Legged Robots for Last 50 Feet Delivery

Presented by:

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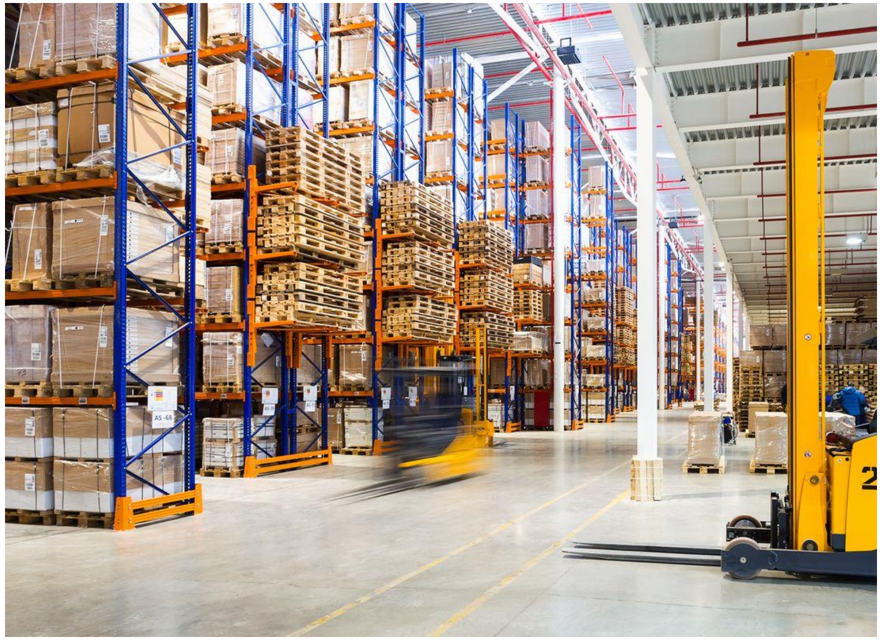
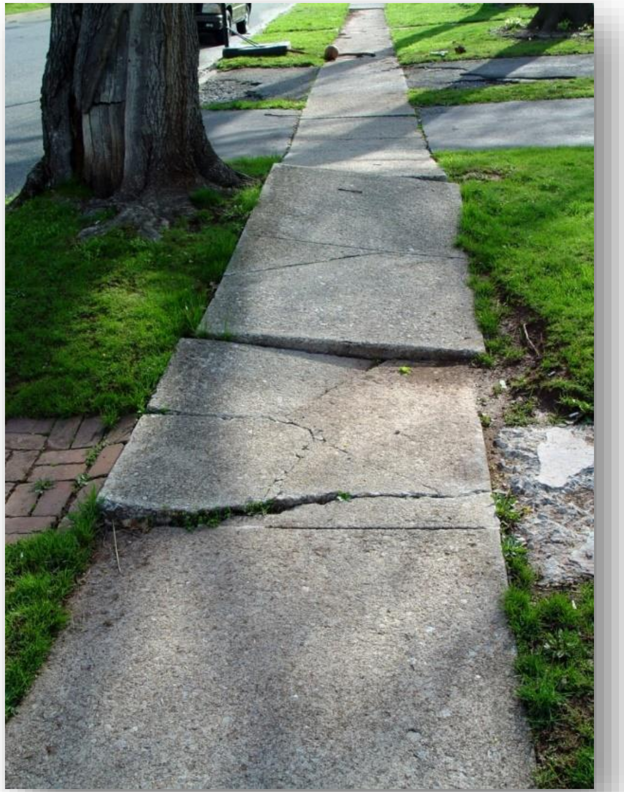
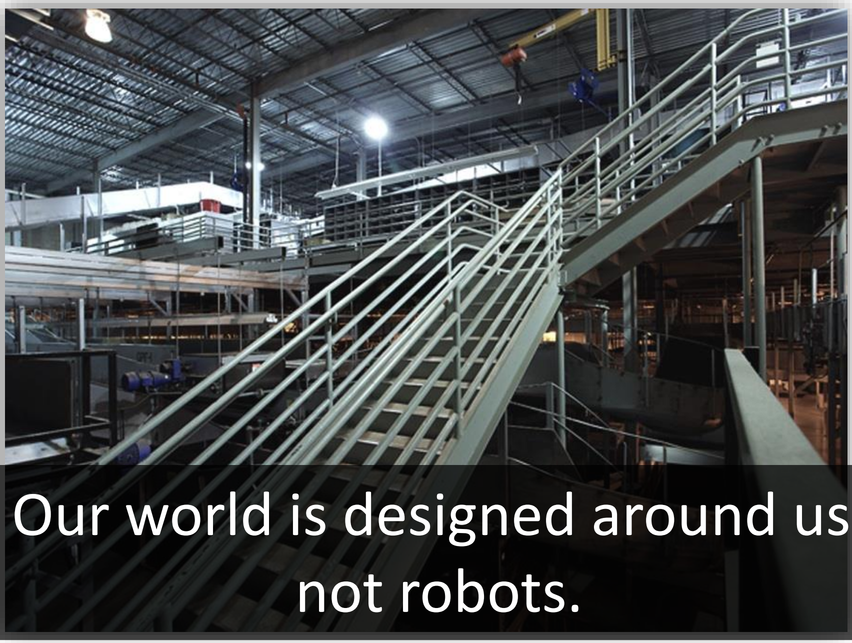


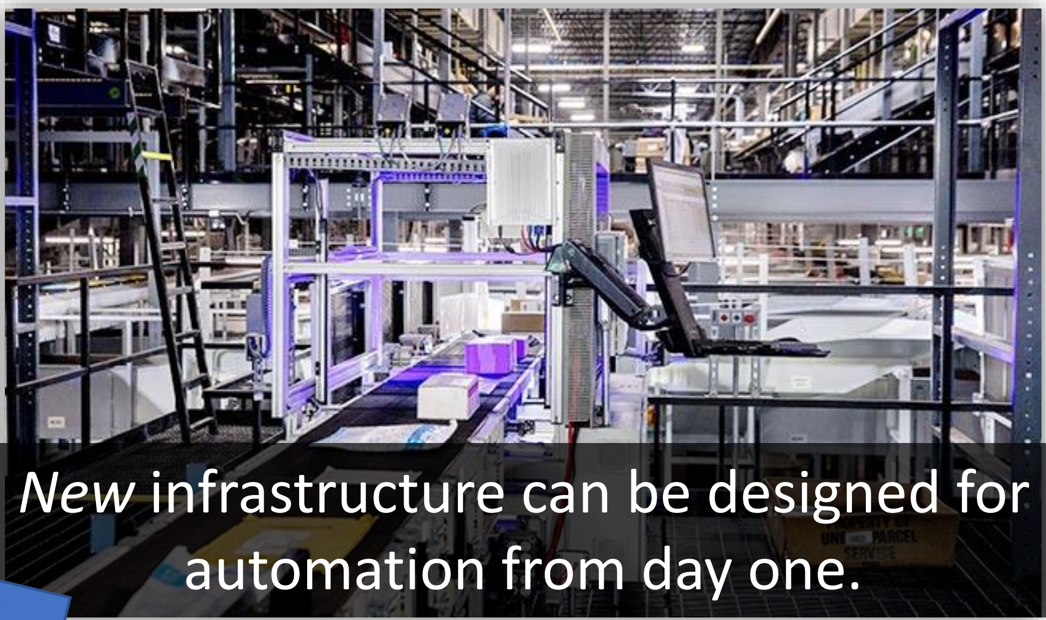
Most parts of the logistics chain are rapidly automating.

