# PARAMETRIC MECHANISM DESIGN THROUGH NUMERICAL OPTIMIZATION AND PHYSICS SIMULATION

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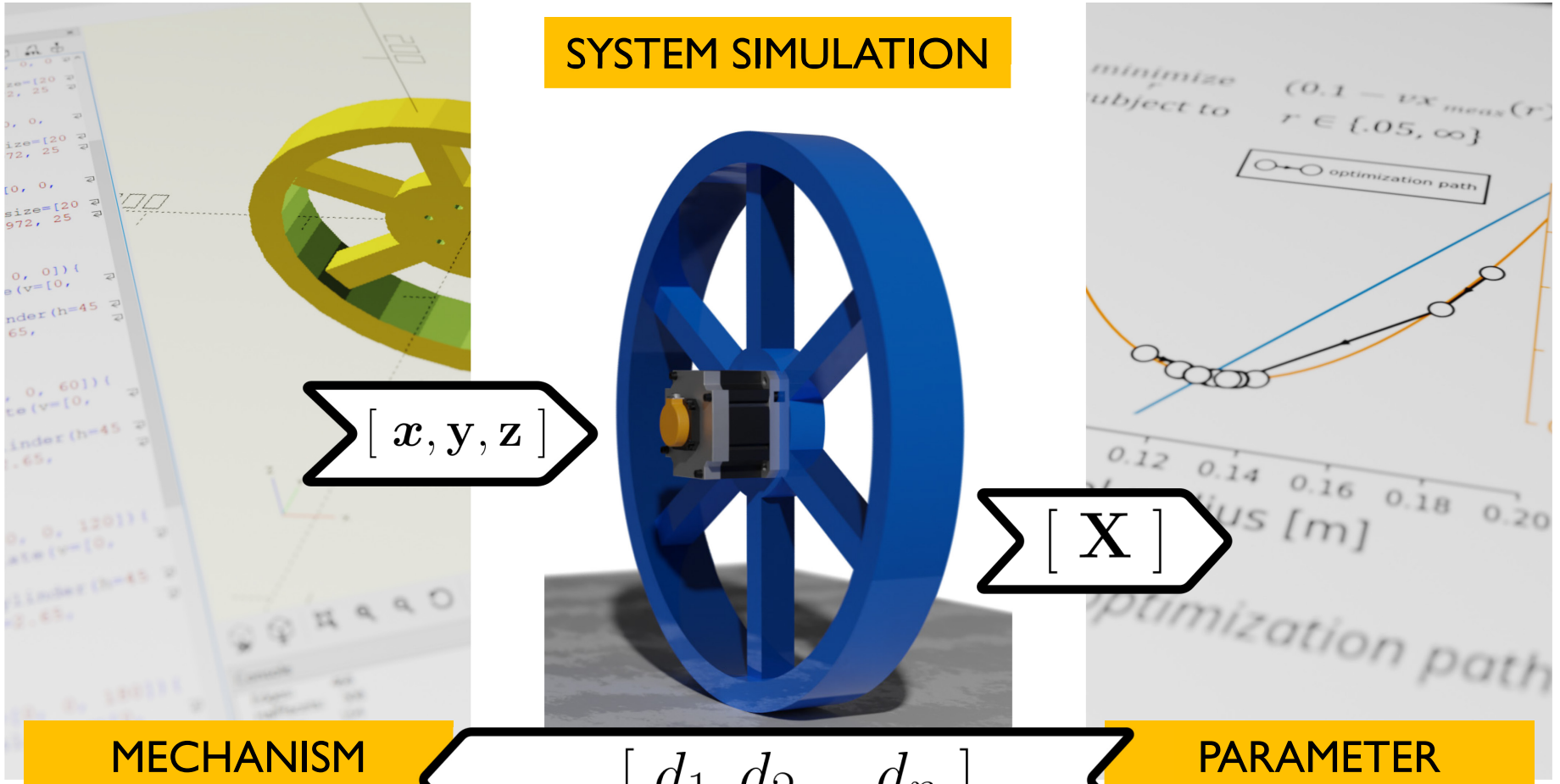
# THE DESIGN-BUILD-TEST APPROACH IS FLAWED

- Lengthy development time, high cost for TRL 7+ hardware.
- Limited testing capabilities due to environment differences.
- Unoptimized hardware wastes resources.

