# AN OPTIMIZATION-BASED TOOLCHAIN FOR PARAMETRIC MECHANISM DESIGN

Alexander Schepelmann, NASA Glenn Research Center, 21000 Brookpark Road, Cleveland, Ohio, 44135, USA

INTRODUCTION

- **Design-build-test approaches** for spaceflight hardware are resource intensive and can produce suboptimal designs.

- **Virtual design approaches** that couple machine learning with high-fidelity simulation could reduce the need for iterative protoyping, accelerate the engineering design cycle, and reduce cost.

- This work presents a modular NASA-developed **toolchain to optimize hardware mechanisms** virtually using numerical optimization and multi-body physics simulation.
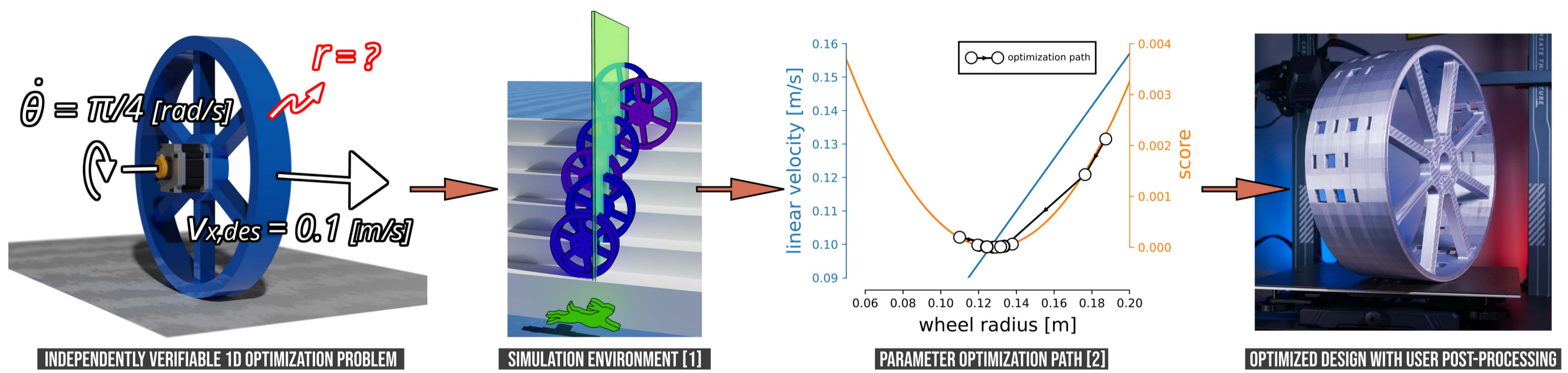
TOOLCHAIN OVERVIEW