The human world *isn't designed* for robots

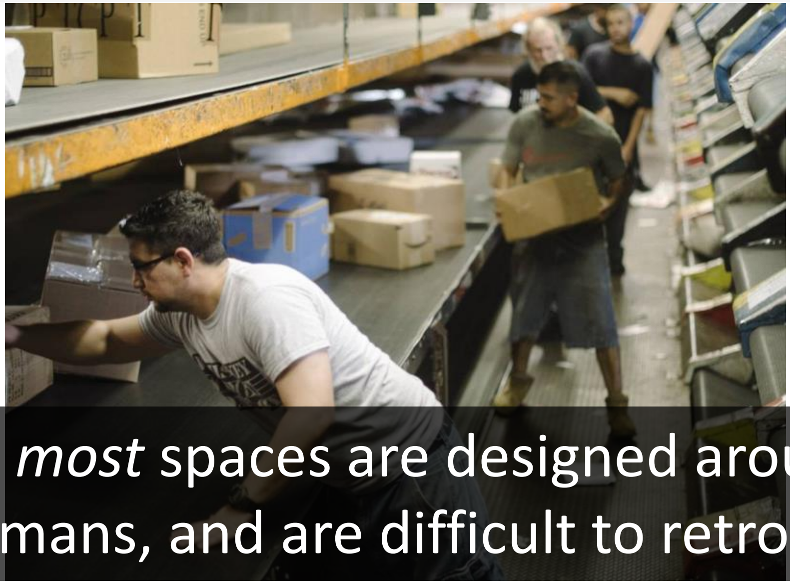




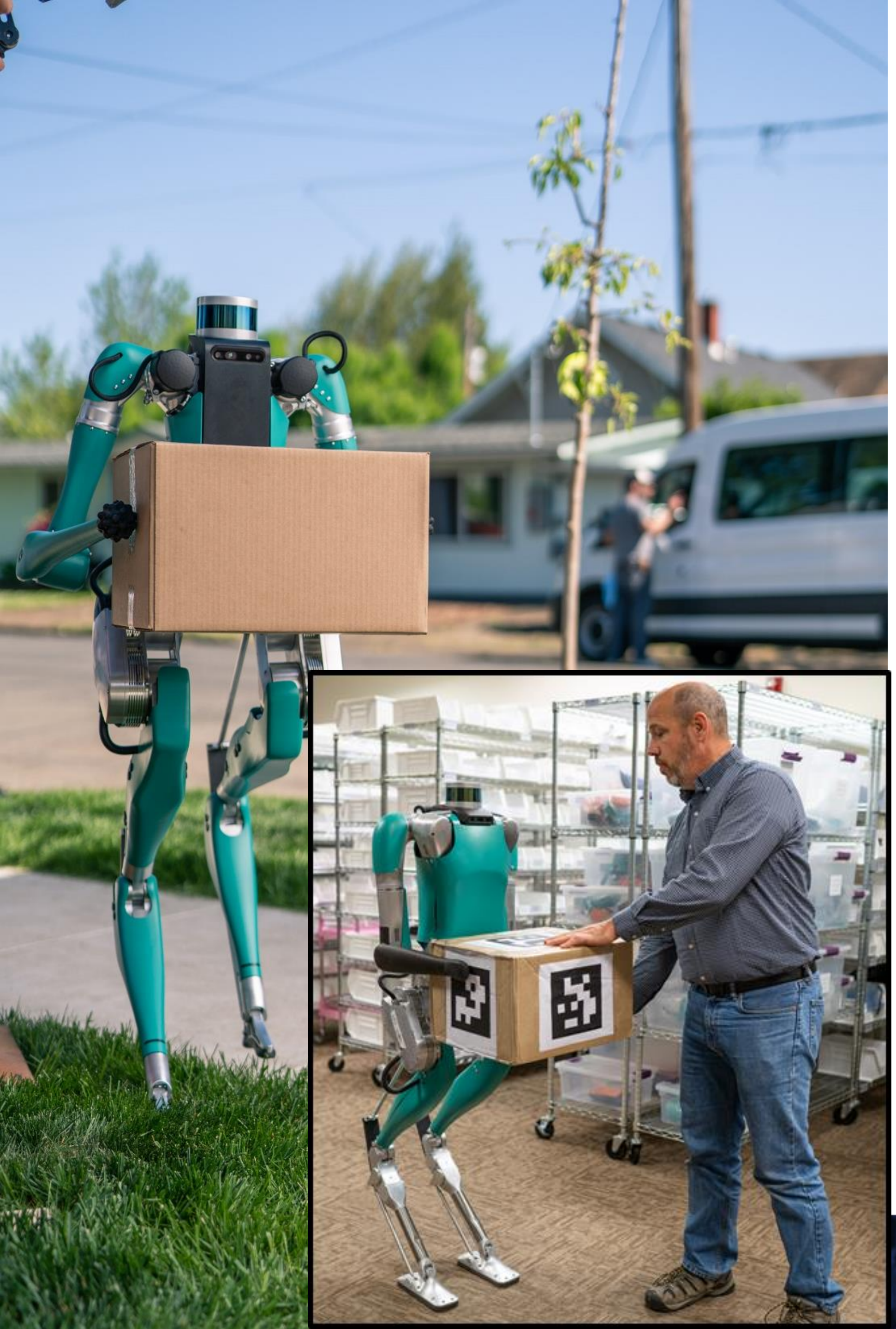
Our world is designed around us, not robots.



New infrastructure can be designed for automation from day one.