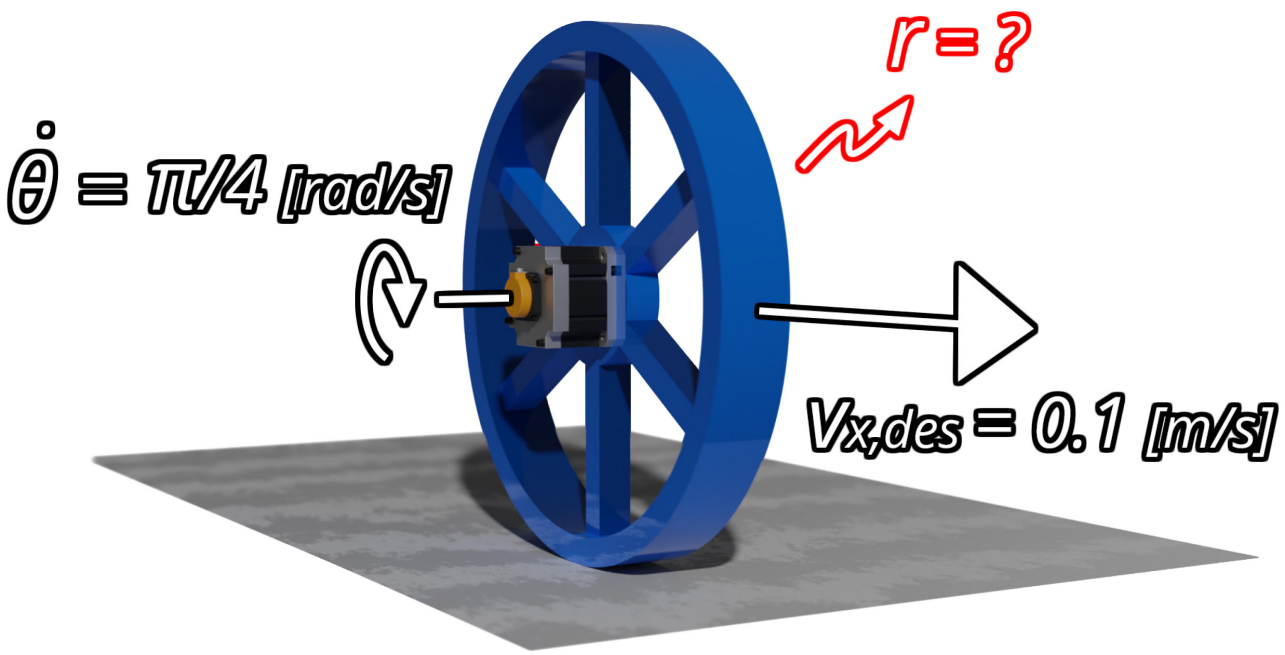
# DESIGN CAN (AND SHOULD!) BE LARGELY AUTOMATED

Optimization-based design with physical simulation can reduce the time, effort, and cost required to develop and deploy hardware that is *optimized for its operating environment*.

