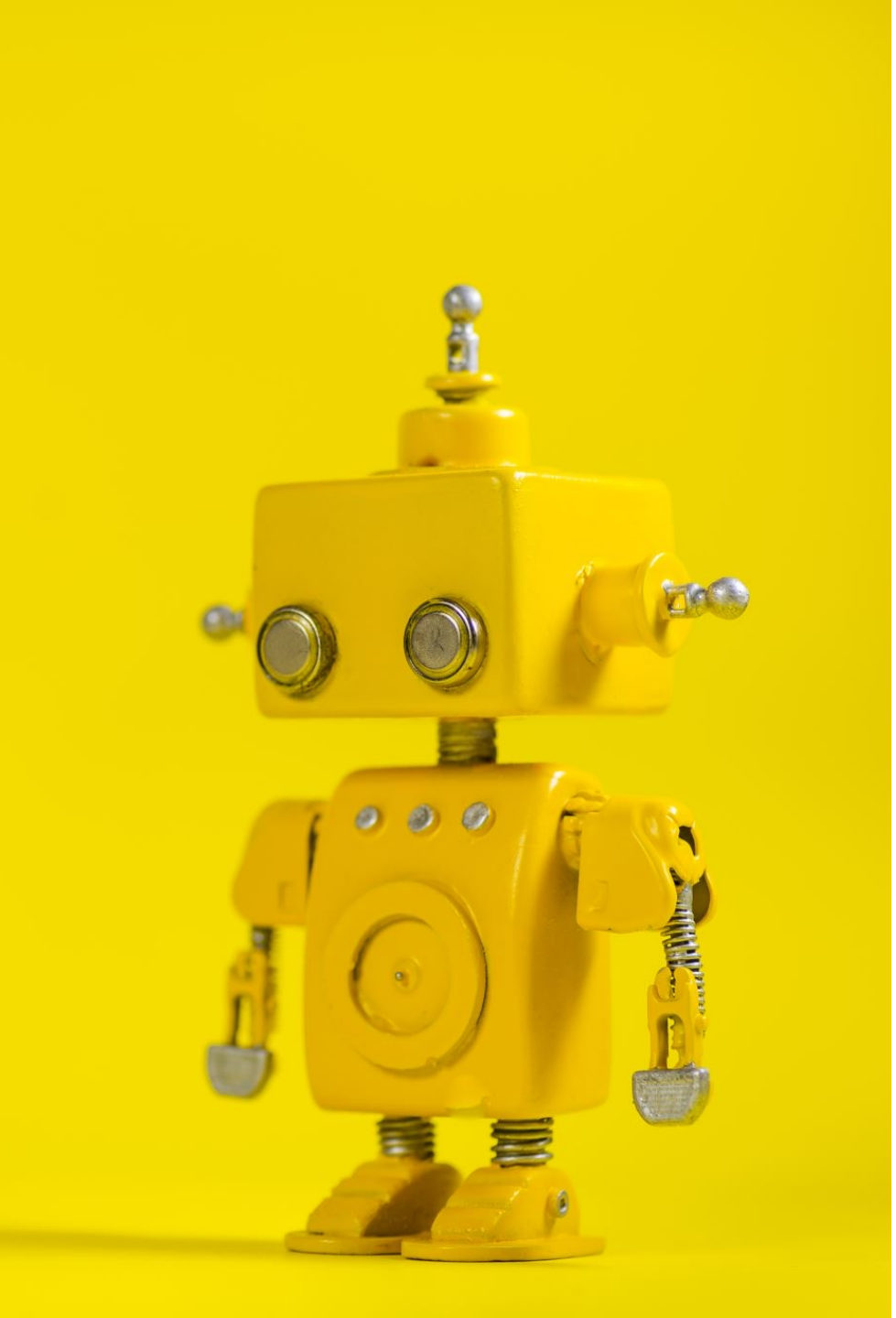
A Brief, Incomplete Review of Mobile Robotics May 24, 2021

Camillo J. Taylor

Raymond S. Markowitz President's Distinguished Professor
Computer and Information Science Dept
University of Pennsylvania



Mobile Robots – Why are they interesting?

- Embodied robotic systems provide a lens for thinking about intelligence, the problems that living creatures must solve and strategies for solving those problems

Why is the Military Interested?