But *most* spaces are designed around humans, and are difficult to retrofit.



Legged robots provide human-like mobility *and* do not require new infrastructure

Cars do roads well.

- No need to reinvent the wheel. Leverage the efficiency of wheels for long distances, and high cargo capacity for aggregating demand.

Legs do sidewalks and stairs well.

- Legs are hard to build, but we’ve spent two decades learning how. Use legs to access the customer’s preferred delivery location.

Re-use existing infrastructure wherever possible to *increase addressable market*.

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Why legs + vehicles?

The existing paradigm of package aggregation in a road-legal vehicle is efficient, and a delivery driver is able to place the package in the customer’s preferred location. But this is hard to automate.

Current automation solutions are largely point-to-point (which is inefficient) and can’t deliver to the door (which forces changes to customer behavior).

move + carry

move + inspect

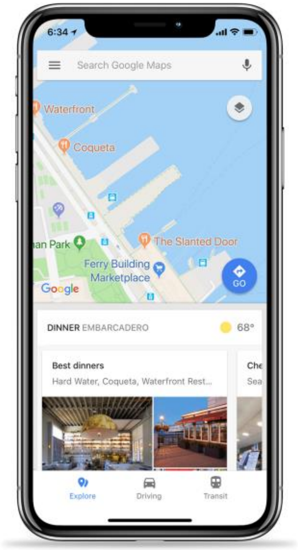
move + interact

Human-like mobility is required for many jobs
…not just logistics

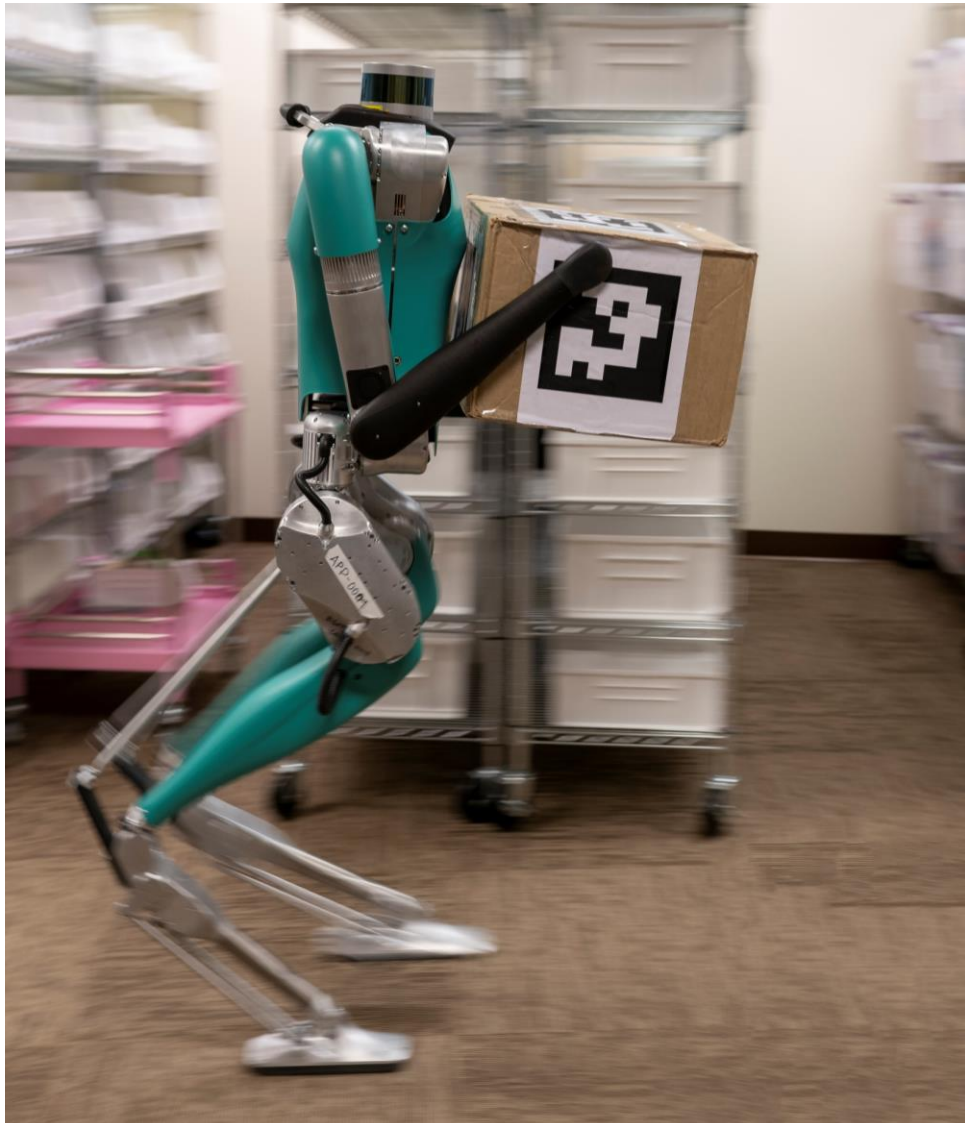
Mobile computing provides an app ecosystem for *information*

Hardware

API



Apps



Digit provides an app ecosystem for *labor*

Common Platform

Hardware

Human-like mobility
Rugged design
Long battery life
Integrated computing
20 kg payload capacity
Near + far range sensors

Software APIs

Mobility stack

Balance and posture
Movement planning
Handle stairs/obstacles/terrain
Walk from A to B indoors or out

Perception stack

Map the environment
Identify obstacles
Recognize objects and people

Manipulation stack

Grasp objects
Pick and place

Software Apps

Move + Carry

Carry packages point to point
Manual labor (the robot alone)
Last mile (with vehicle)

Move + Inspect

Monitor infrastructure
Autonomous: security
Local teleop: military / law enf.

