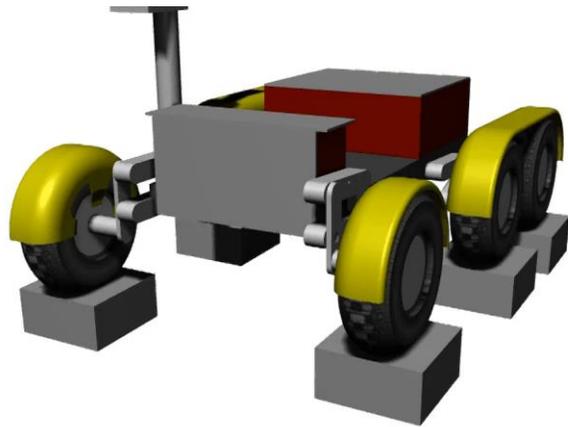
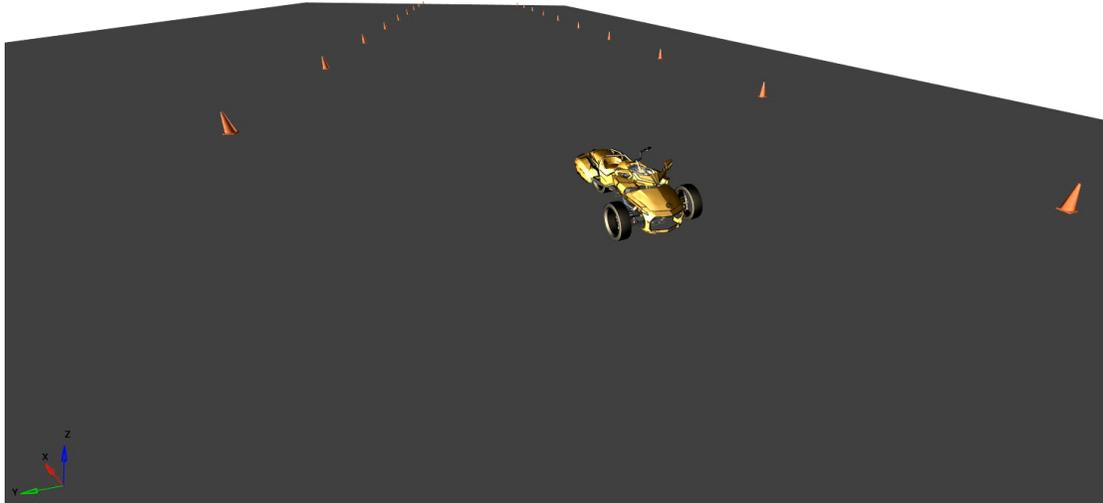