# MECHANISM OPTIMIZATION TOOLCHAIN



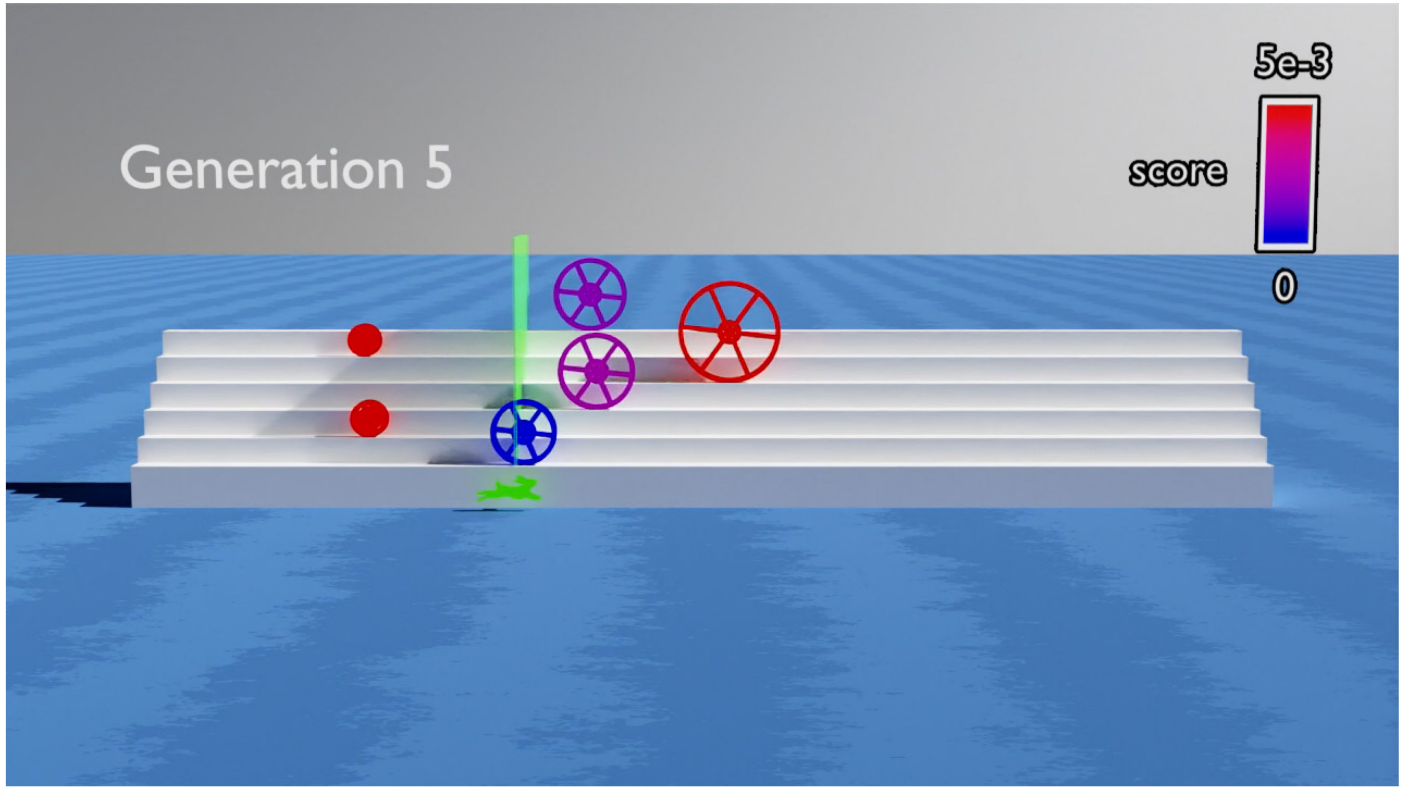
# EXAMPLE: WHEEL RADIUS OPTIMIZATION




*Wheel mechanism.*

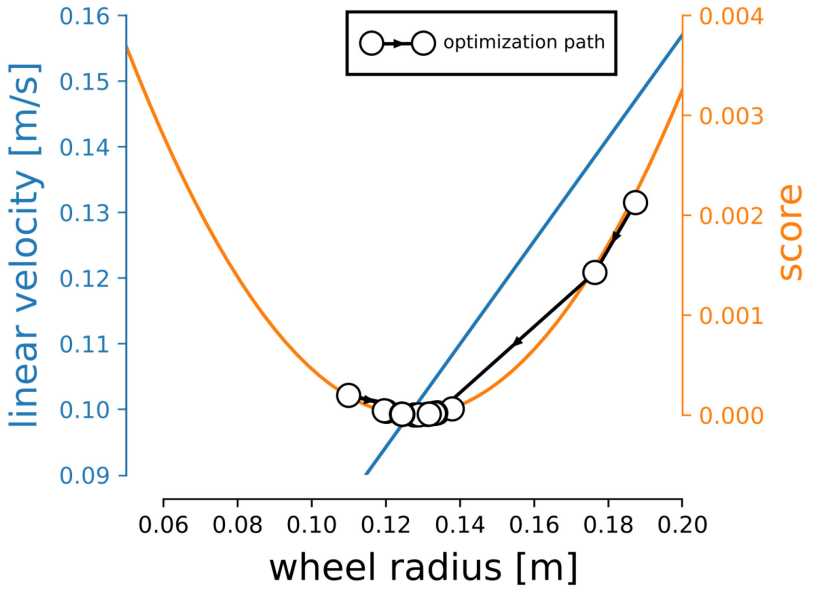
- **Analytically:**
  - $v = r\dot{\theta}$
  - $r = 127.3\ [mm]$