Move + Interact

Telepresence, remote interaction
Virtual tourism: hike with family

Core Product

App Ecosystem

OTA app downloads and platform updates

- Updates can apply to the core “mobility operating system” APIs
    - E.g. faster footstep planning
- *Or* updates can be app-specific
    - E.g. faster box-picking/placing
- The fleet learns as a whole

Outdoor move+carry

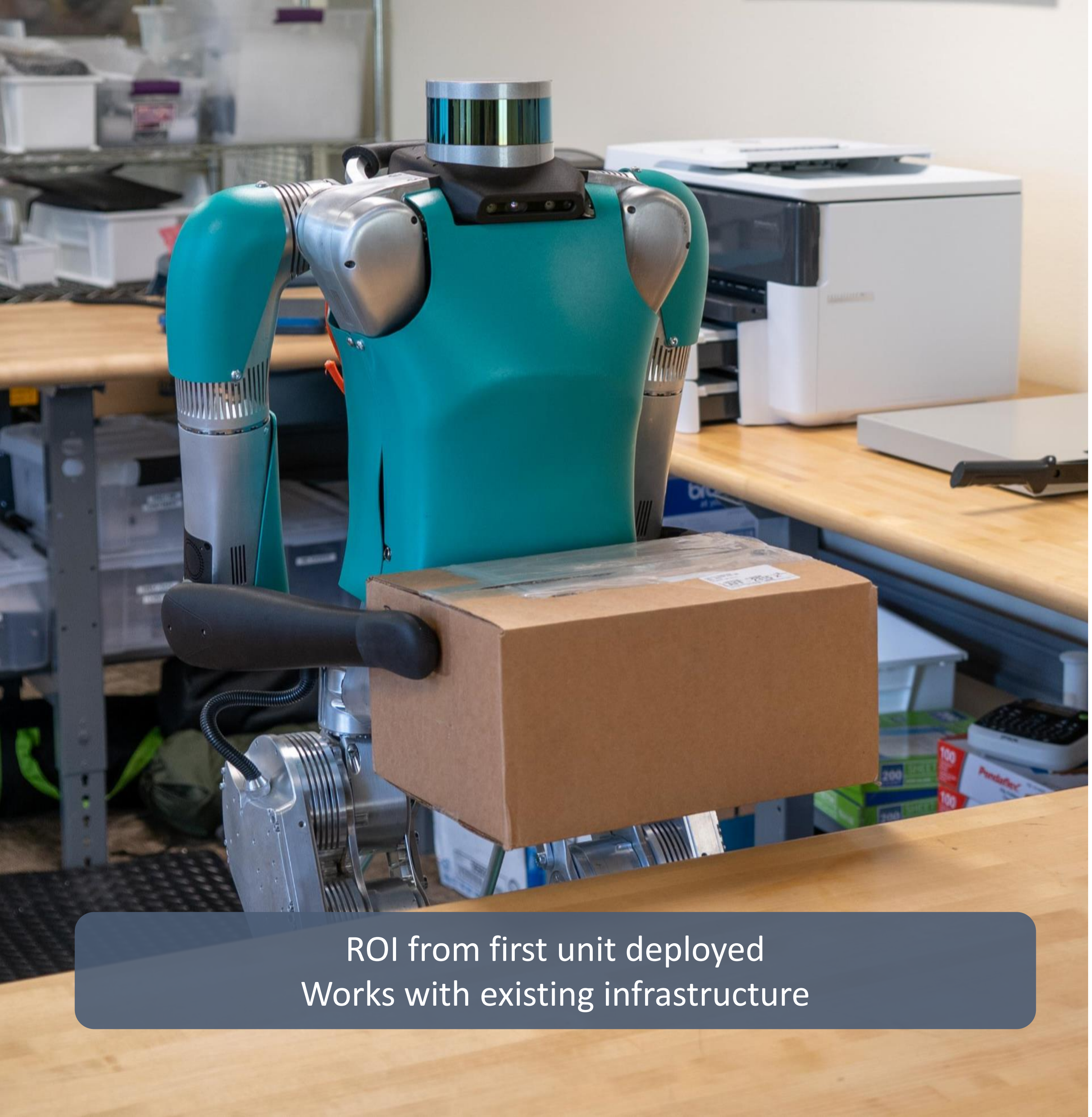
Ongoing partnership with Ford

Video link: https://youtu.be/CUhuhIeQNos

Indoor move+carry

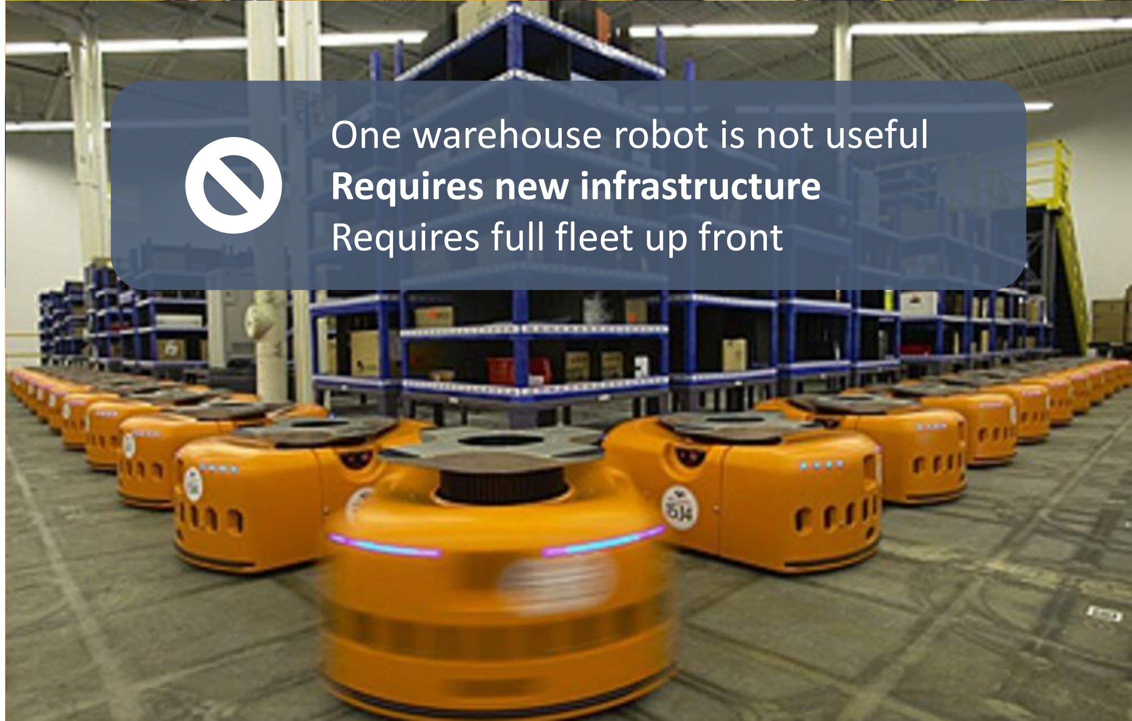
Ongoing partnership with multinational logistics company