SYSTEM SIMULATION

$[x, y, z]$ $[X]$

MECHANISM GENERATION $[d_1, d_2, ... d_a]$ PARAMETER OPTIMIZATION
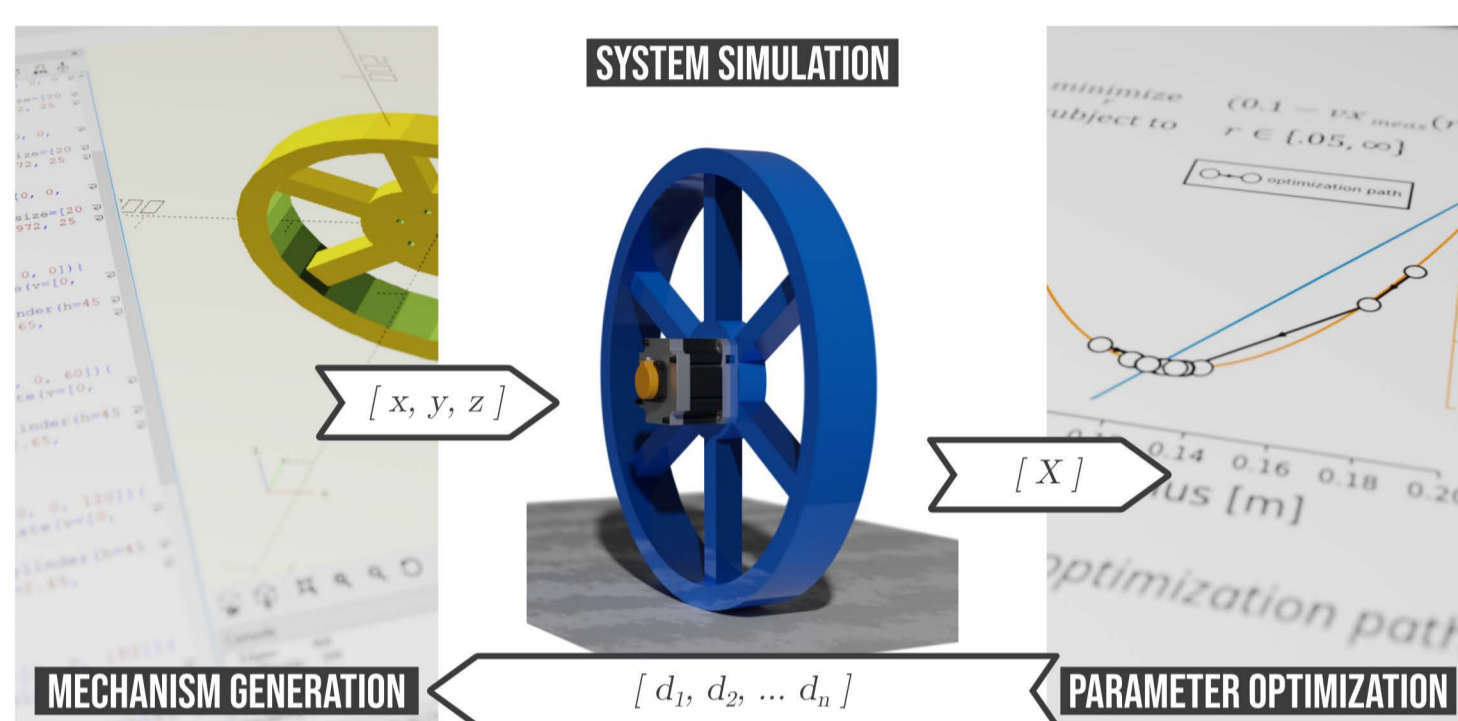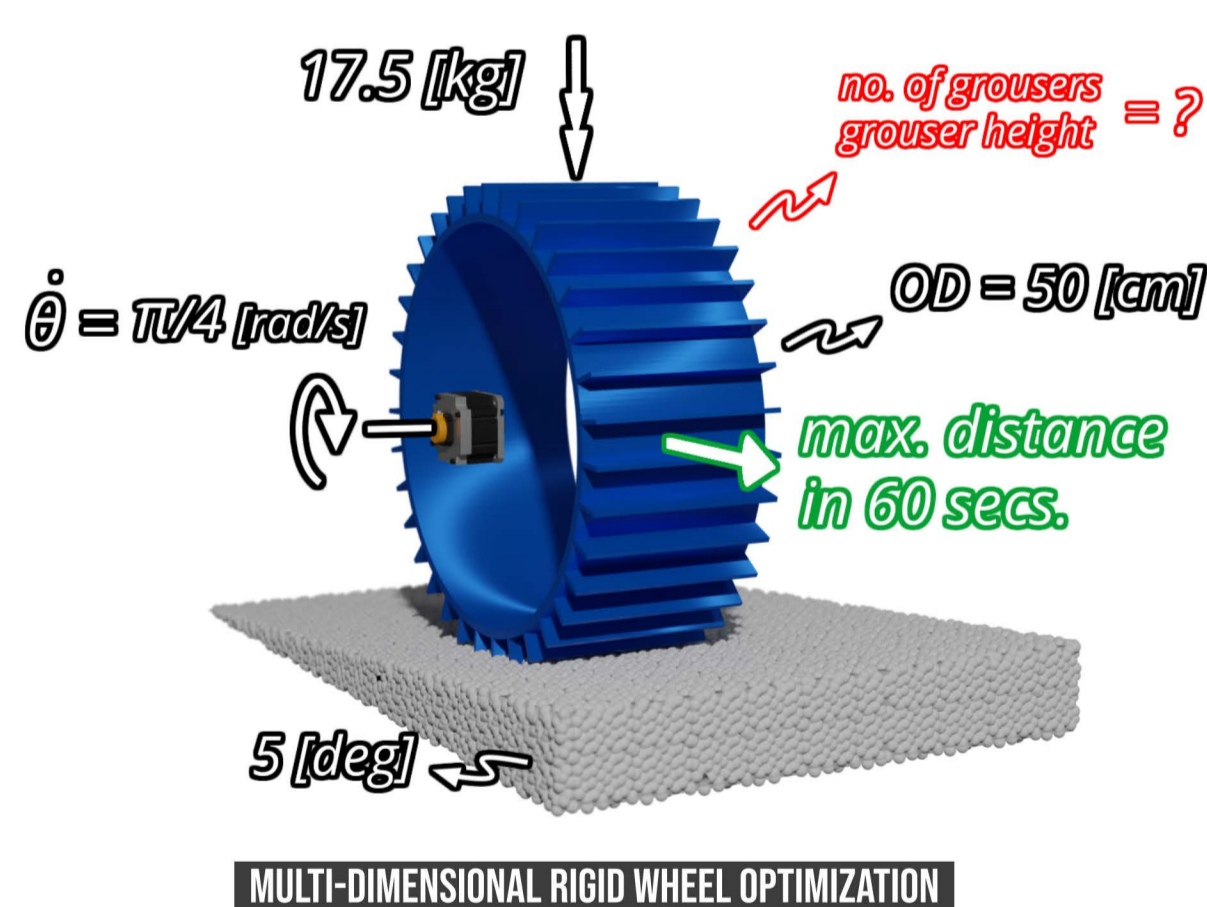
The toolchain:

- Enables **multi-objective optimization**.

- Generates **parametric CAD files** that can be further post-processed by an end user.

- Is **expandable** to optimize full systems and non-mechancial parameters such as control variables.
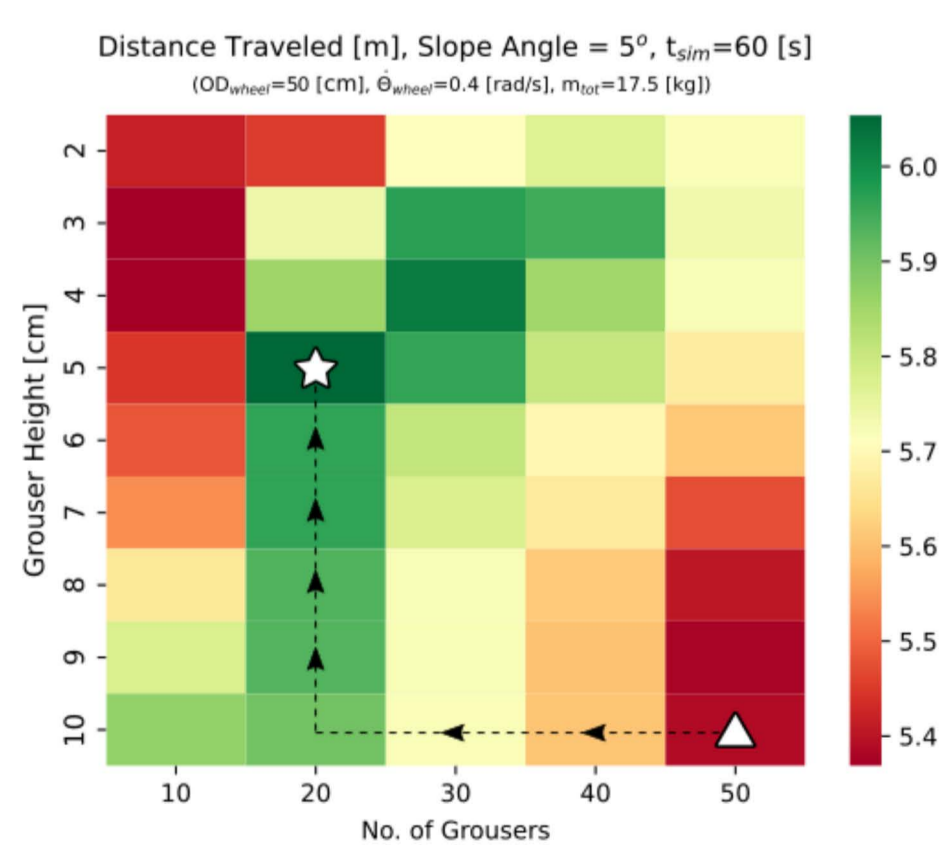
TOOLCHAIN VALIDATION