To relieve humans of tasks that are Dirty, Dangerous and Dull

To provide, where possible, advanced capabilities, speed, strength, sensing modalities etc.

Aspects of Mobile Robotics

- Mobility
- Perception
- Planning, Control Decision Making – linking perception to action

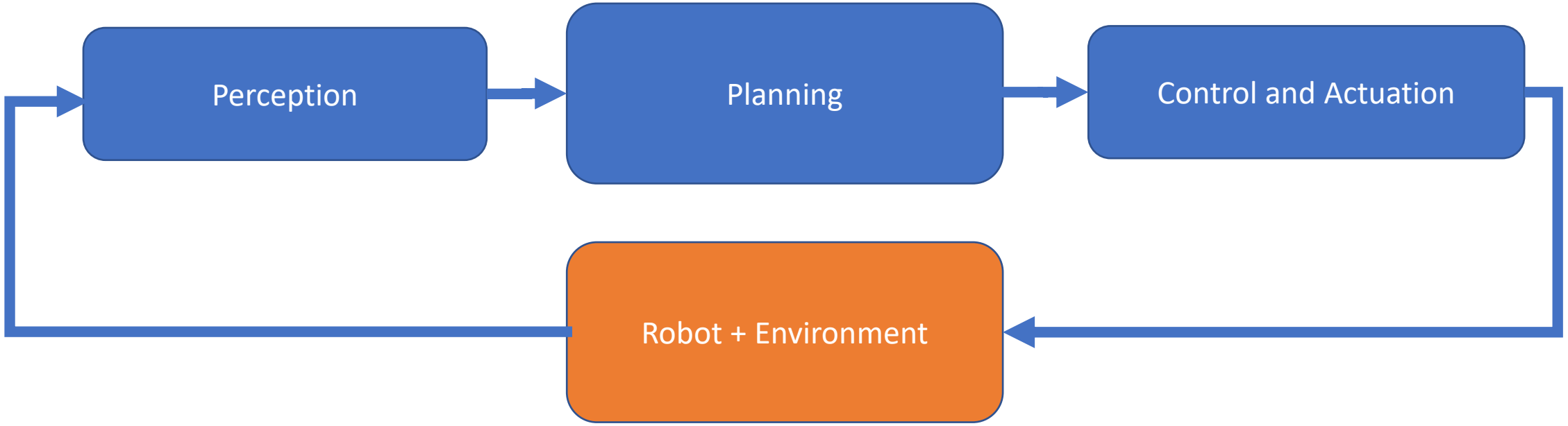
Autonomous Driving

- VaMors – Dickmans et al 1980s
- CMU Navlab – 1984
- DARPA Grand Challenge - 2004, 2005
- DARPA Urban Challenge - 2007