Video link: https://youtu.be/LSk8uCHN5CY

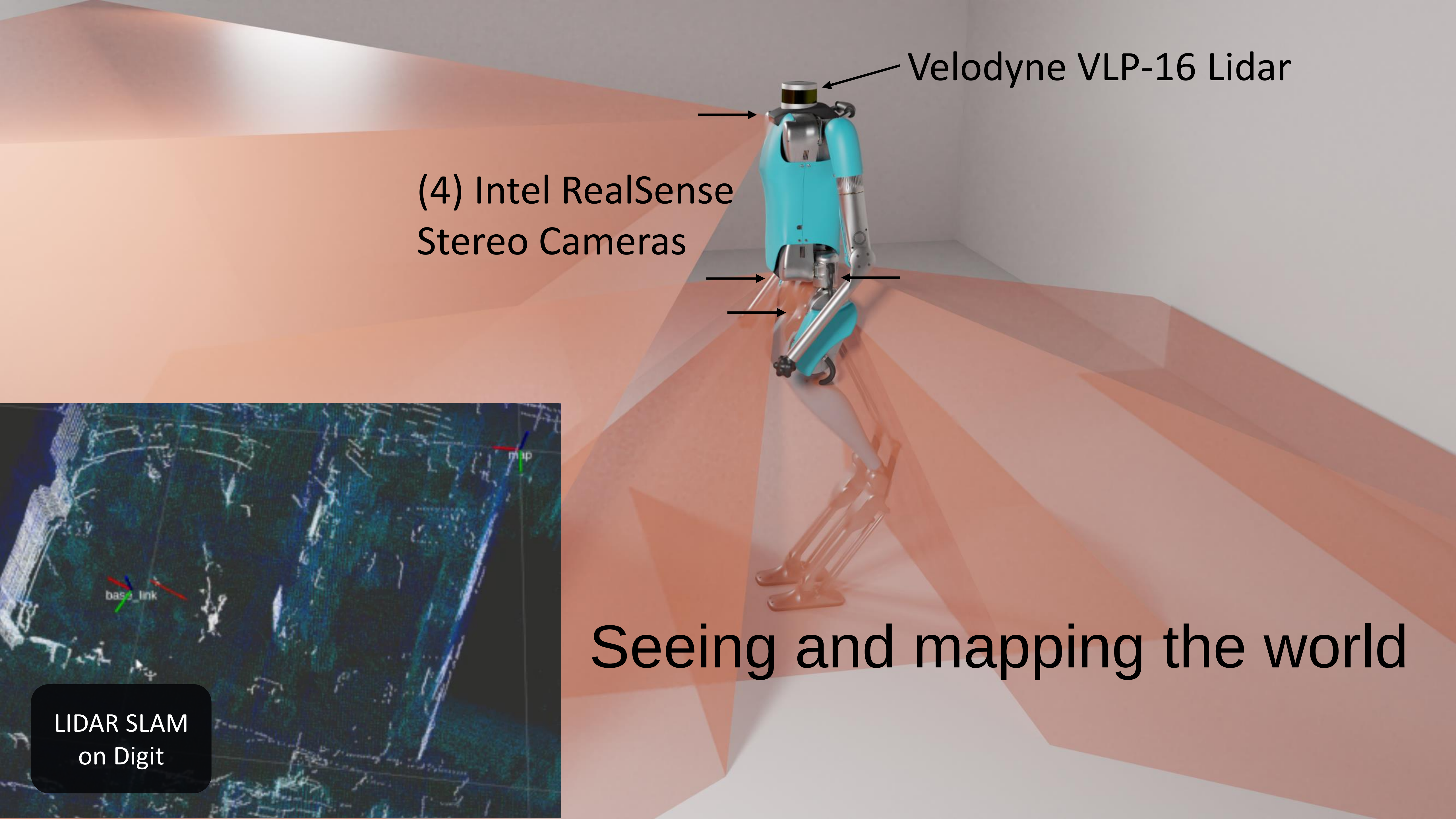


ROI from first unit deployed
Works with existing infrastructure

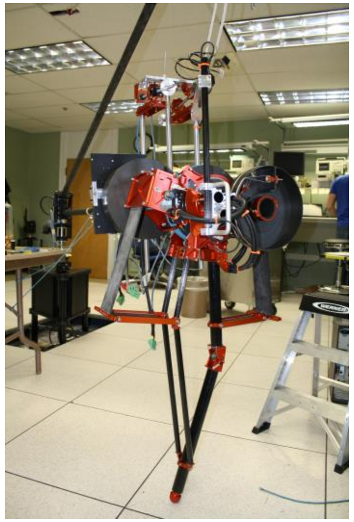
The first autonomous taxi is useful
Operates with existing infrastructure
Scales to large fleets



One warehouse robot is not useful
Requires new infrastructure
Requires full fleet up front


Velodyne VLP-16 Lidar
(4) Intel RealSense
Stereo Cameras
LIDAR SLAM
on Digit
Seeing and mapping the world

Technology development timeline



MABEL
2004-7

ATRIAS 1.0
2009-13

ATRIAS 2.0
2014-15

CASSIE
2016-17

DIGIT V1
2018-19

DIGIT V2/V3
2019/20

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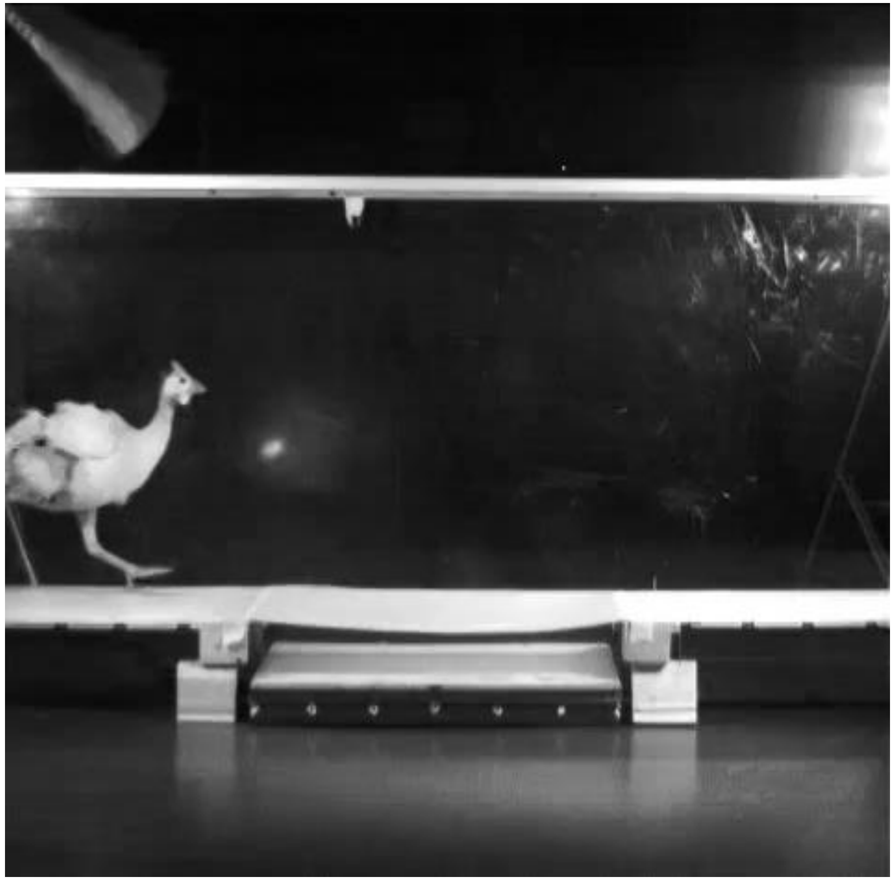
Our core technology: mobility for imperfect worlds