Use of AI for simulation and digital twins

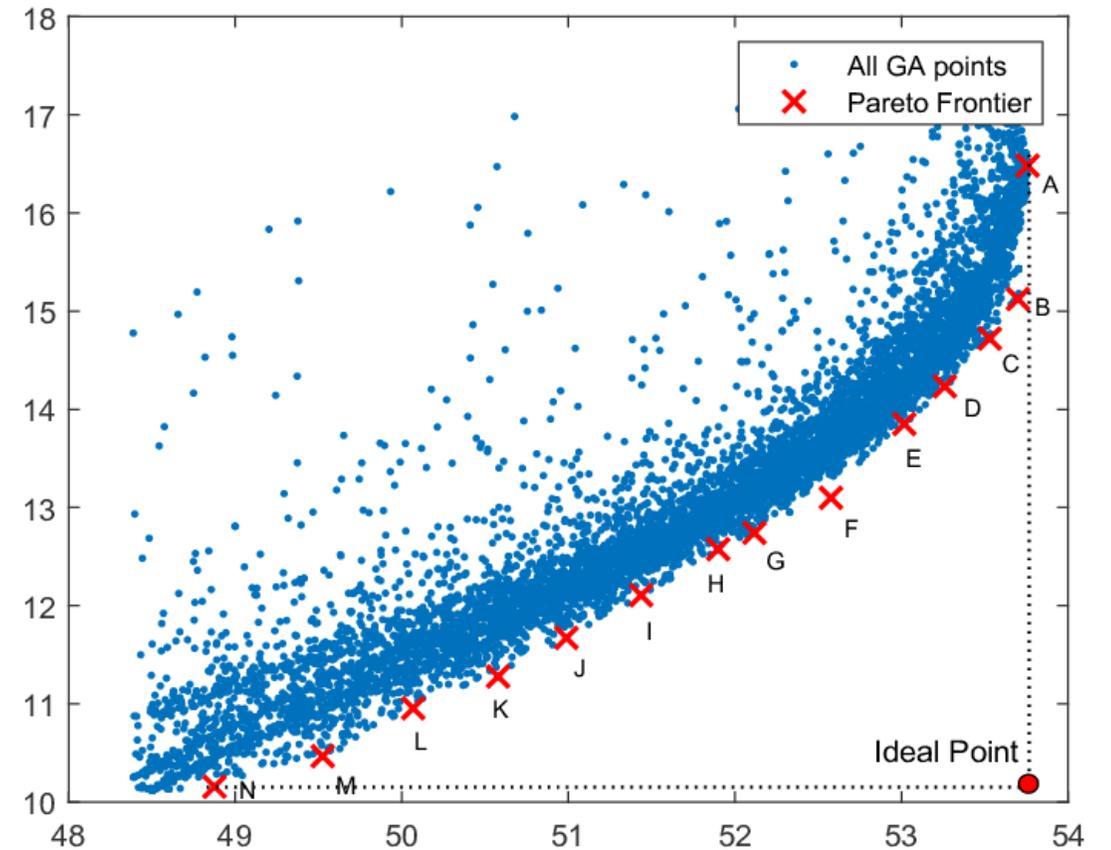
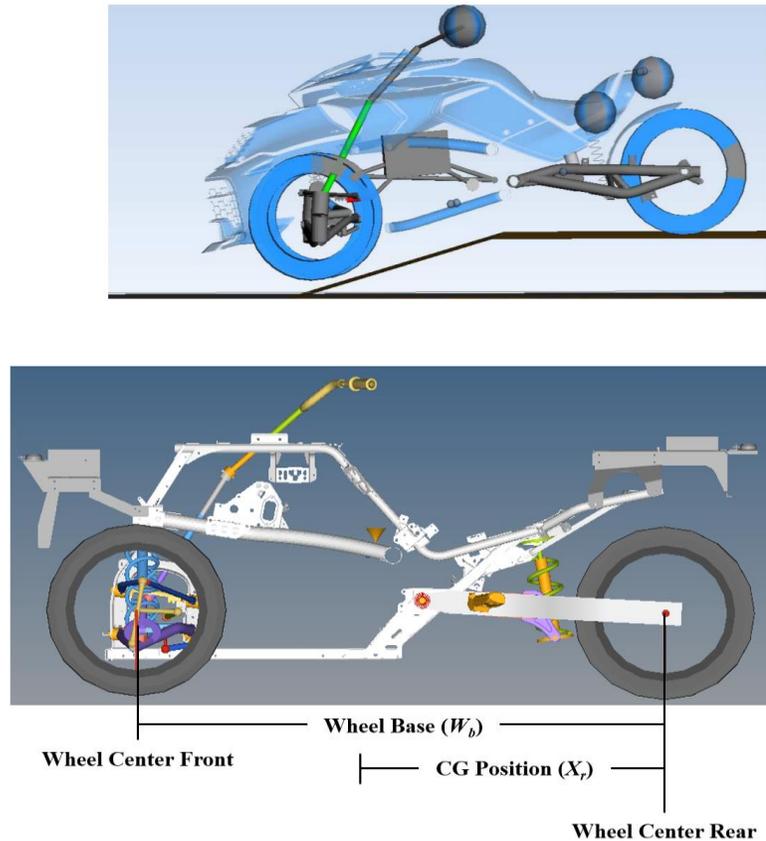


First, physics sandboxes are now key to develop and test vehicles

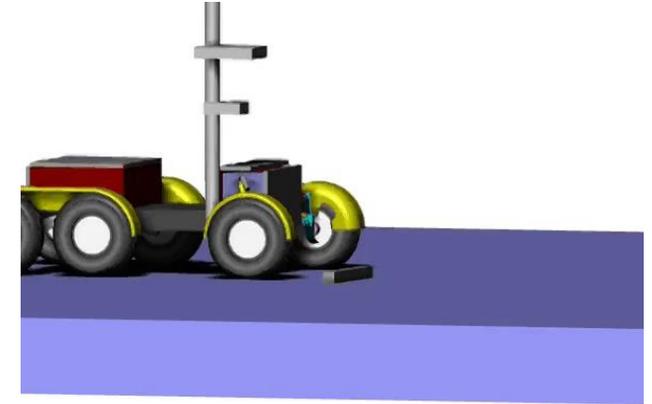


Those digital twins have been used to guide design choice and find best trade-offs

