

Martian Terrain



In the past, both NASA JPL's **Spirit** and **Curiosity** rovers have been stuck in loose terrain, resulting in months of mission time lost.

Tractive Solutions



Adaptive wheels have been used to **increase contact patch** for more traction.

Similarly, grouser wheels have been made due to both their **granular flow benefits** and **higher contact patch**.



Standard Optimization and Performance Metrics

- GROVER autonomously varies tread heights – it does not need to be controlled.

Using a **gradient descent algorithm** and **proprioceptive sensing**, GROVER optimizes both the **slip ratio** and the **tractive efficiency**.

$$s = 1 - \frac{V_x}{r\omega} \quad \eta = \frac{F_x \cdot r(1 - s)}{T}$$

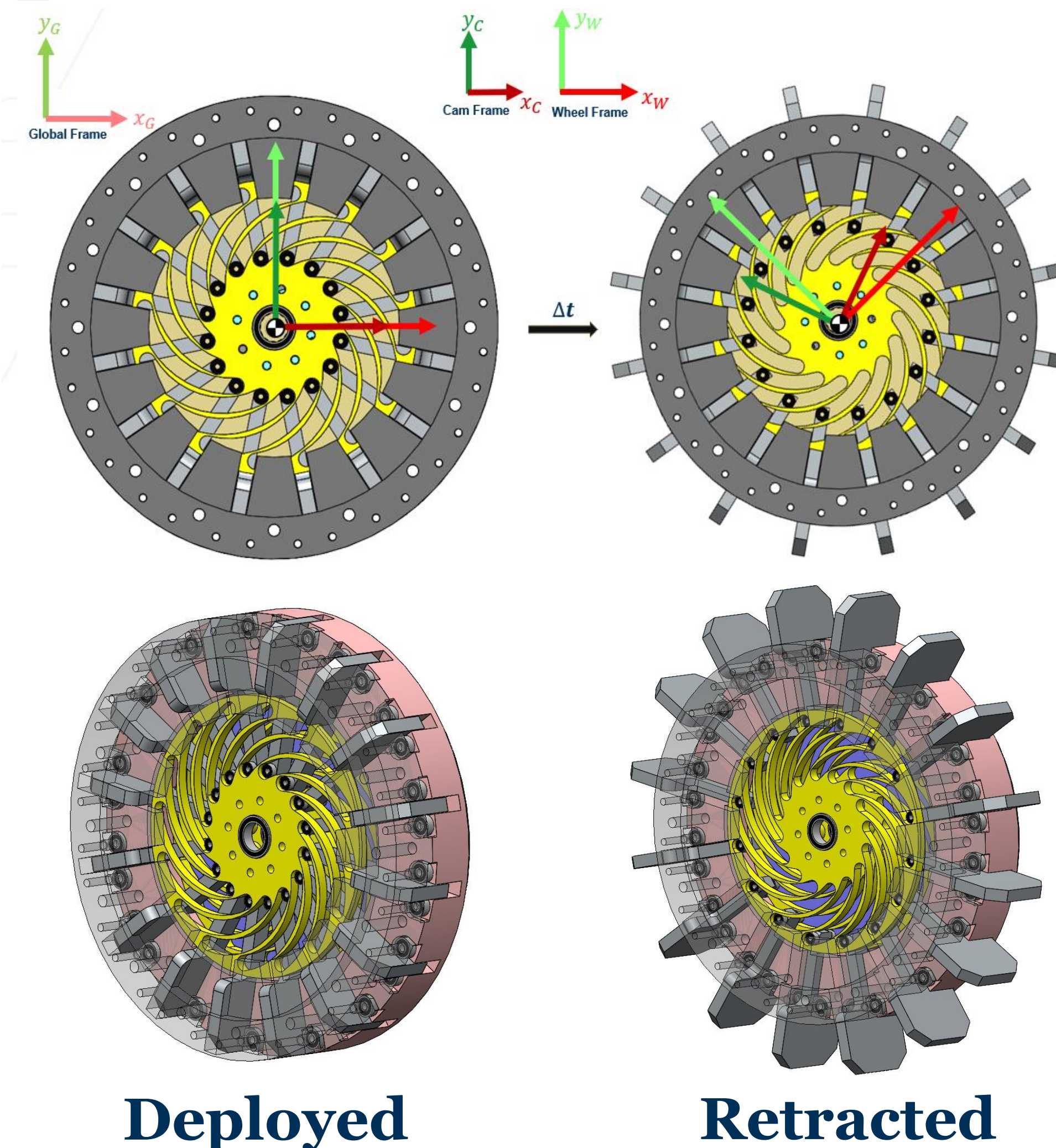
Slip Ratio

Tractive Efficiency

GROVER Design: Spiral Cam Overview

Grouser Rover Over Varied Extraterrestrial Regime

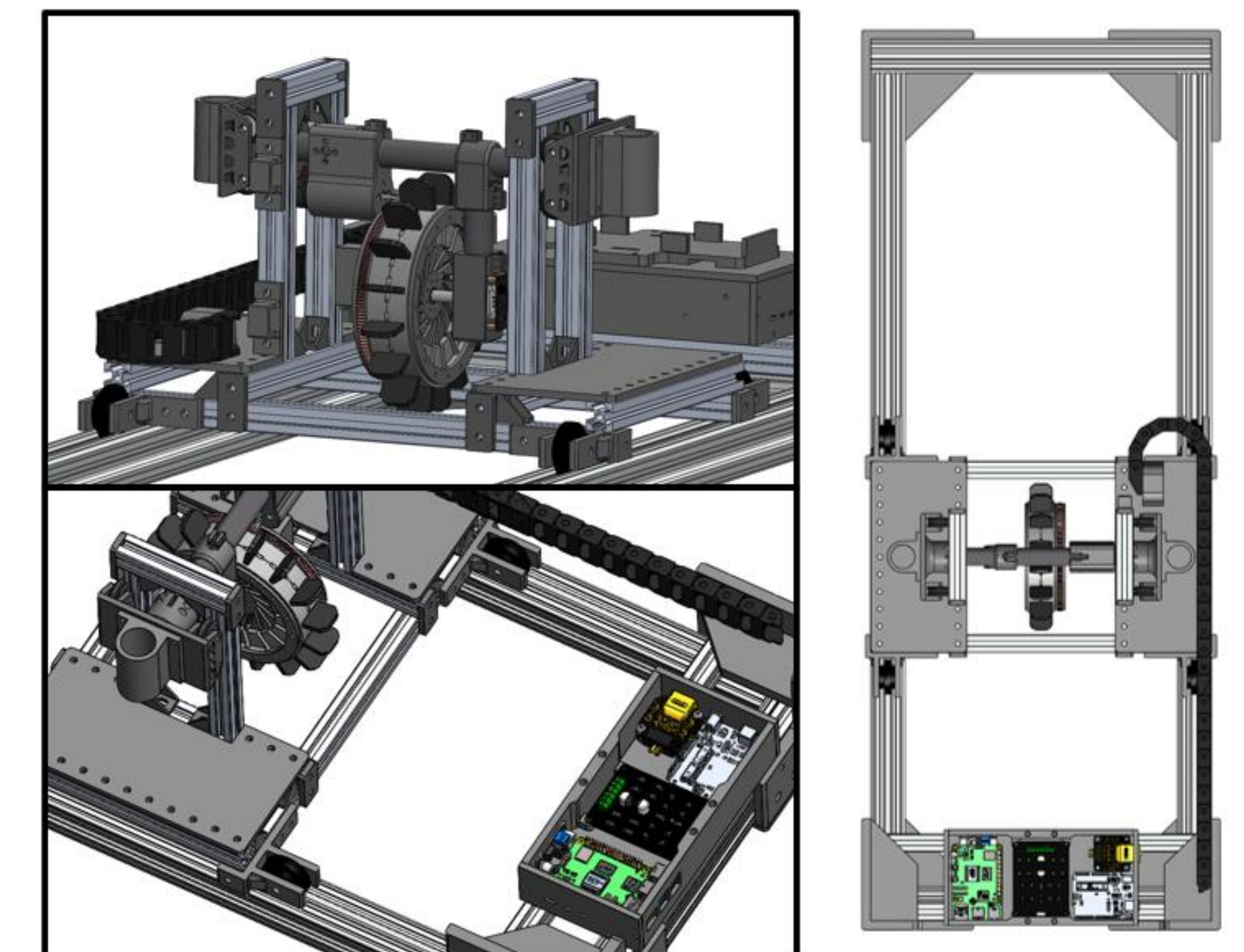
- Spiral Cam** is driven by an 8.4 Volt high torque continuous rotation servo.
- PID control** between wheel and cam frame is used to obtain grouser height of 0-17.5 mm within milliseconds.
- Grousers act as followers to the cam and are **continuously variable**.



Wheel Test Bed Design and Evaluation Process

A **4 ft-long dynamic testbed** enables controlled testing of the wheel across various terrain types to collect relevant surface interaction data.