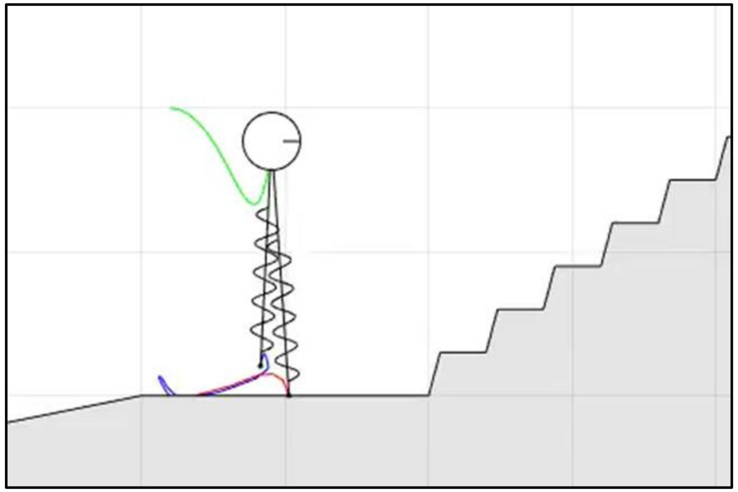


Science: Understand and model the dynamics of a highly capable system.

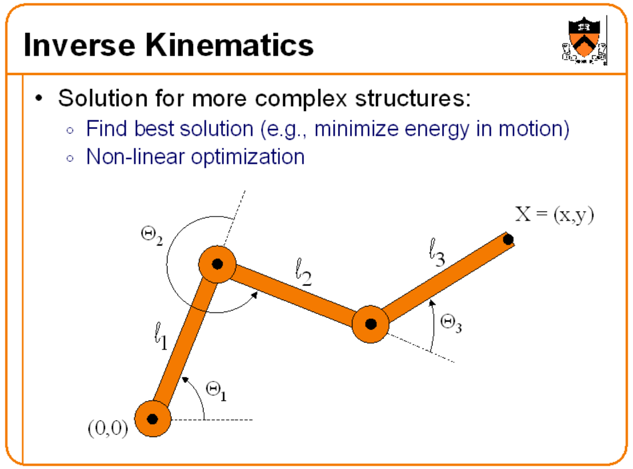
Engineering: Incorporate these principles into products, and physics ensures that the capabilities will be similar “for free”.

Our control hierarchy

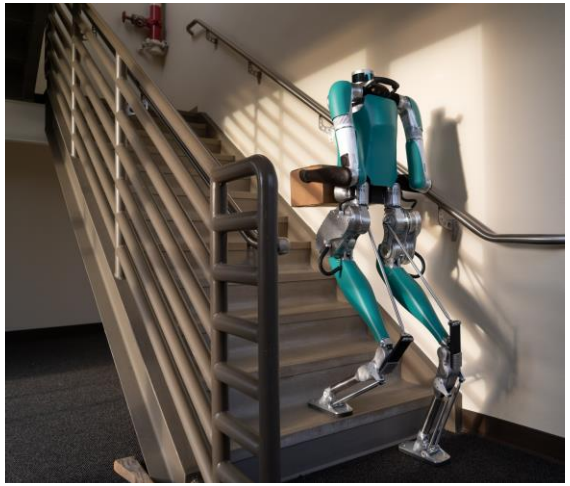
- **1Hz:** User input, high-level intent, waypoints, task-level decisions