- By optimizing multiple parameters and find best trade-offs using DOEs and optimization

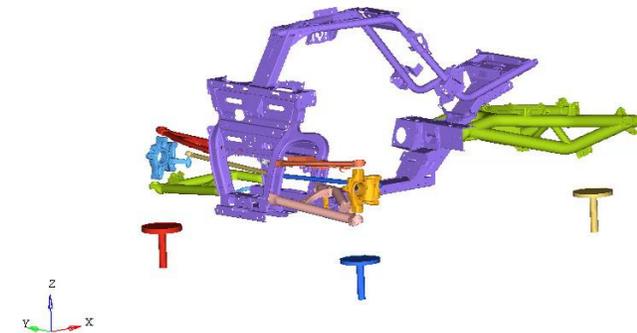


And evaluate input loads on the structure



Tire-model agnostic

1: MS Model
Transient : Time = 0.000000 : Frame 1



They allow making new vehicle that will operate in different gravity

- MESR vehicle seen at NASA's Ohio proving ground

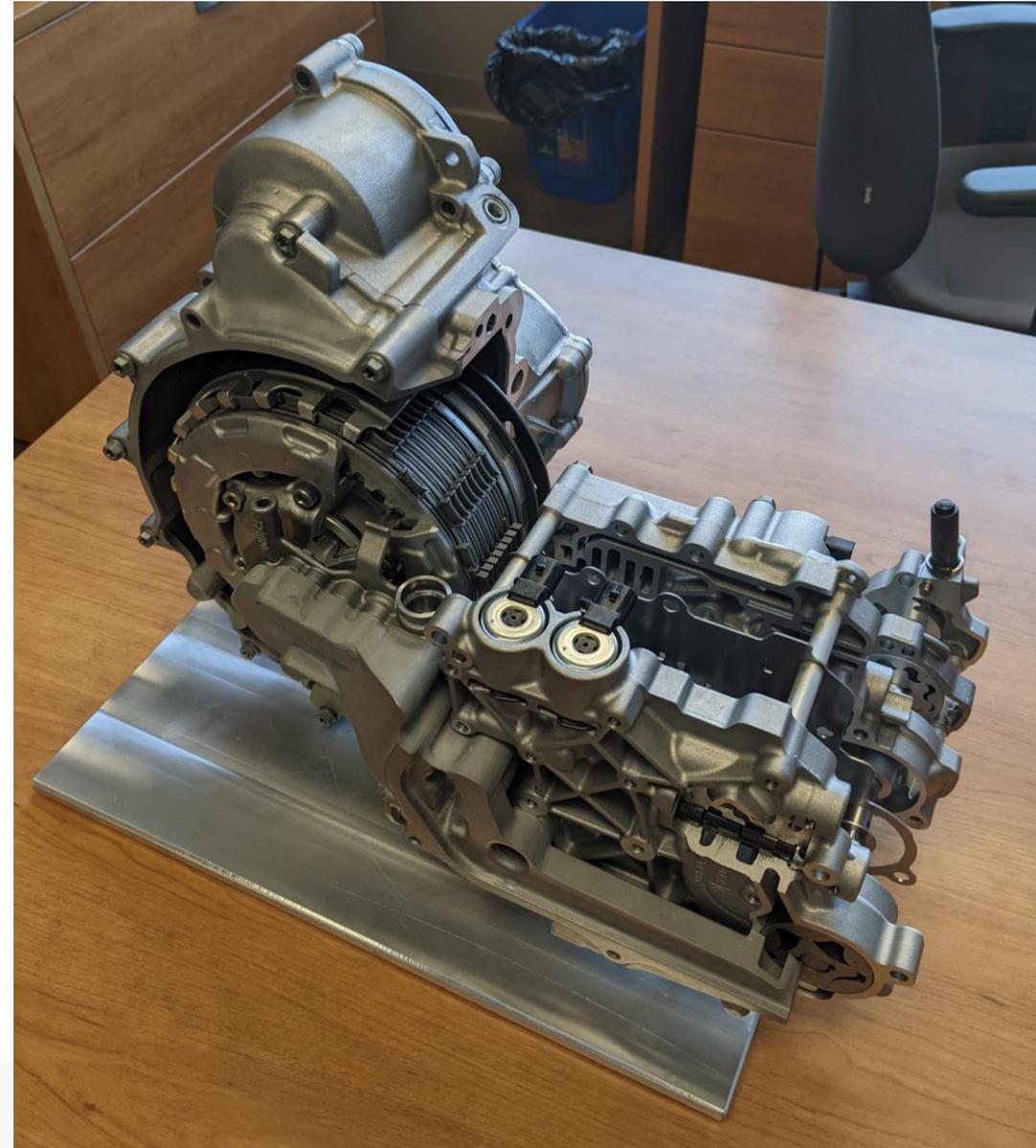


We are now building driver-in-the-loop and immersive simulators using said models



Second, Machine learning and AI applications in vehicles are exploding in popularity

- This clutch is fully automated on the Can-am Spyder thanks to machine learning
- The hydraulic pressure sent to the clutch is adapted continuously for:
 - Tolerance variation
 - Wear
 - Coefficient of friction loss



Allowing to learn and adapt in complex systems

- The machine learning algorithm correlates the clutch torque to the pressure during the launch if favorable conditions are met