Uptake in Industry

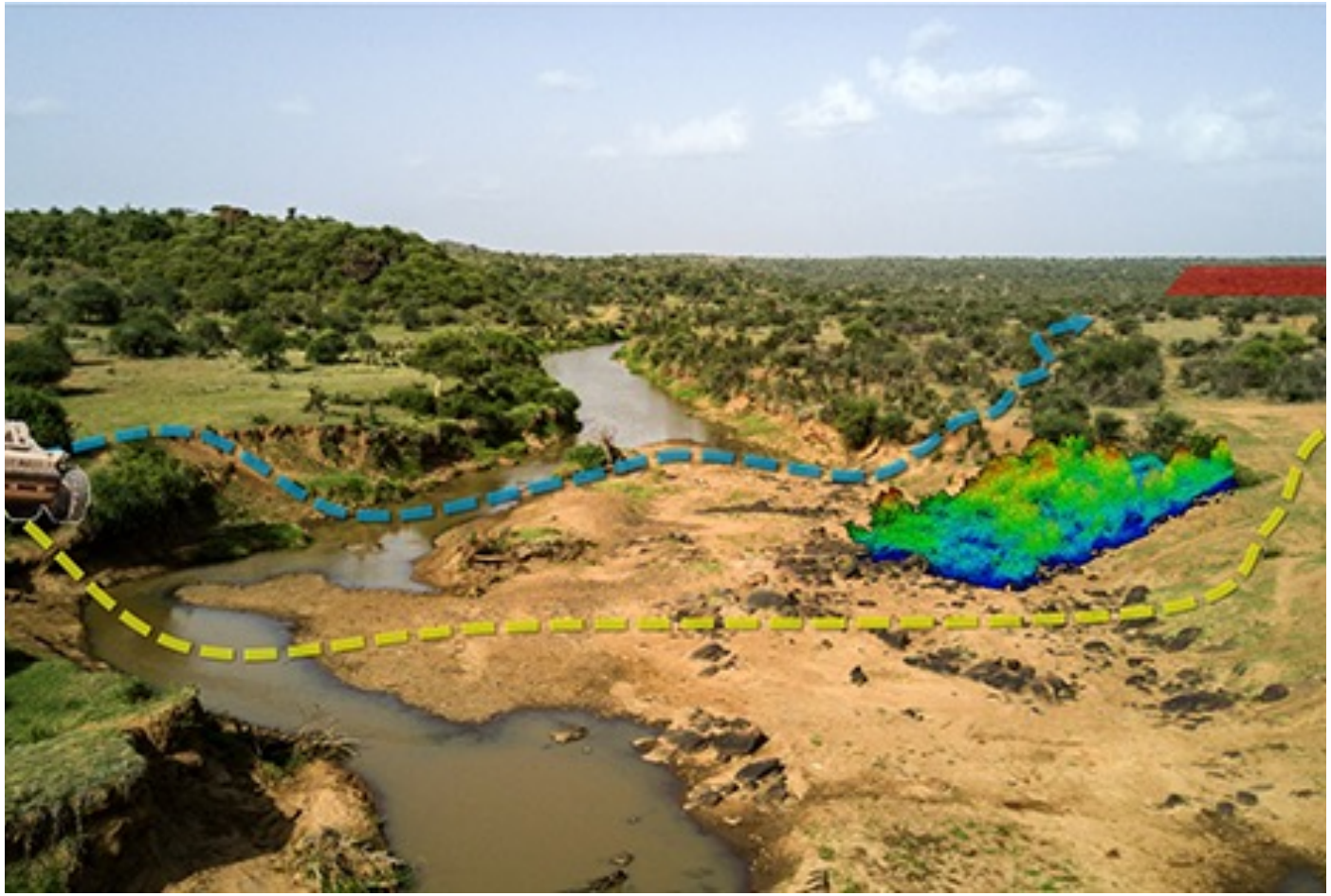
- Waymo
- Zoox
- Lyft
- Argo AI
- Toyota
- Ford
- Aurora Innovation
- And many others ….