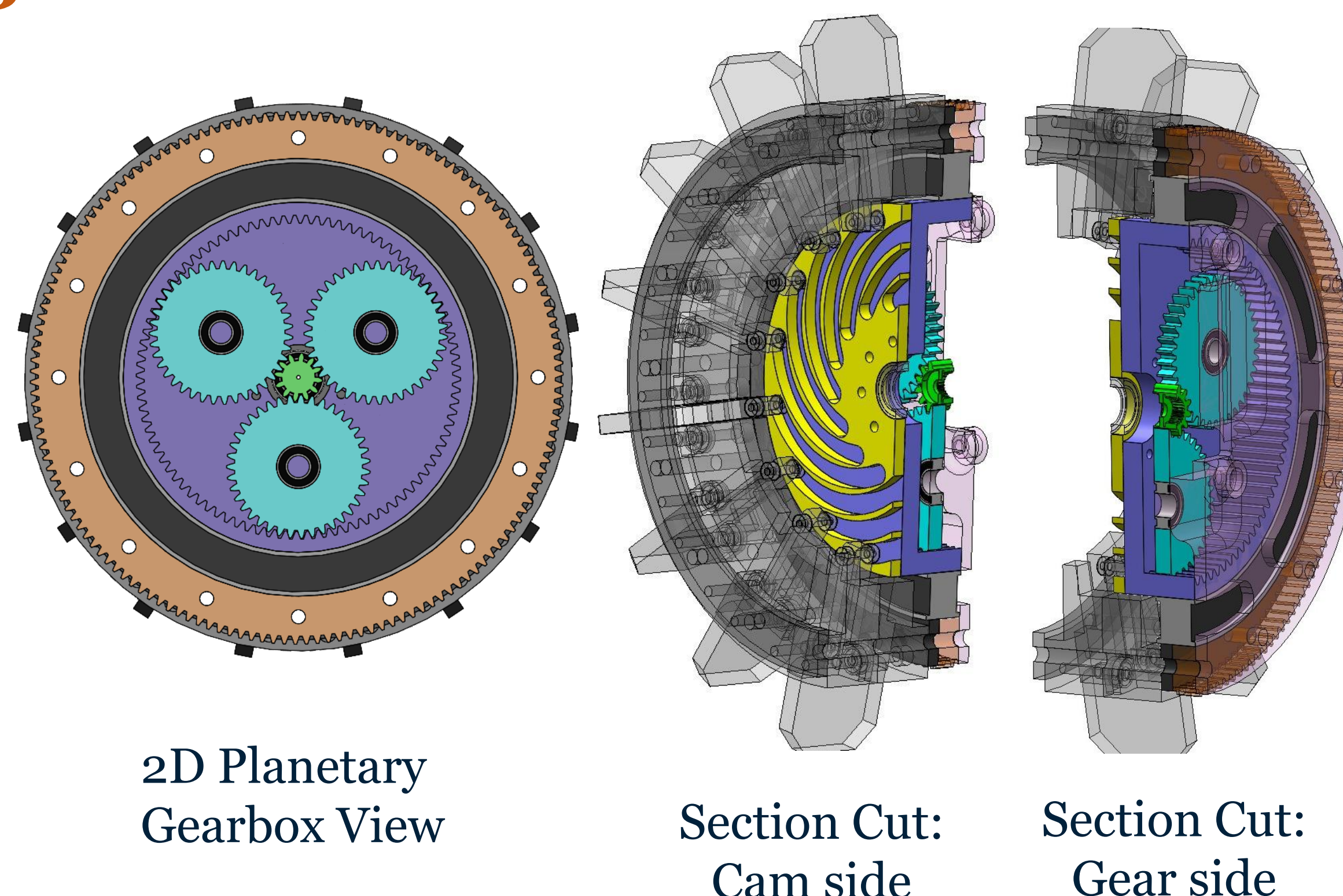
- A **5 μm linear encoder** measures the **testbed's linear velocity** with to estimate slip.
- A **Berry IMUv3** captures **acceleration data** at the center of the wheel frame along with barometric sinkage.
- Telemetry data allows for **back EMF estimation**, providing insight into **motor torque** for tractive efficiency calculations.



GROVER Design: Gearbox Overview

- Servo is attached to a sun gear which drives a ring gear output obtaining a **7.5:1 gear ratio**.
- This resolves a total of **33 N m** of torque at the ring gear output

This allows for GROVER to **always fully deploy grousers**, as it can lift the entire rover weight.



Offboard Rover or Test Bed

Control Signal
Power
Data Package