- It finds the kisspoint pressure and coefficient of friction



US008744709B2

(12) **United States Patent** (10) Patent No.: **US 8,744,709 B2**
 Gauthier et al. (45) Date of Patent: **Jun. 3, 2014**

(54) **VEHICLE CLUTCH CONTROL METHOD** (58) **Field of Classification Search**
 None
 See application file for complete search history.

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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 (22) PCT Filed: **Mar. 14, 2011**
 (86) PCT No.: **PCT/CA2011/000277**
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 (87) PCT Pub. No.: **WO2012/083411**
 PCT Pub. Date: **Jun. 28, 2012**

Prior Publication Data
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United States Application Data
 Application No. 61426346, filed on Dec. 10, 2010 (2006.01)

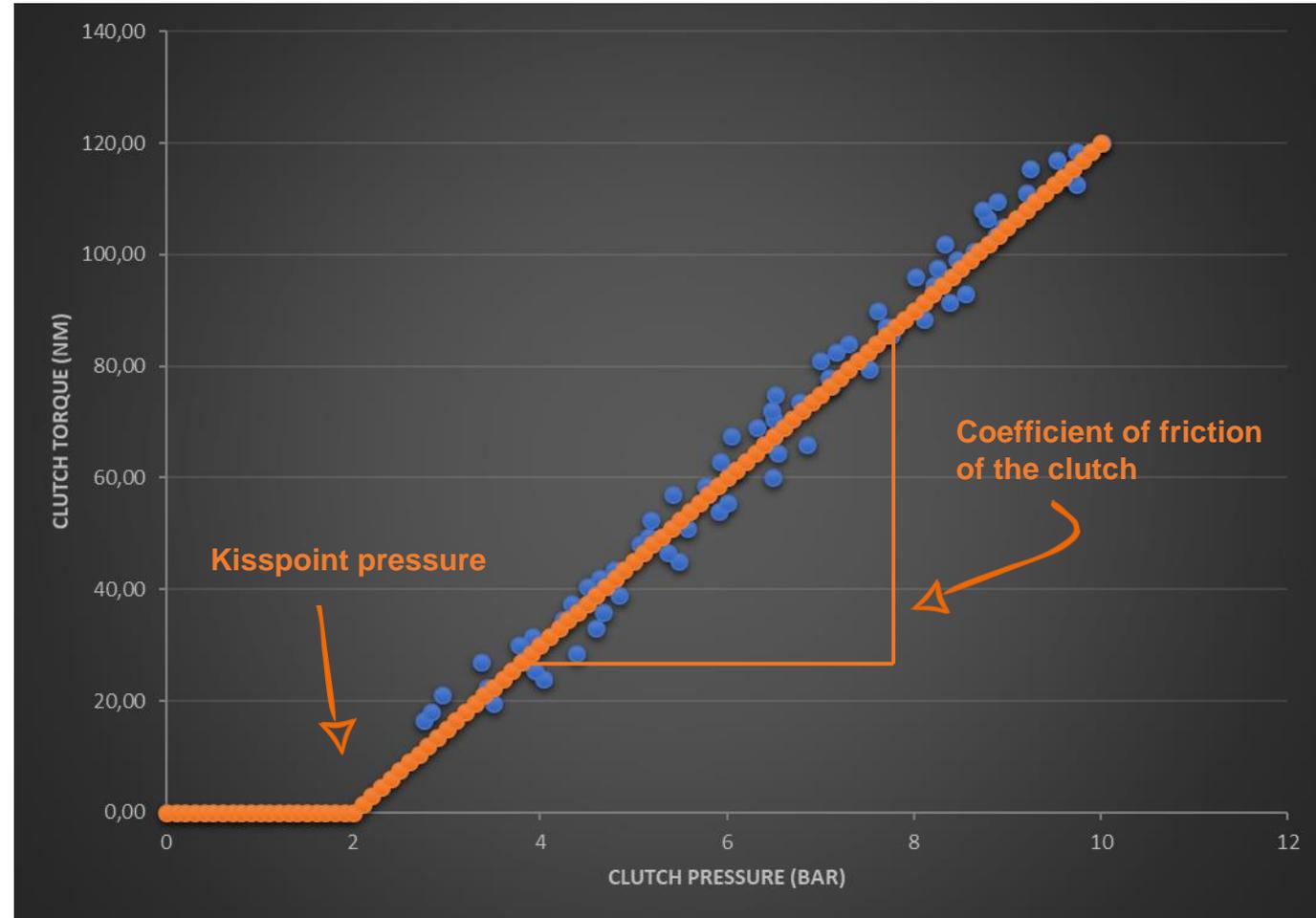
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 21 Claims, 11 Drawing Sheets