Traditional System Diagram



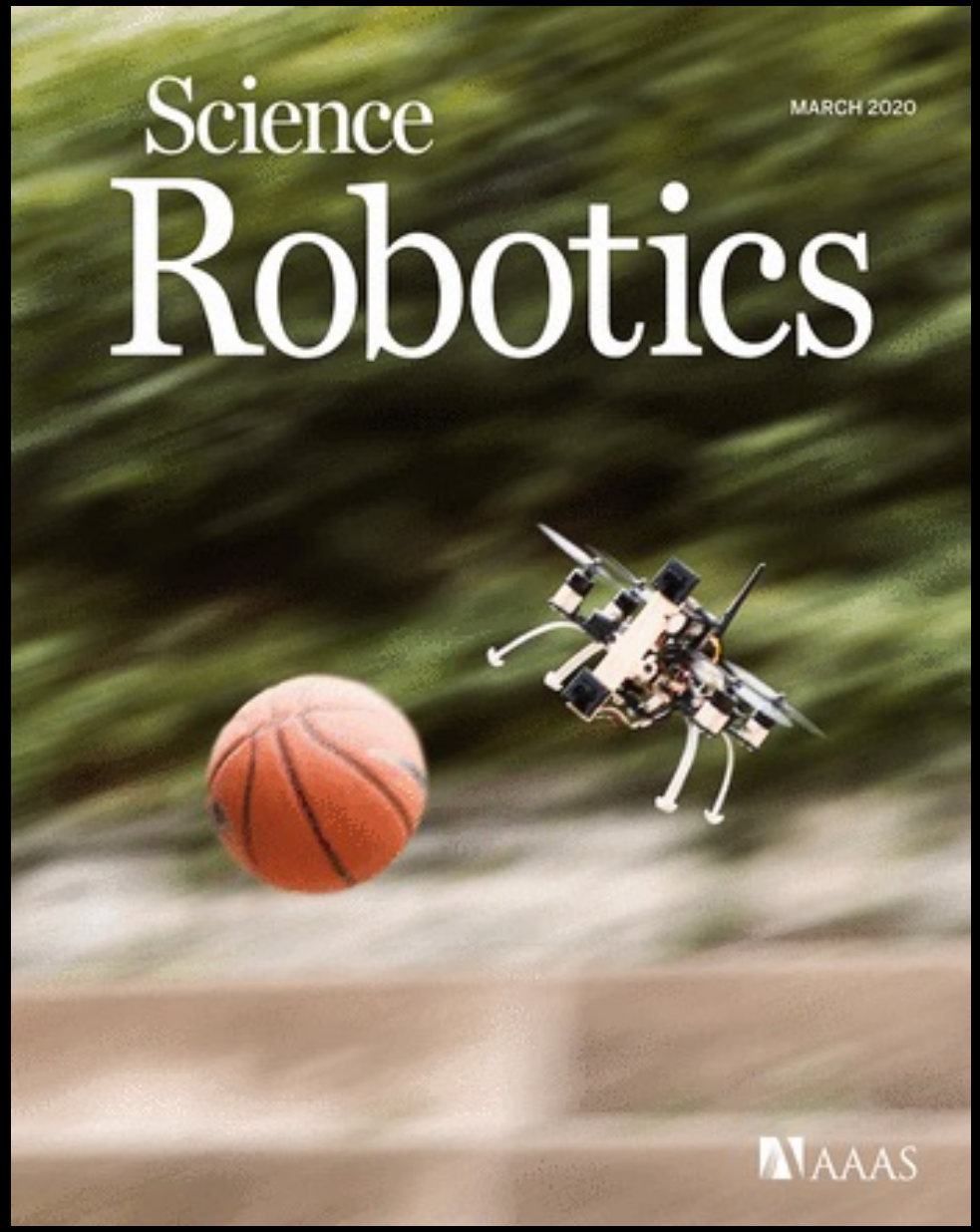
DARPA Racer

- Current DARPA program focused on off-road navigation.
- Challenges
  - Perception of terrain – dirt, slopes, water hazards, brush
  - Complex interactions with terrain
  - No prior map



Autonomous Flying Systems, Technical Challenges

- Fitting all required elements, perception planning and control into the available payload
- Handling the dynamics of a flying platform
- Example – High Speed Dodging Scaramuzza et al. U. Zurich

