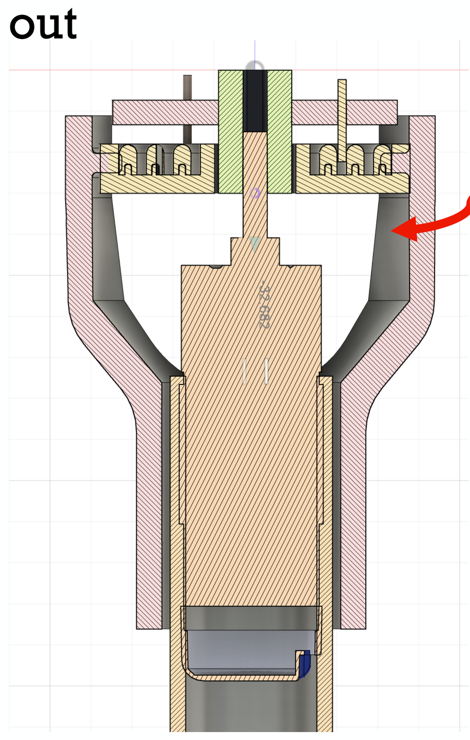


As the servo spins the gear assembly, the main gear cams trace out a straight path for the followers, which pushes the wheel segments out

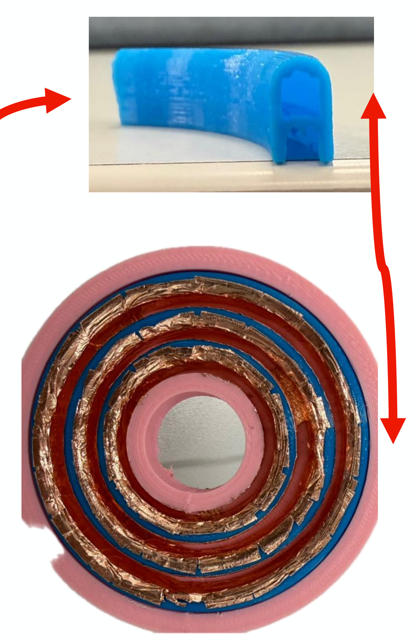
Open Wheel

INDIVIDUAL WHEEL SEGMENT

Each segment has an internal slot of carbon reinforcement for maximum bend and impact resistance



CAD Model Section Analysis of Slip Ring Setup



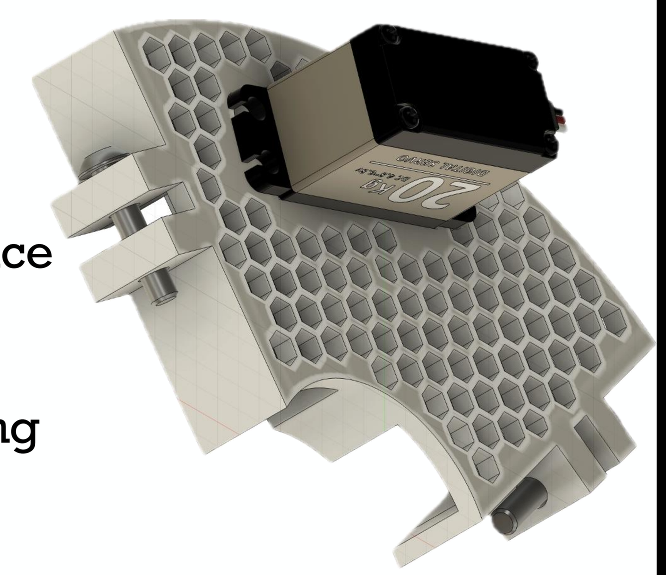
Stationary Section of Slip Ring And Ring Section Cut Out

Slip Ring:

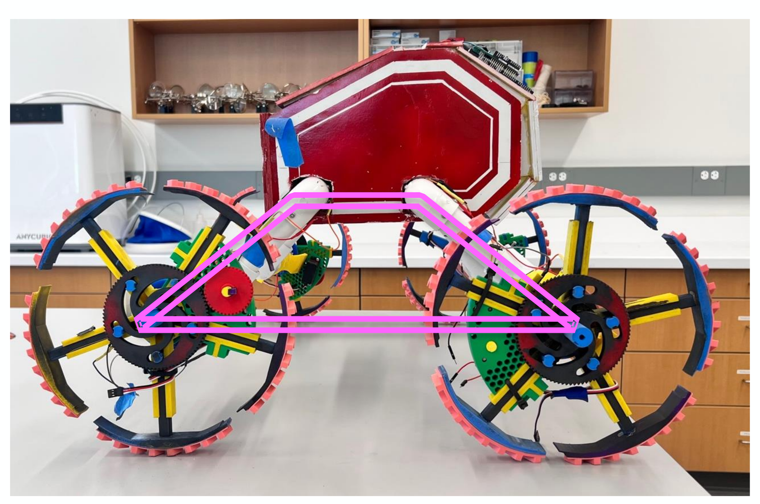
- Stationary, greased copper-plated TPU rings and a rotating plate with protruding copper rods that contacts the rings to transmit power and signal to the servo attached to the end wheel.
- Retail options too expensive, so we designed and built in-house.

Servo Assembly:

- The bracket has hexagonal hole cutouts to reduce weight.
- The servo is attached as close to the axle as possible to reduce imbalances while maintaining enough clearance for the wheel to rotate freely
- Changed to chevron gears to prevent slipping.



CAD Model of Servo Motor Mount to Wheel



Side View Profile of Rover

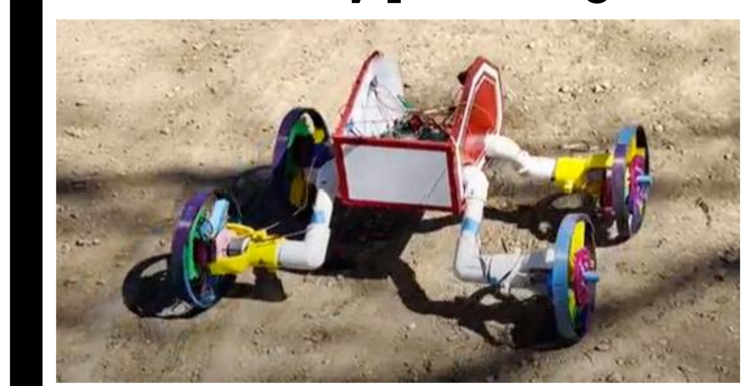
Chassis:

- Foam board body minimizes weight while maintaining high durability, combined with PVC limbs for high durability and a low retail price.
- Trapezoidal configuration allowed for an elevated chassis that could clear obstacles

TESTING AND FIELD PERFORMANCE

TESTING/VALIDATION

Using simulations that match the sand dunes, the rover was tested with on carpet, compacted sand, gravel, and 'mulchy' sand. The mulch and compact sand had inclines of 11° and 6°, respectively. The torque difference between expanded and closed wheels was significant but he however the stability of the rover was very promising.



Rover on slight Incline (6°)

Rover on high Incline (11°)

RESULTS

The rover successfully completed 3 out of 5 courses on the sand dune terrain. Primarily three straight-line sandy courses and the rocky paths with ease, showing strong performance on uneven surfaces. However, the incline course and the 90° turn course proved more challenging, and the rover was unable to fully account for the them.

Rover On Straight Line Sandy Course

Rover On Straight Line Rocky Course

CONCLUSION AND FINAL WORKS

- Designed and built an autonomous rover for sandy and rocky terrain, incorporating an expanding wheel concept
- Completed **3 out of 5 competition courses**, with strong performance on straight obstacles and limitations on incline and turning tasks
- Key challenges:
  - The in-house slip ring system introduced reliability issues
  - Final rover exceeded weight limit (**6.7 Kgs vs 5 Kgs target**)
  - Wheel durability failure impacted performance
- Key takeaways:
  - Pay attention to **weight and size** throughout the design process with **system integration**

This project demonstrated the practical benefits of integrating active suspension, expanding wheels, and additive manufacturing into rover design. By leveraging rapid prototyping, the team achieved rover stability and maneuverability without requiring costly hardware. Notably, testing showed consistent results, highlighting the exceptional system dependability. This result suggests this system may outperform other suspension solutions.