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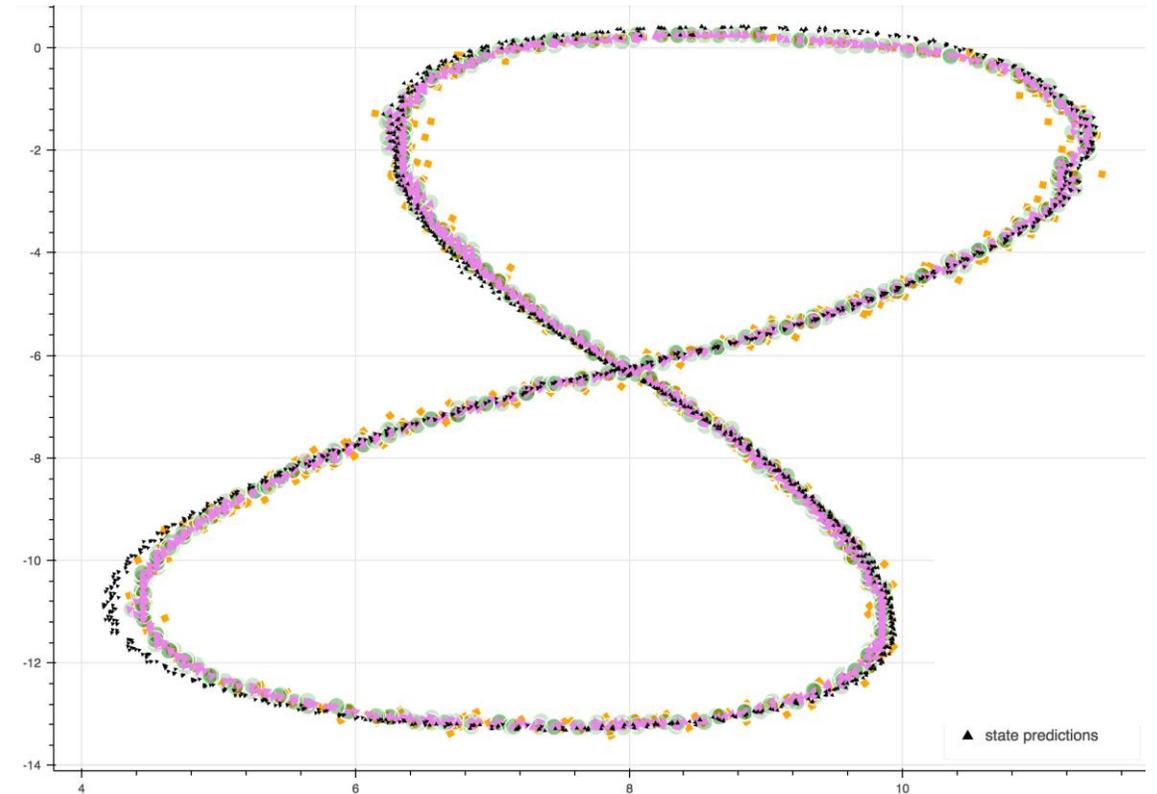
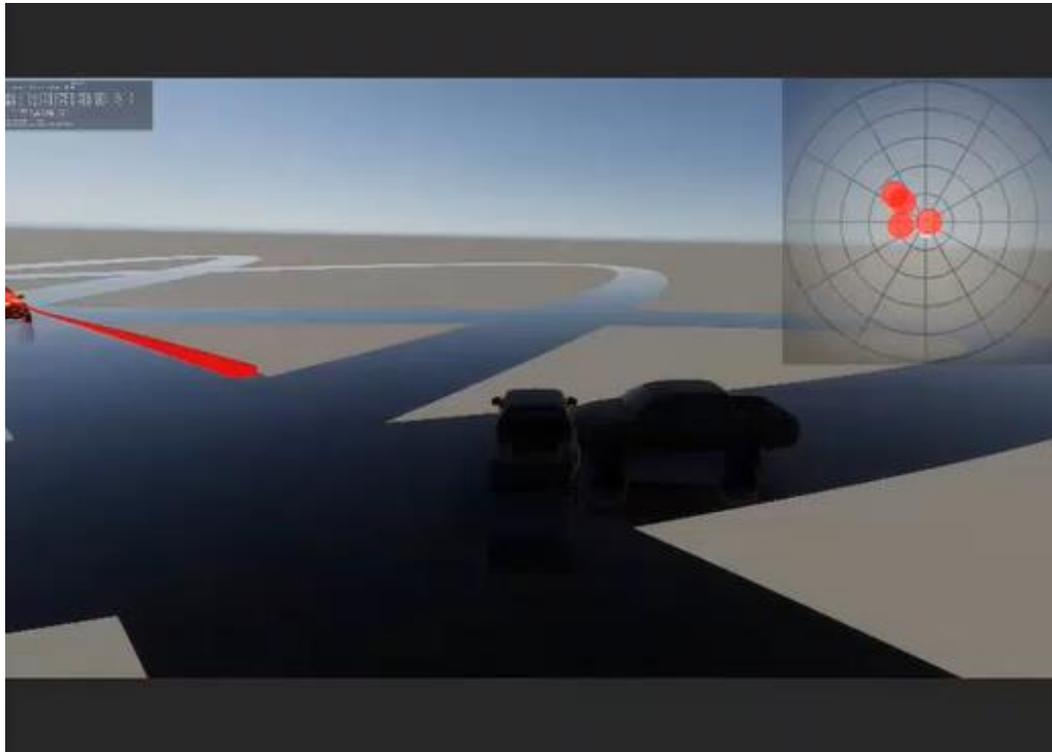
Primary Examiner—Thomas Tarca
Assistant Examiner—Adam Alharbi
794 Attorney, Agent, or Firm—BCT LLP