# EXAMPLE: WHEEL RADIUS OPTIMIZATION (CONT'D)



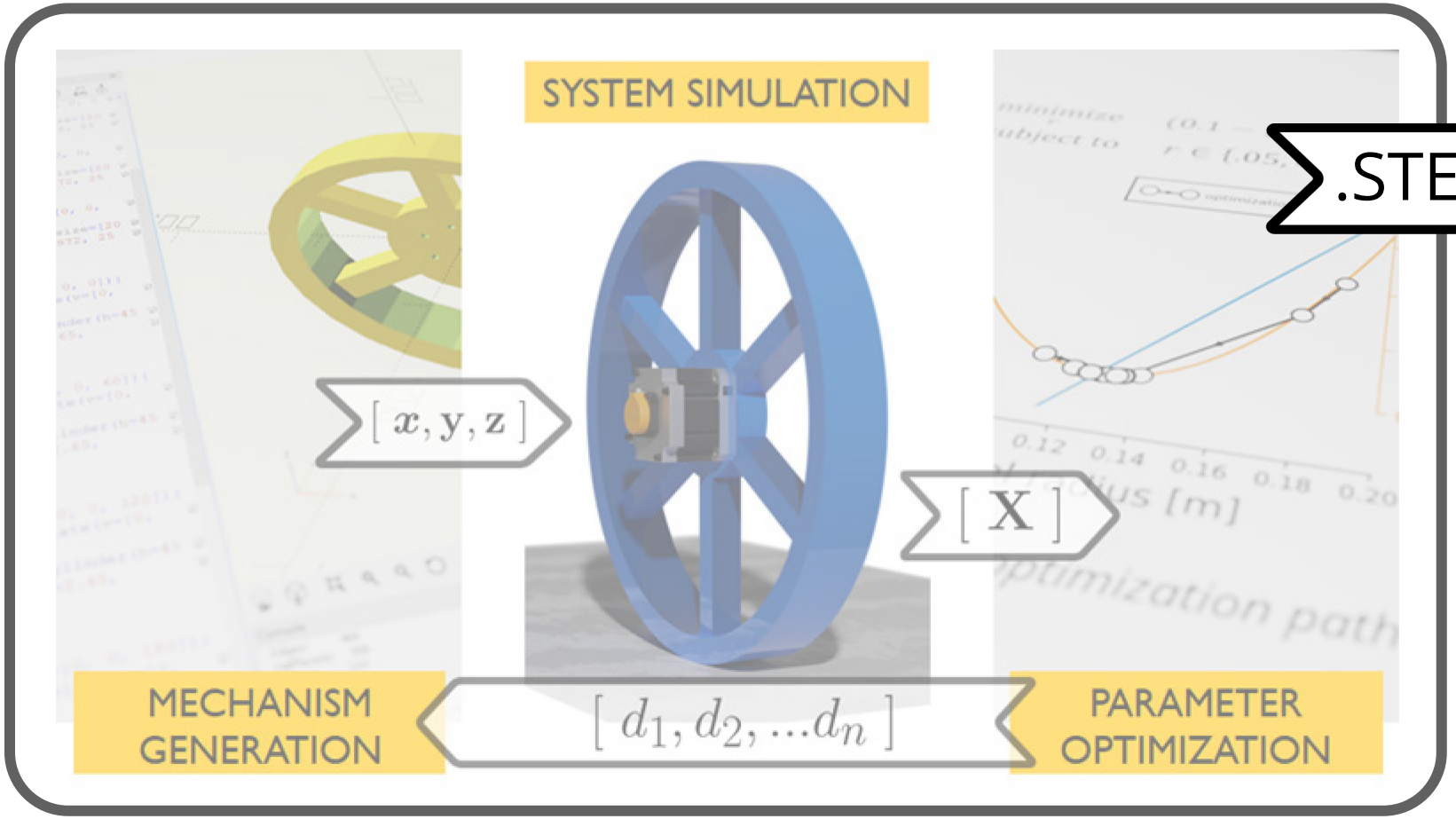

*Wheel radius optimization in simulation environment via CMA-ES [1].*

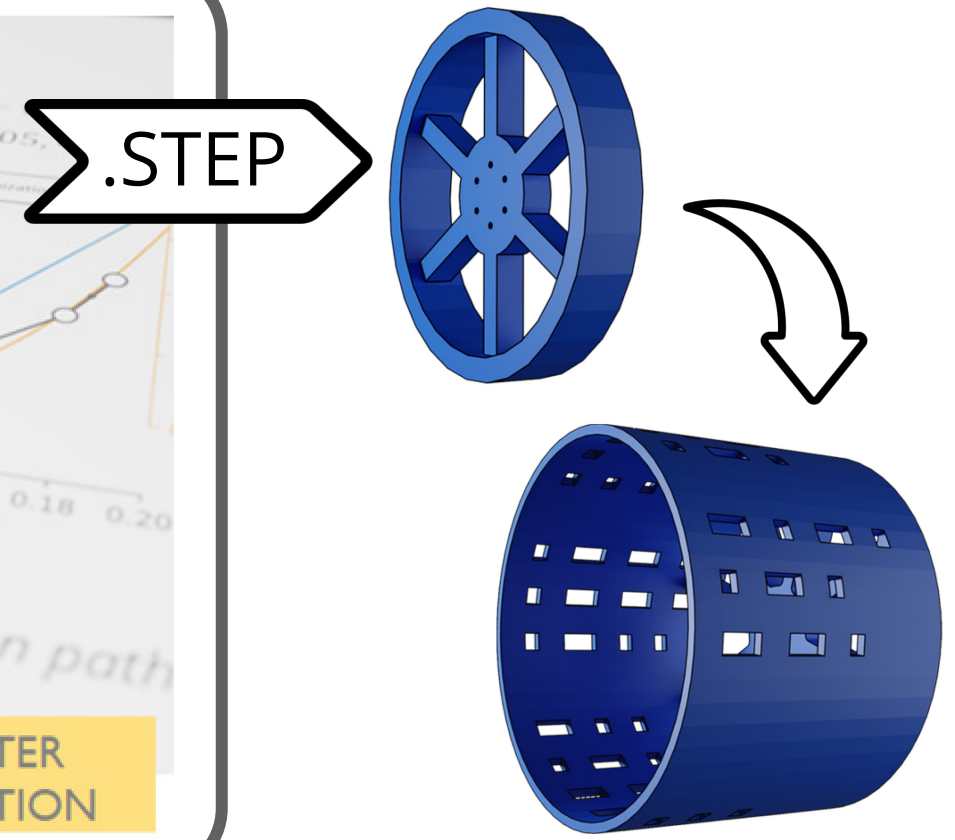
$$\underset{r}{\text{minimize}} \quad g(r) = (0.1 - vx_{meas}(r))^2$$
$$\text{subject to} \quad r \in \{.05, \infty\}$$