$\dot{\theta} = \pi/4$ $[rad/s]$ $r = ?$

$V_{x,des} = 0.1$ $[m/s]$

INDEPENDENTLY VERIFIABLE 1D OPTIMIZATION PROBLEM

SIMULATION ENVIRONMENT [1]

PARAMETER OPTIMIZATION PATH [2]

OPTIMIZED DESIGN WITH USER POST-PROCESSING

RIGID WHEEL OPTIMIZATION

17.5 [kg]

no. of grousers grouser height = ?

$\dot{\theta} = \pi/4$ $[rad/s]$ OD = 50 [cm]
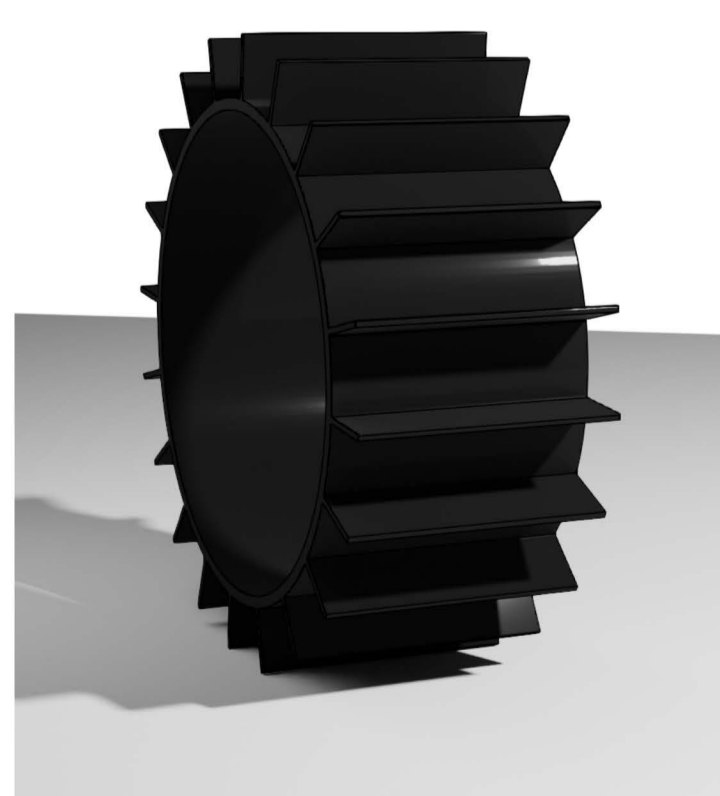
max. distance in 60 secs.

5 [deg]

MULTI-DIMENSIONAL RIGID WHEEL OPTIMIZATION

- The toolchain was used to **optimize the geometry of a rigid wheel** traversing a 5 degree incline of GRC-1 simulant.