30Hz: Continuously updated plans



2 kHz: Classical control, such as inverse dynamics, PD gains, etc



∞ kHz: Dynamics Foundation

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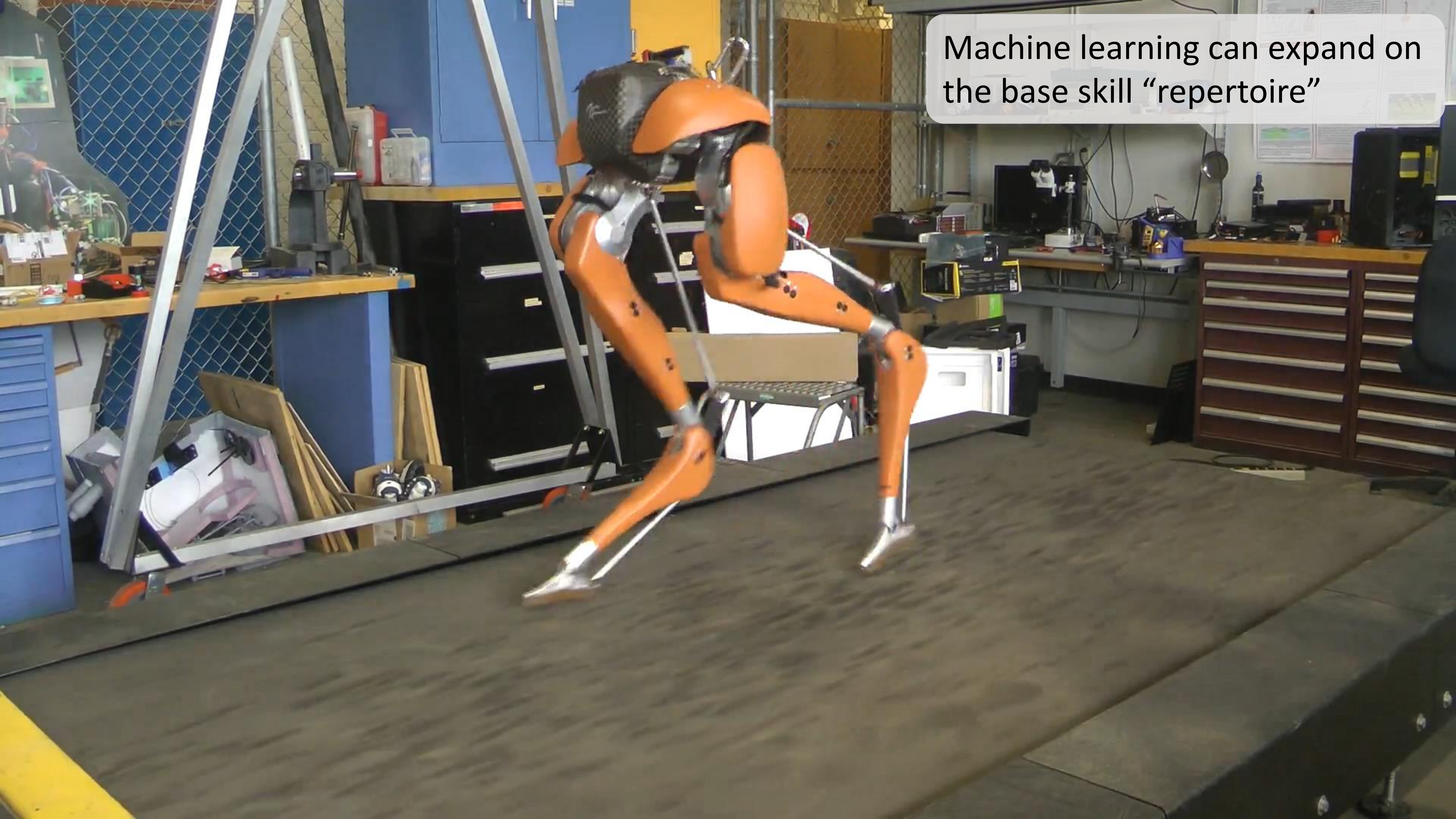
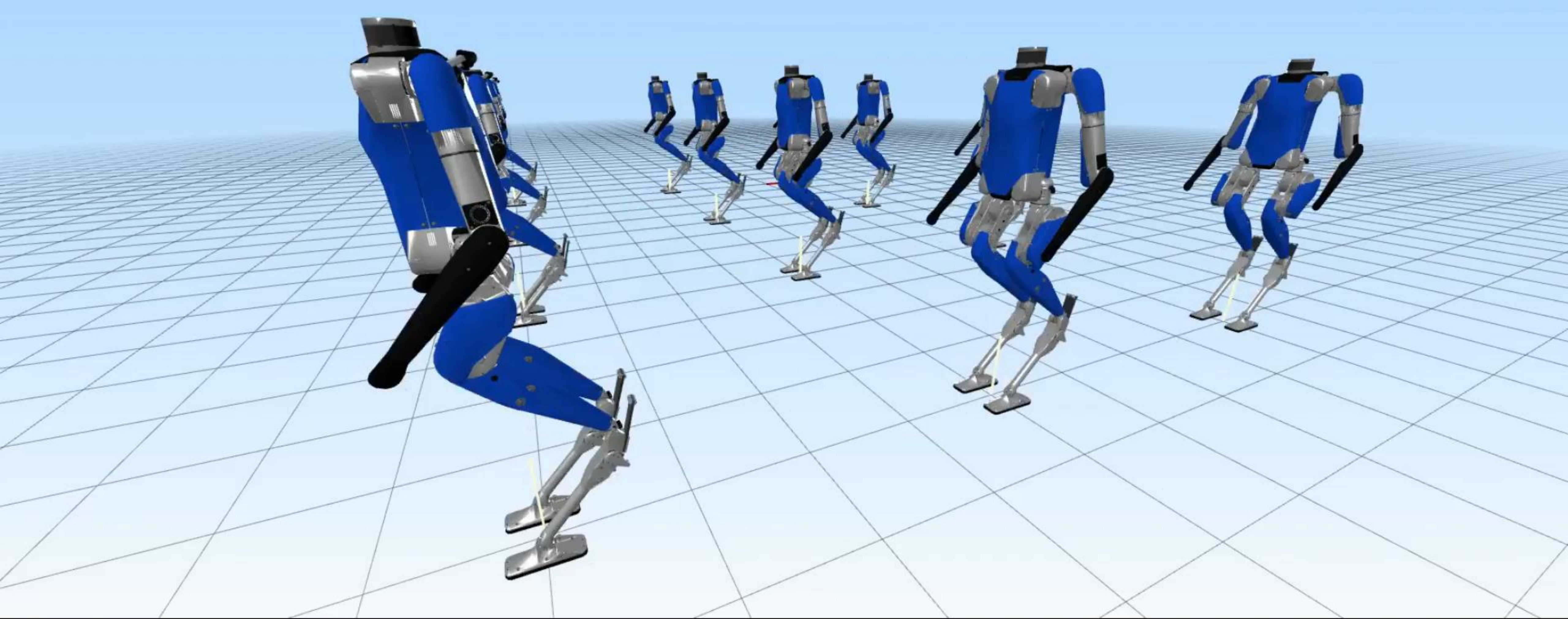
Machine learning can expand on the base skill “repertoire”



Machine learning can expand on the base skill “repertoire”