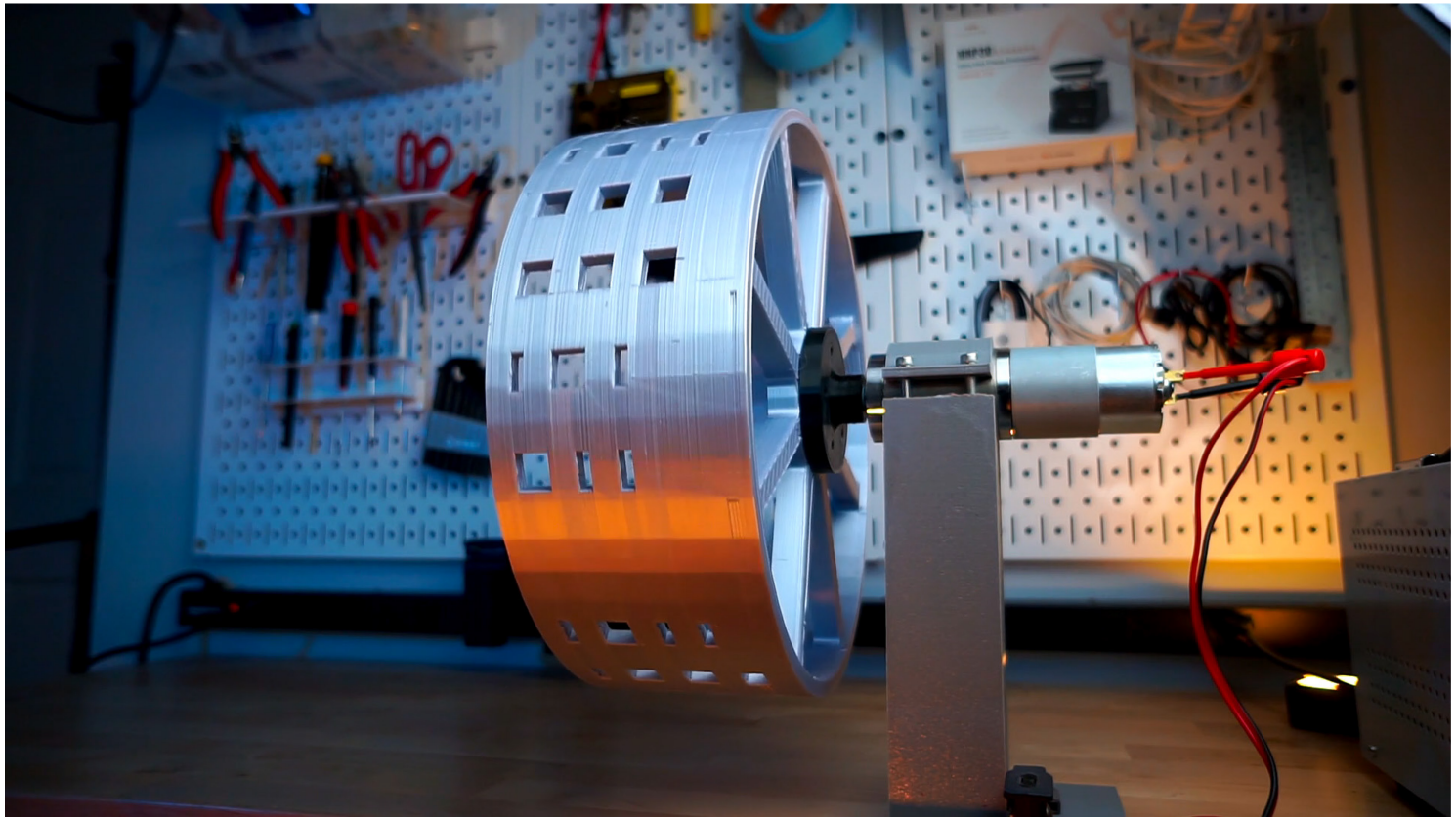

*Cost space and optimization path.*

# MECHANISM DESIGN TOOLCHAIN

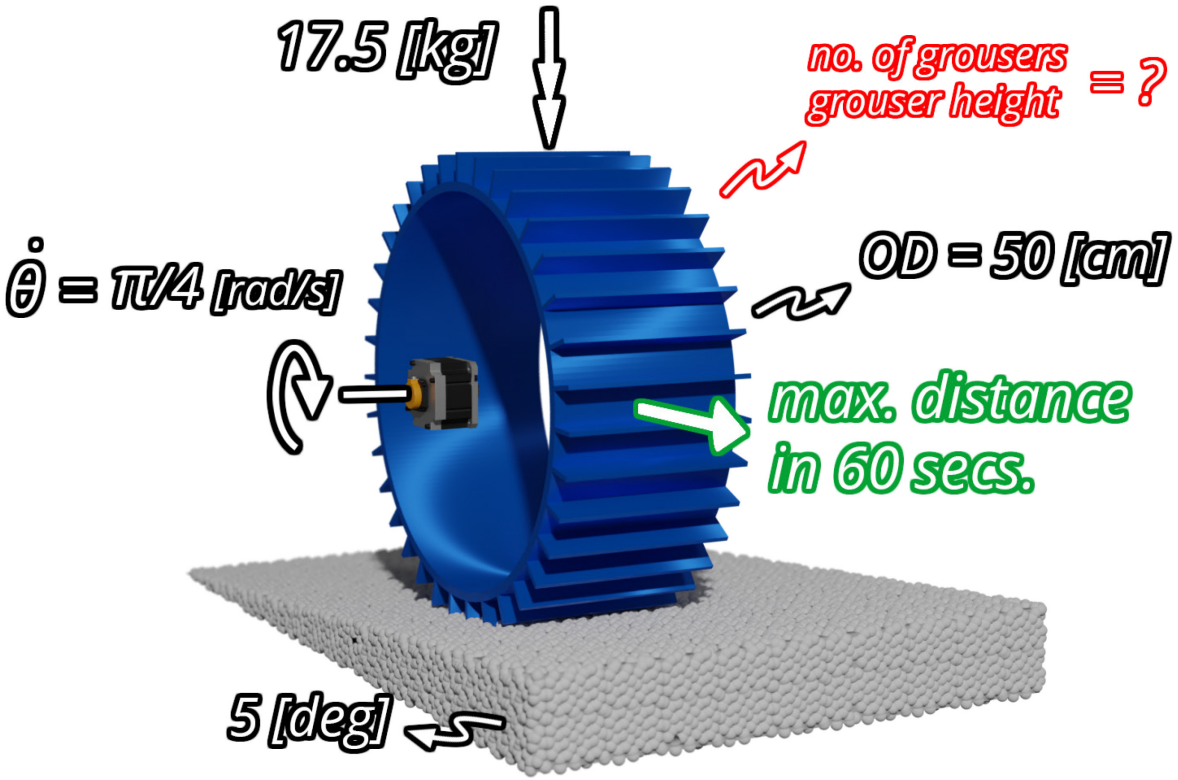


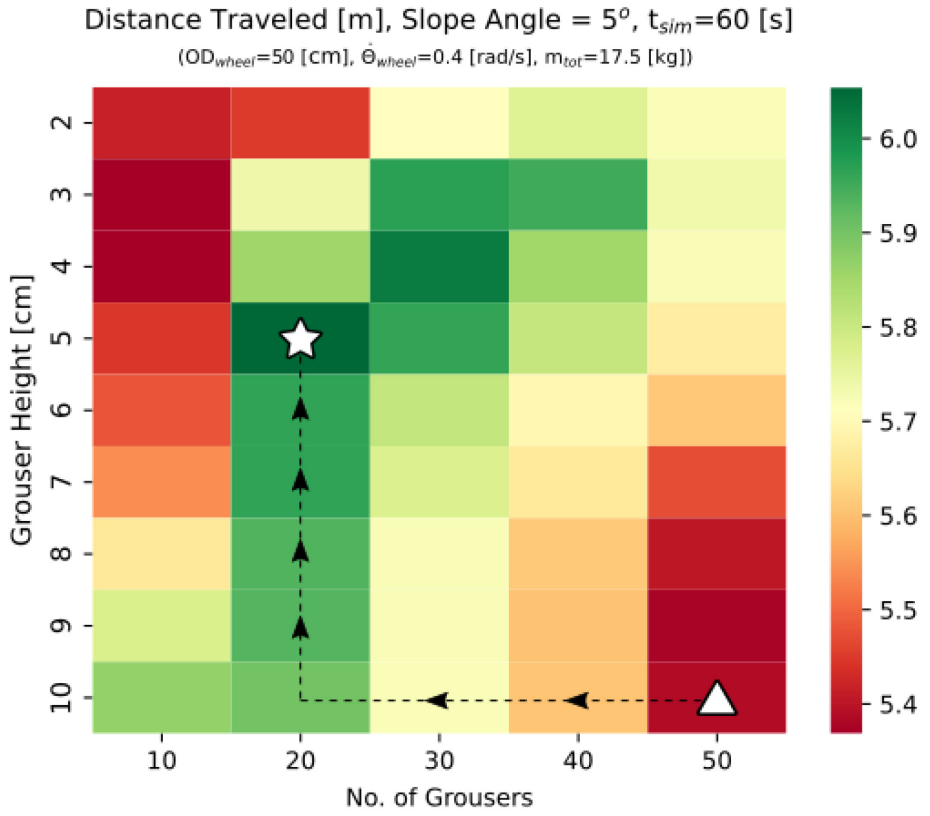
# OPTIMIZED MECHANISMS ARE PARAMETRIC AND REMAIN FULLY EDITABLE



# MULTI-DIMENSIONAL OPTIMIZATION

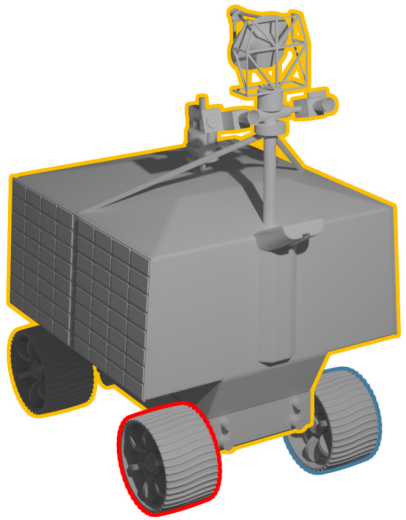


