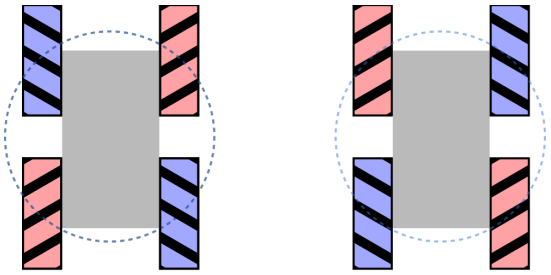
Slanted Grousers for Planetary Rover Wheels. O. S. Lawlor[1], [1]U. Alaska Fairbanks, 2380 Steese Hwy, Fairbanks, AK. (Contact: lawlor@alaska.edu)

Introduction: Planetary surfaces are irregular and dusty, so rovers will require robust ground-contact hardware, both for exploration and future construction. Fixed-axle wheels remove the complexity of steering, but differential turning can dig into the terrain rather than move the rover. We show slanted grousers can make fixed-axle rover turns require less wheel torque and energy.

Background: Wheel grousers (lugs) of different types have been well studied for agriculture, varying the grouser count, size, spacing, and angles [1]. More recent systematic testing of various grouser heights [2] and shapes [3] in dry sandy terrain is more applicable to rover design. Slanted or fully helical grousers [4,5] have been evaluated experimentally and via simulation.

Slanted grousers produce less torque variation during open cage wheel rotation [1]. They do induce side forces that are dynamic and large, but still smaller than pull forces [3]. Figures 1 and 2 explore possible rover configurations using various combinations of slanted grousers.



(a) Radial slant (b) Tangent slant

Figure 1: View from underneath a 4-wheel rover, showing (a) grousers slanted along the **radius** of the turning circle, which makes zero point turns easier for the robot to initiate; and (b) grousers slanted **tangent** to the turning circle. Right/left handed wheels are shown in blue/red for clarity.

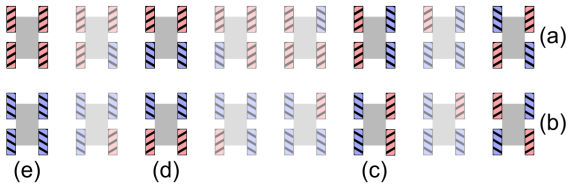


Figure 2: All 16 possible wheel configurations: (a) radial and (b) tangent as above, (c) front-back [3] and (d) left-right symmetry, and (e) uniform slant. Odd "1 out of 4" configurations shown in gray.

Testing: Our six wheeled testing rover masses 75 kg and has a 1.2 meter roughly square wheelbase, with 285 x 180mm wheels with 24 helical grousers 7mm high (5% of radius [2]). The front wheel axles mount directly on the frame, while the middle and back wheels pivot on a bogie bar. The wheels do not steer, so the robot turns using only tank-style differential drive.

On loose gravel, we performed 360 degree zero point turns under torque control with the rover's front and back grousers slanted differently.

Grouser Slant	*Energy/turn 70% torque*	*Energy/turn 60% torque*	*Min turn torque*
(a) Radial	7.1 kJ	8.2 kJ	40%
(c) Front-back	7.8 kJ	8.9 kJ	50%
(b) Tangent	10.3 kJ	11.5 kJ	55%

Figure 3: 6-wheel rover in radial slant grouser configuration, after four full rotations on gravel.

Conclusions: Radial slanted wheel grousers allow heavier rovers to make zero-point turns without steering hardware. Work continues to quantify this effect and validate its load and terrain limits. Tangent slant may produce less sinkage and terrain disturbance in some situations, which we would like to quantify.

One challenge is slanted grousers may require separate left and right handed spare parts, while straight grousers use only one wheel type.

For configurations (a-c), turning each helical wheel in opposing directions may allow holonomic omnidirectional translation with a sufficiently smooth wheel, and we are exploring how the grouser and terrain types influence this possibility.

References: [1] Watyotha C. et al. (2001) *J Terram.* 38, 1-14. [2] Inotsume H. et al. (2019) *J Terram.* 85, 39-57. [3] Nagaoka K. et al. (2020) *J Terram.* 90, 23–30. [4] Thoesen A. (2019) ASU PhD. [5] McBryan T. (2022) ASU MS.