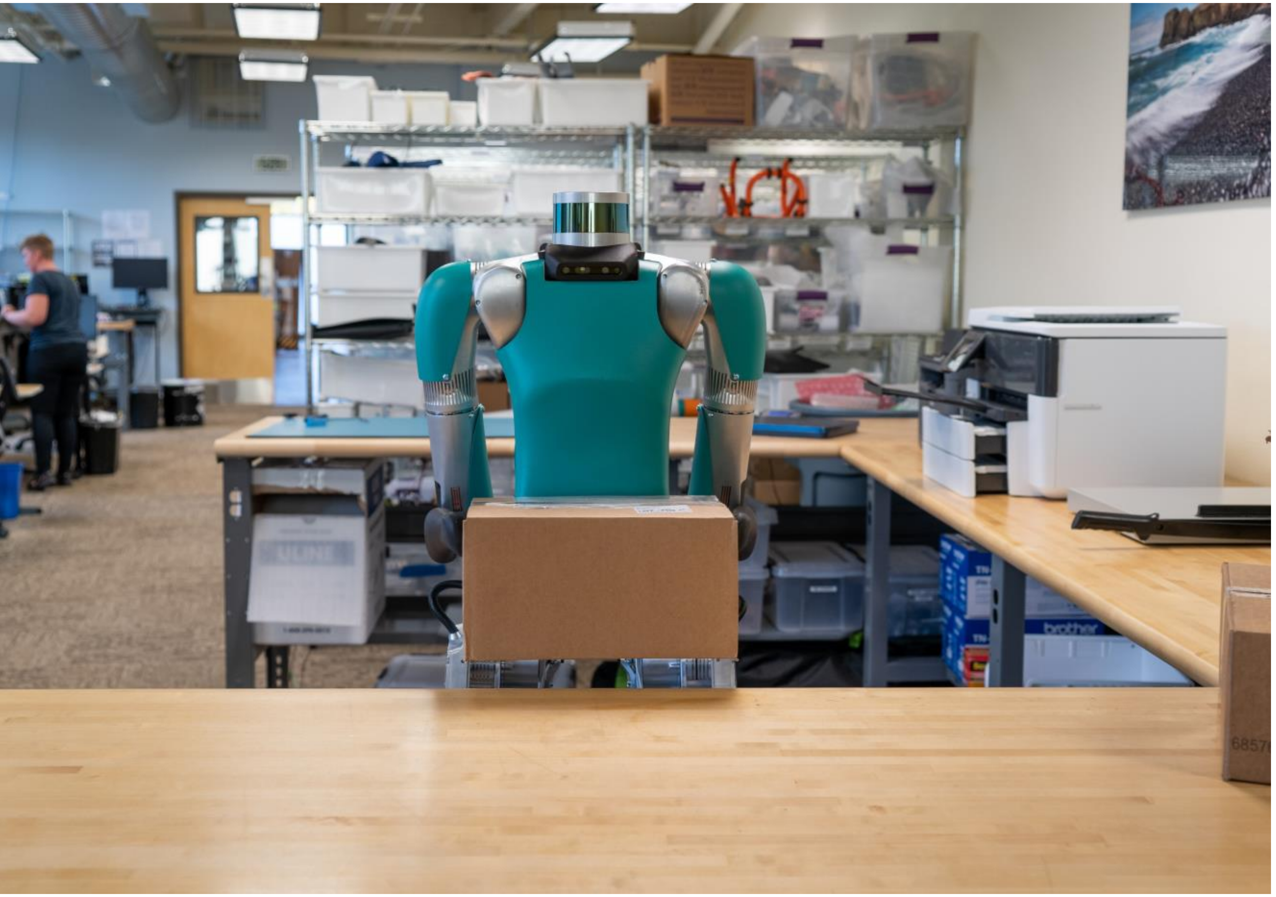
Kinematic reference motion

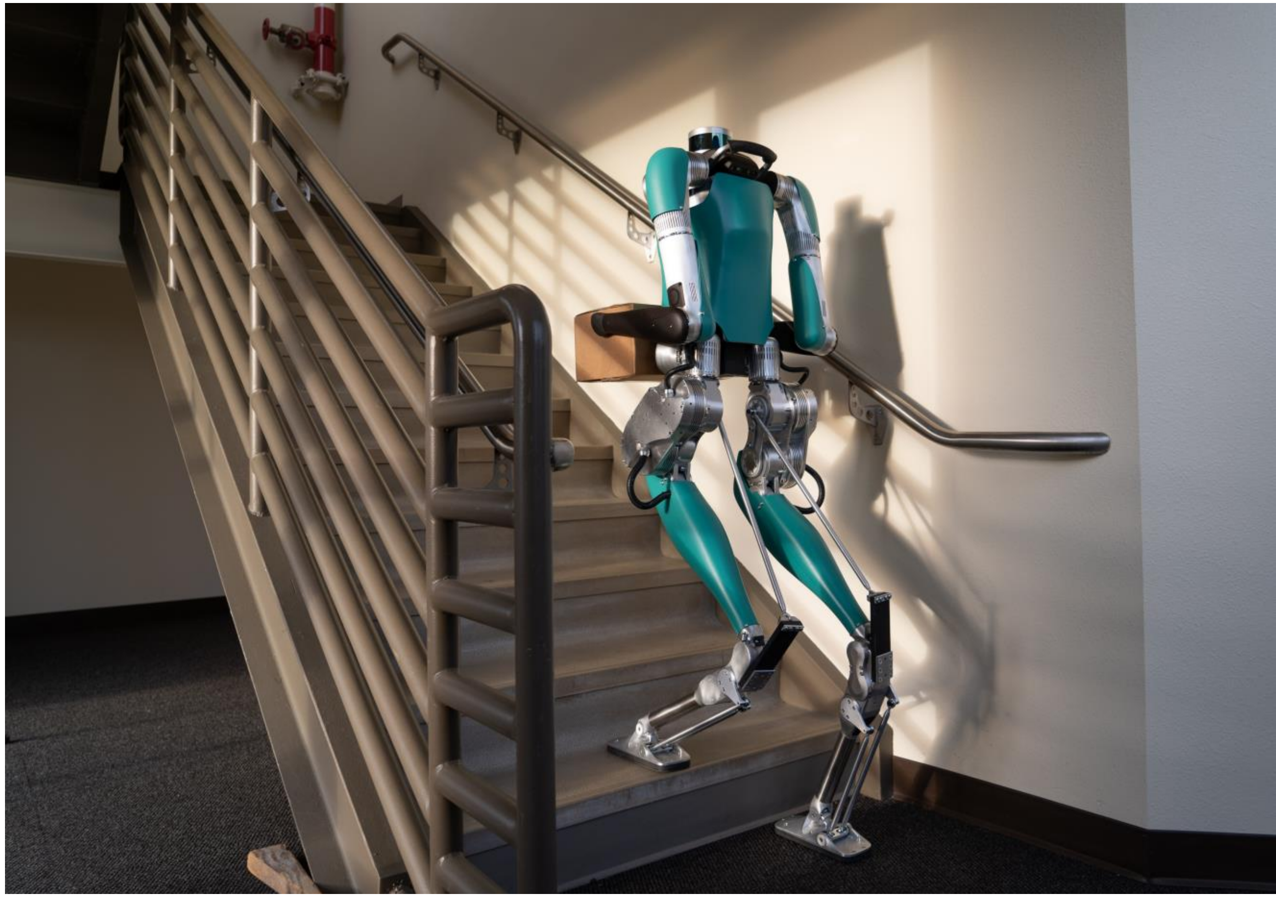


Fully Autonomous Operations

Waypoints and “box move” task user-defined
Picking/placing and walking autonomous


FIRE
EXTINGUISHER





Bipedal robots are ready to work in human spaces

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Or visit MODEX Booth 1508

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