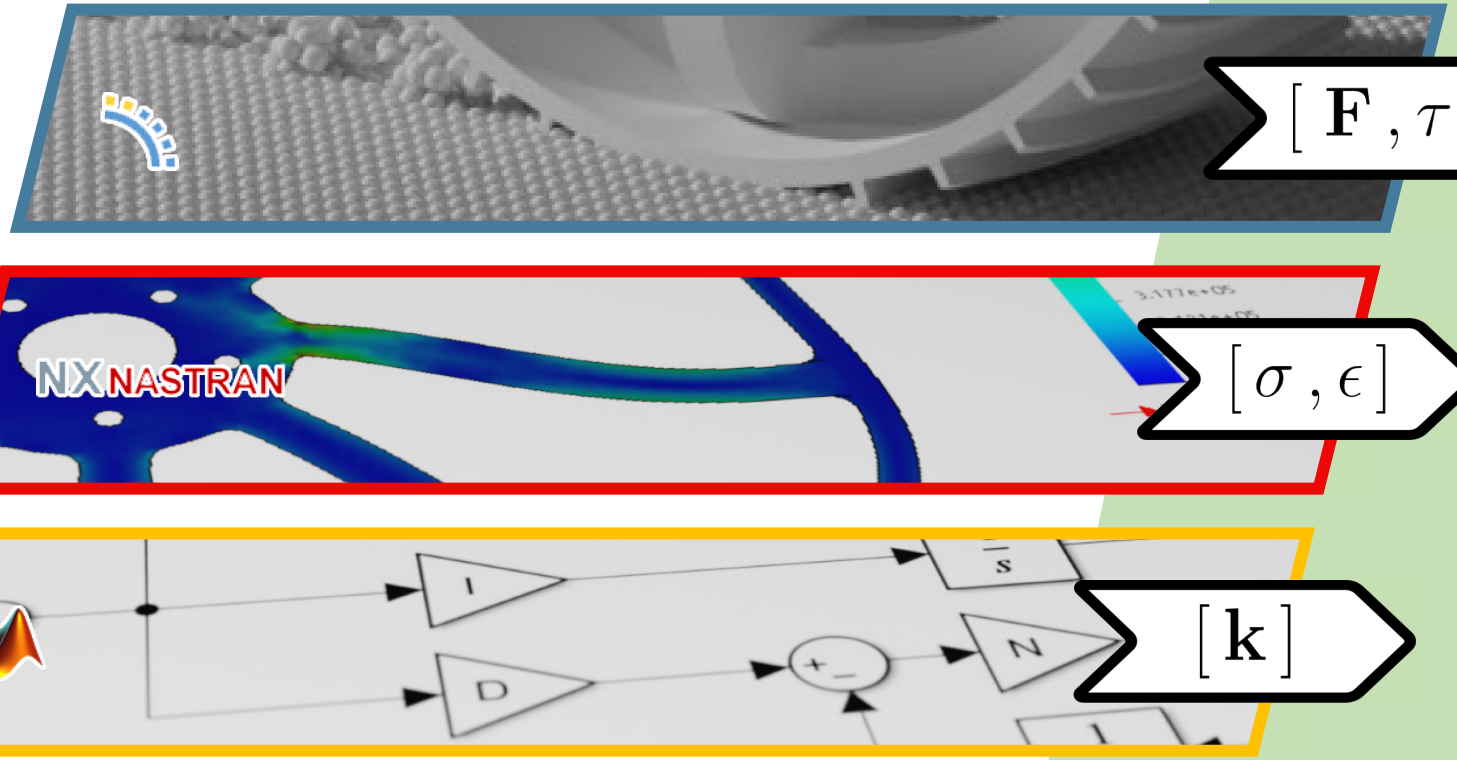

*2D wheel optimization problem in granular media.*



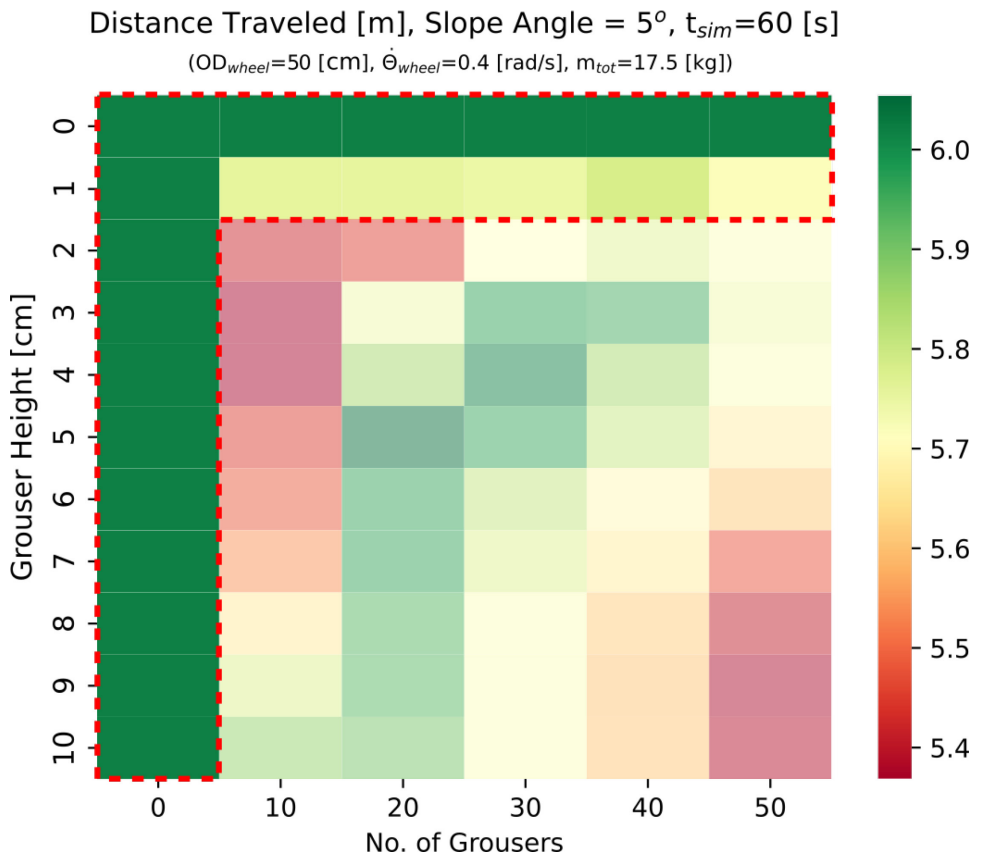

*Parameter optimization using discrete hill climbing. Simulated in Chrono [2].*