- **Grouser number and height** were optimized to achieve maximum travel distance over 60 seconds of simulation time.

- The toolchain finds **the optimum parameter combination** within the search space using a discrete optimizer.

- A **wheel prototype is being manufactured** to validate the wheel's performance on a new NASA-developed tesbed.

Distance Traveled [m], Slope Angle = 5°, t_{sim}=60 [s]
(OD_{wheel}=50 [cm], $\dot{\theta}_{wheel}$=0.4 [rad/s], m_{tot}=17.5 [kg])

DESIGN SPACE PARAMETER SWEEP AND OPTIMIZATION RESULTS

OPTIMIZED WHEEL DESIGN
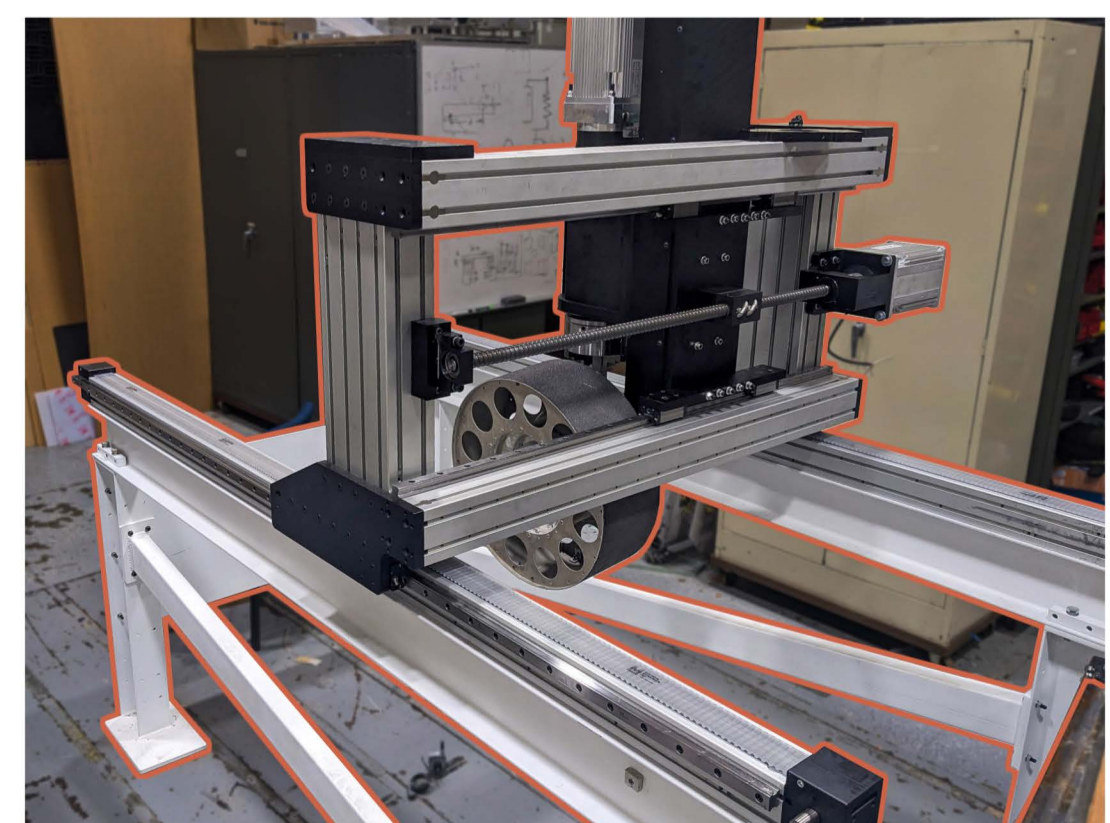
GLENN RESEARCH CENTER'S ROBOTIC MECHANISM TESTBED

REF

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- N. Hansen and A. Ostermeier. Completely derandomized self-adaptation in evolution strategies. *Evolutionary Computation* 9(2).