ABSTRACT
 A vehicle has an engine having a crankshaft, a hydraulically controlled multi-plate clutch operatively connected to the crankshaft, and an output shaft operatively connected to the clutch. The clutch selectively transmits power from the crankshaft to the output shaft. A propellant element is operatively connected to the output shaft. A hydraulic fluid supply system is fluidly connected to the clutch for supplying pressurized hydraulic fluid to the clutch. A controller is connected to the hydraulic fluid supply system. The controller receives a torque signal indicative of engine torque and controls the hydraulic fluid supply system based at least in part on the torque signal. A clutch control method and system are also disclosed.



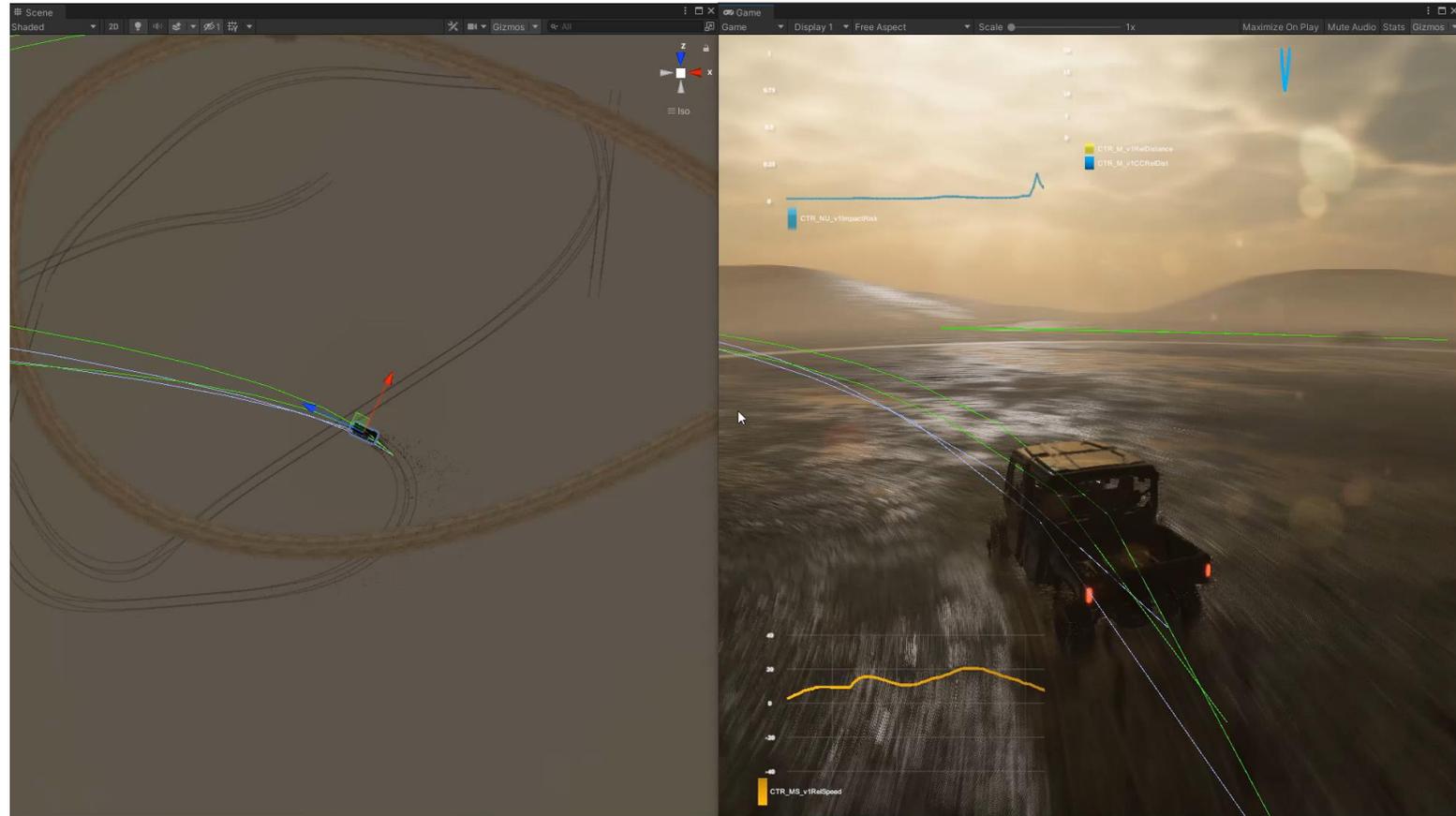
We use AI to estimate vehicle trajectories

- Fusing GPS, yaw rate sensor, steering, throttle and brake
- And avoid future collisions



A 2nd order Vold-Kalman gives excellent results for trajectory prediction

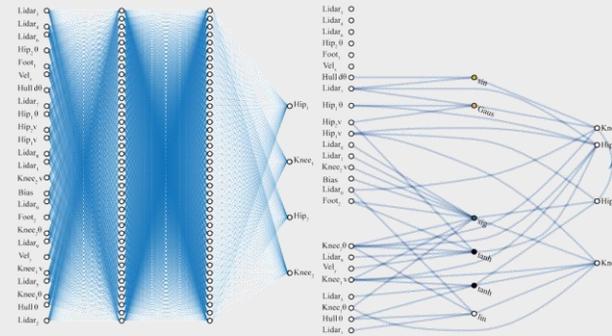
- This could be used for collision avoidance for example or issuing warnings
- Very light in terms of resources and can be done for the closest 10 vehicles if C-V2X information is received