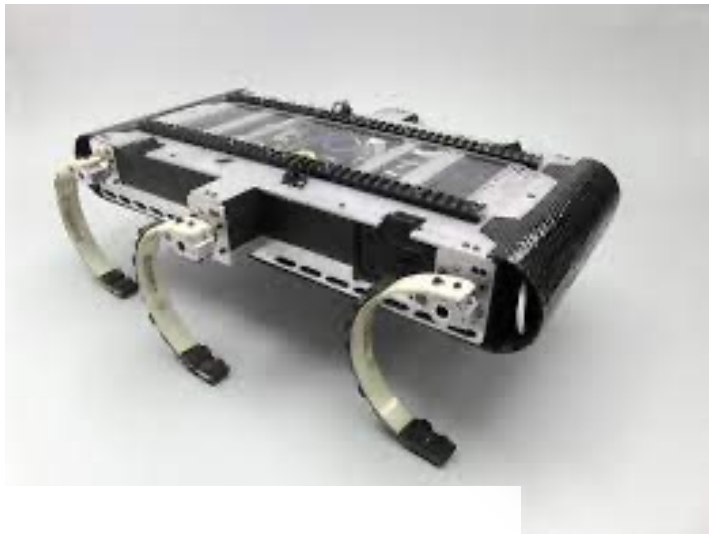


Building Exploration Mission

Legged Locomotion

Complex dynamical system involving periodic contacts

Complex Planning and control problem



Rhex Kod*Lab

Boston Dynamics
Big Dog 2004

Boston Dynamics

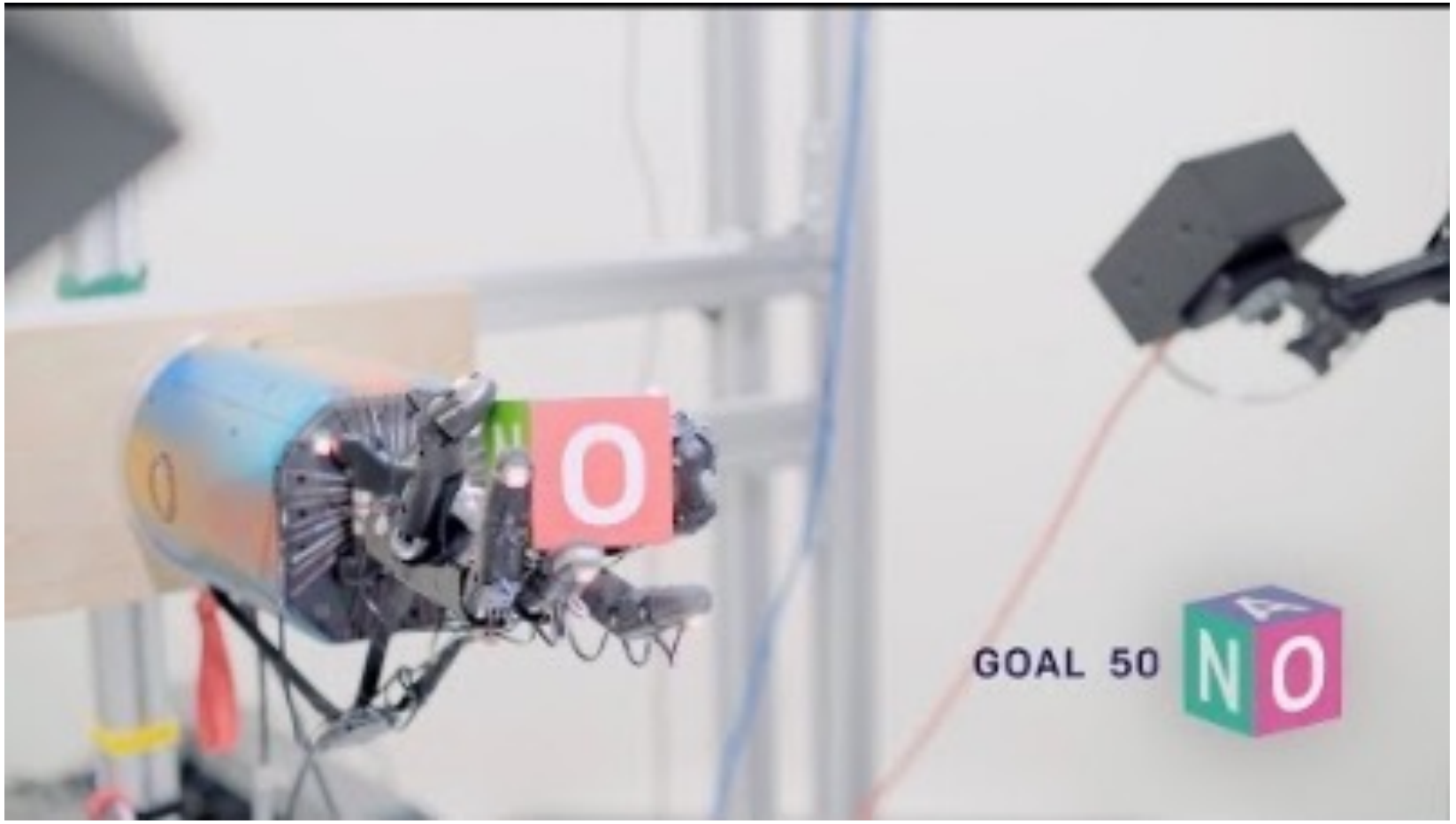
DARPA Robotics Challenge 2015

- Goal design a humanoid robot capable of accomplishing a range of tasks.
  - Driving a cart
  - Opening a door
  - Operating a drill