# MULTI-OBJECTIVE FORMULATION ENABLES MODULARITY AND CO-OPTIMIZATION

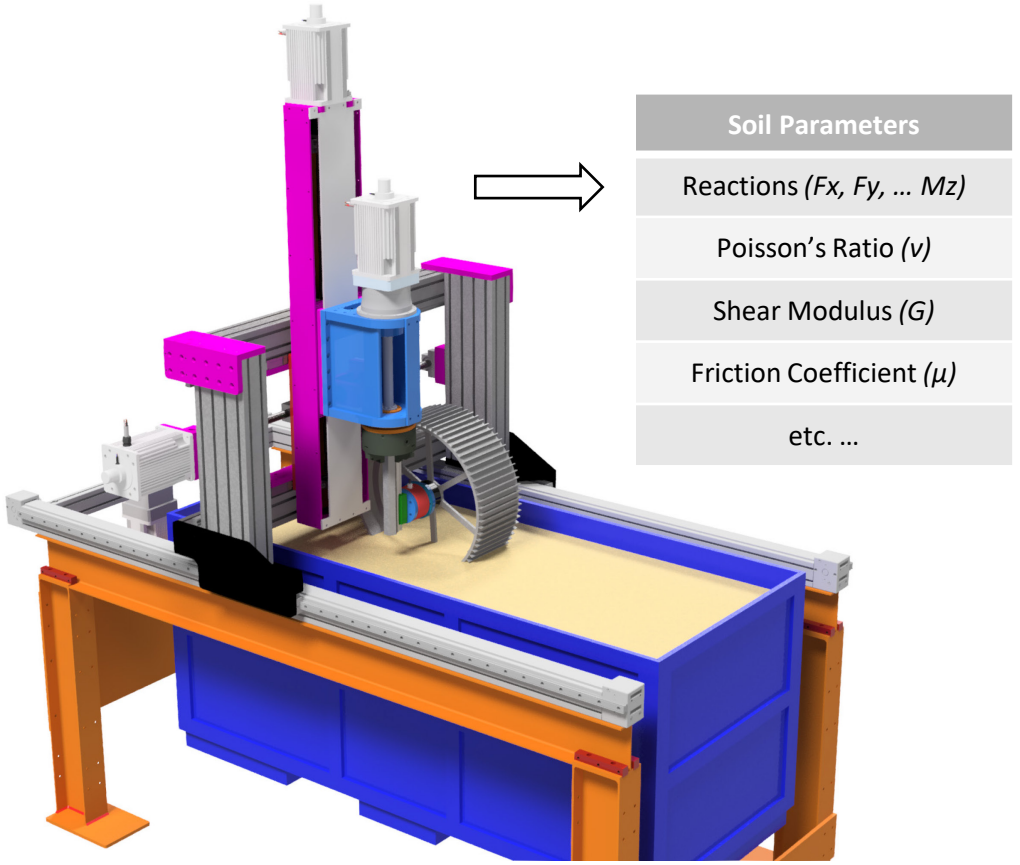




# NEXT STEPS




*Soil model should be tuned to range of interest.*




*GRC Soil Characterization Rig.*

# THANK YOU! QUESTIONS?

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Sources:
[1] N. Hansen and A. Ostermeier. Completely derandomized self-adaptation in evolution strategies. *Evolutionary Computation* 9(2).
[2] A. Tasora *et al*. Chrono: An open source multi-physics dynamics engine. *High Performance Computing in Science and Engineering – Lecture Notes in Computer Science,* Springer, 2016.