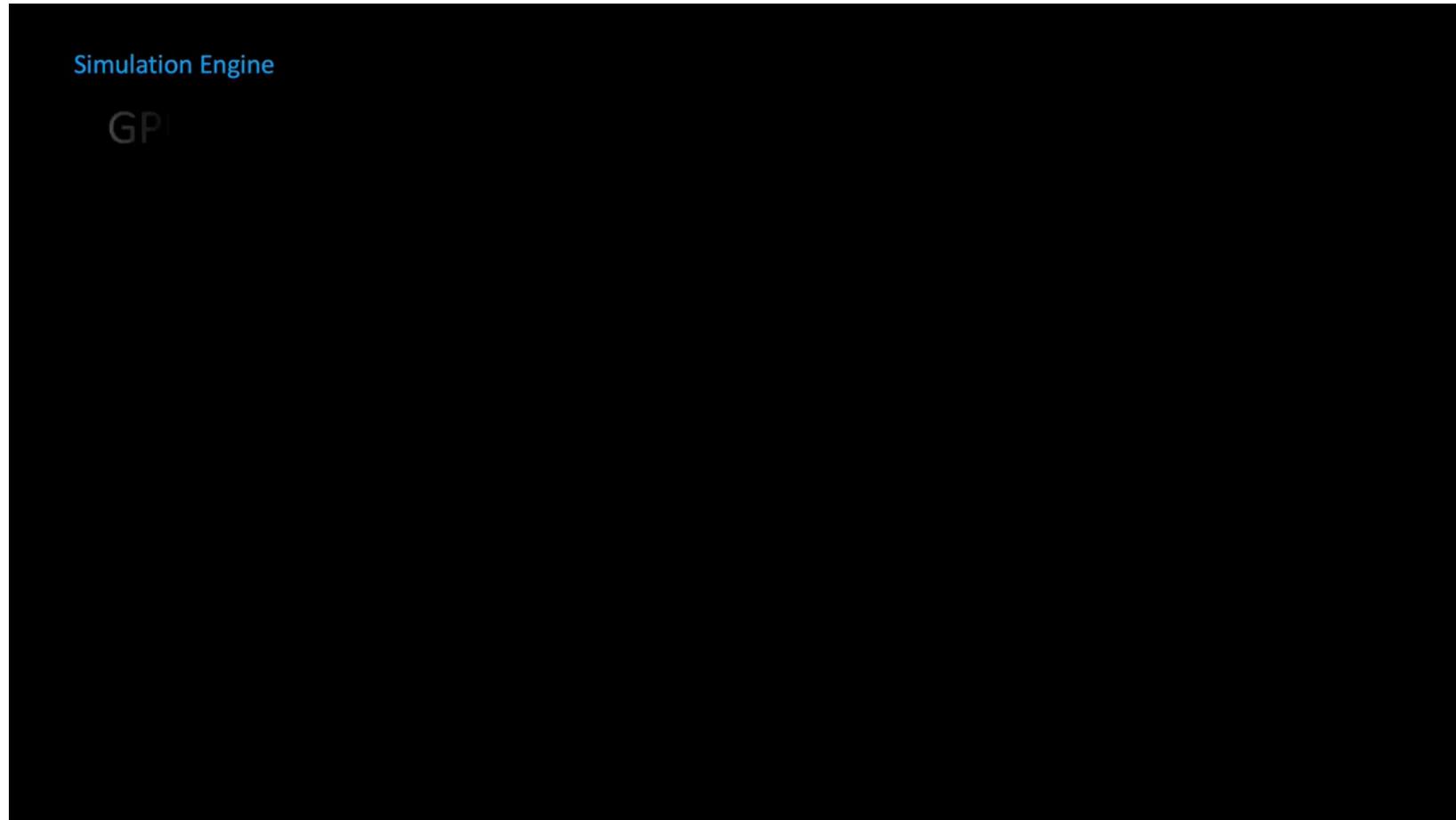
AI and Digital Twins can be used together to accelerate development despite the growing complexity



+



We are beginning to simulate virtual sensors and validate software stack for autonomous driving in a virtual environment



Source: LG SVL

Digital vehicle + Digital environment



- We already have high-fidelity digital twins for dynamic behavior
- We plan to scan our real test environment with LiDAR

Vehicle hardware and control logic being tested with multiple vehicles and scenarios

We can use this to develop bots that drive the vehicle on an off-road test track

- In a virtual sandbox:
 - We are starting to use Reinforcement Learning to control Throttle, Brake and Steering
 - Rewards for staying on track
 - Rewards for maintaining a high speed and scoring good checkpoint times
 - We randomize parameters such as weight and traction to make the controller robust
- Once satisfied with our model, we will try zero-shot generalization from simulation to natural environments
 - Using GPS, cameras, flash lidars and radar with Nvidia Drive
 - Having a C-V2X collision avoidance supervisor and Geofencing to limit collision risk and avoid vehicle leaving certain areas





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