Learning in Robotics

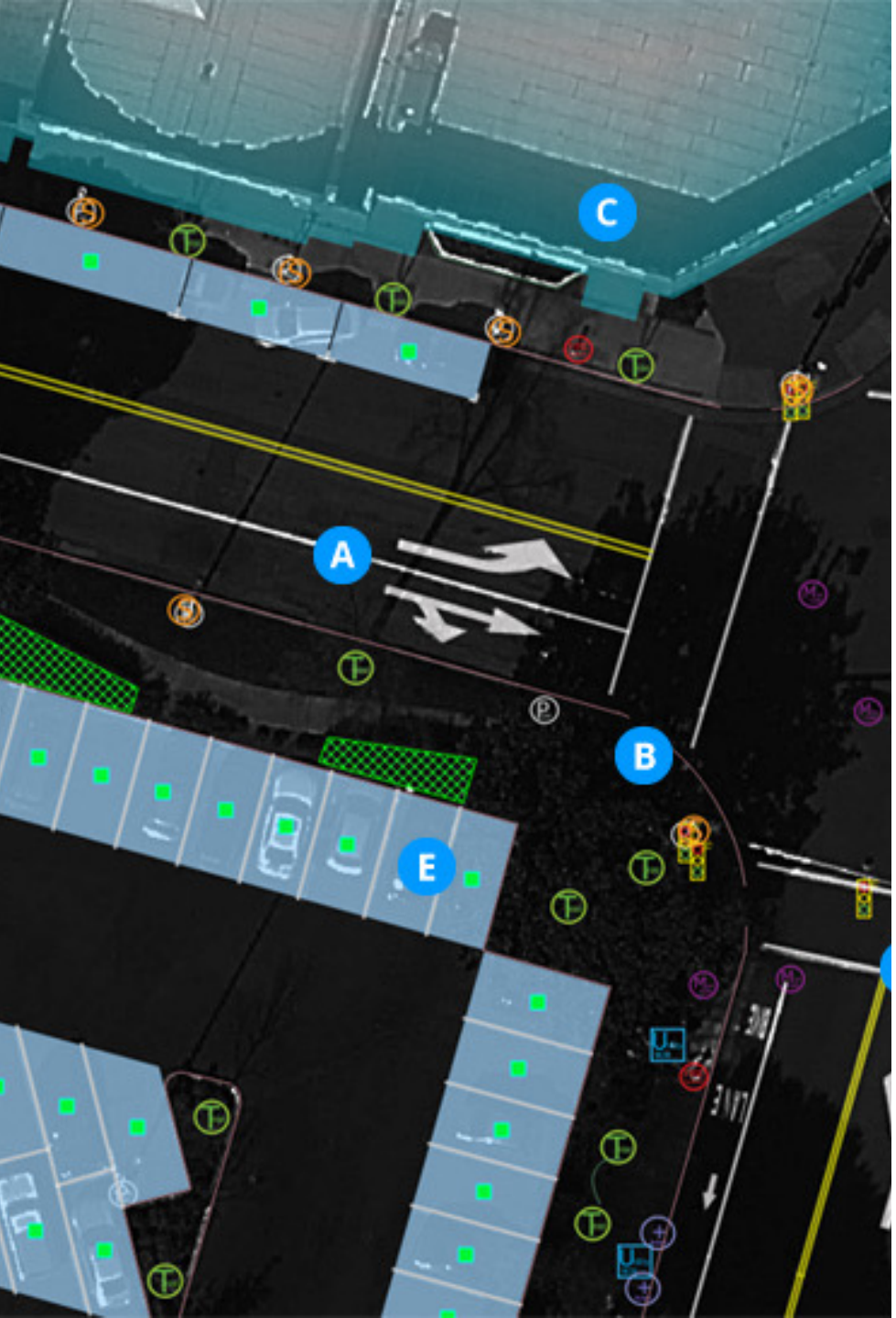
- Tremendous recent interest in new paradigms in robotics that replace complex engineered perception control and planning systems with flexible functions that can be trained from data.
- Possible advantages
  - Reduce the engineering effort required to develop and deploy systems
  - Improve the robustness of the resulting systems by avoiding modeling errors.

Open AI : Learning Dexterity



Current Challenges in Mobile Robotics

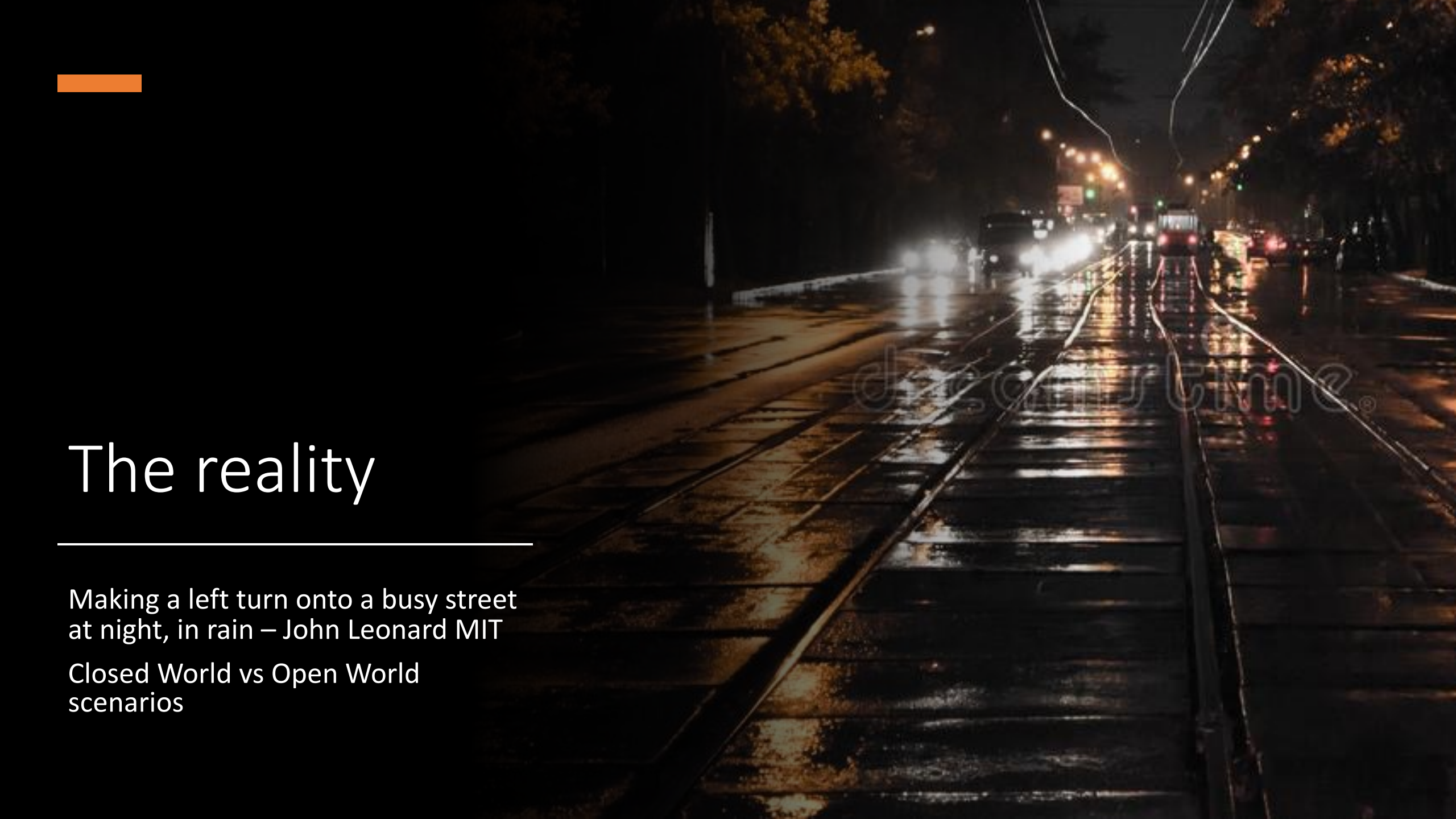
- Current systems are more brittle than we would like. They can perform poorly in situations they are not designed for or trained in.
- We would like systems to be able to learn quickly from experience and generalize appropriately
- We would like systems to construct more abstract representations to facilitate learning and to enable language level communication with human interlocutors.



High Definition Mapping

- High Definition Mapping companies provide detailed road maps for autonomous vehicles
- Lane markings, street signs, parking spaces
- The goal – know as much about the environment as possible – avoid surprises

The reality

Making a left turn onto a busy street at night, in rain – John Leonard MIT

Closed World vs Open World scenarios