



MODULE 1: INTRODUCTION TO AUTONOMOUS ROBOTS AND VEHICLES

Nicholas HO, PhD
Institute of System Science, NUS



About Nicholas Ho



- nicholas.ho@nus.edu.sg
- Lecturer at NUS ISS; Courses covered include:
 - Robotic Systems
 - Autonomous Robots and Vehicles
 - Human-Robot System Engineering
- BEng and PhD degree from School of Mechanical Engineering, NUS
- Specialized in architecture, design & development
 - Artificial Intelligence
 - Augmented/Virtual Reality
 - Internet-of-Things (IoT) & Cyber-Physical System (CPS)





About Nan Zhou



- Senior Lecturer in Software Systems Practice
- PhD and Bachelor of Mechanical Engineering with Robotics Specialization from NTU
- More than 14 years of sensorization, software simulation, intelligent system, digital solution development and integration using industrial IoT and automation technologies in both public and private sectors
- Worked at DSI (A*STAR) and ARTC (A*STAR)
- His interests lie in the applications of machine learning-based automation systems, digital IoT solutions



Course Outline



- Day 1 Module 1: Introduction to autonomous robots and vehicles
Module 2: Holistic design approach for autonomous systems
- Day 2 Module 3: Technical Fundamentals – Autonomous Vehicles & Robotics Technology
- Day 3 Module 4: Standards/Technical Reference for autonomous vehicles
Module 5: Technical Fundamentals – In-depth Technologies and Basics of Simulation & Analysis for Autonomous Vehicles
- Day 4 Module 6: Developing Basic Autonomous Vehicle Systems
- Day 5 Module 7: Developing an MVP (Minimum Viable Product) for your Organization
Final Written Assessment



Reference (Optional)



- Siegwart & Nourbakhsh, Autonomous Mobile Robots, MIT press
- Alain Cardon & Mhamed Itmi. New Autonomous Systems (Vol 1). Wiley. 2016
- Autonomous Vehicles: Navigating the legal and regulatory issues of a driverless world. MCCA Global Tec Forum
- Future Autonomous Systems Overview. Thomas Kazior (Raytheon) and Daniel Lee (UPenn). 2016.

- Introduction to autonomous systems
- Applications and Use Cases
- Future of Autonomous Systems
- Envisioning Exercise



Introduction to Autonomous Systems



Definition of Autonomous Systems



- **Able to operate with no or minimal human intervention**
- The system should be able to operate in an environment where not everything is known prior
- React to unforeseen events
- Make decision based on sensor input



<https://www.industryweek.com/robotics/autonomous-robots-start-european-delivery>

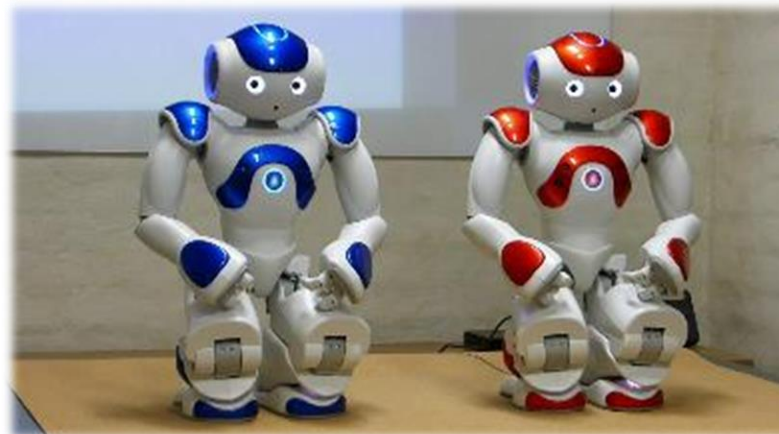


Characteristics of Autonomy and Intelligence



Description: **Systems that are aware and interact with their environment.** DARPA defines intelligent systems as "**systems that know what they're doing**" and **exhibit the following abilities:**

- will be able to infer and reason, using substantial amounts of appropriately represented knowledge
- will learn from their experiences and improve their performance over time
- will be capable of explaining themselves and taking naturally expressed direction from humans
- will be aware of themselves and able to reflect on their own behavior
- will be able to respond robustly to surprises and explore in a very general way
- will be able to interact/interface with humans, if in the loop, using the same language as the human nervous system



<https://ko.videoblocks.com/browse/stock-video-footage>



Mobility in Autonomous Robots?



- Traditional (industrial) robots are bolted to the floor
- Are very good at what they do
- But they cannot move!



<https://newatlas.com/lancaster-university-semi-autonomous-robot-reactors/60123/>



<https://www.elprocus.com/different-types-of-autonomous-robots-and-real-time-applications/>



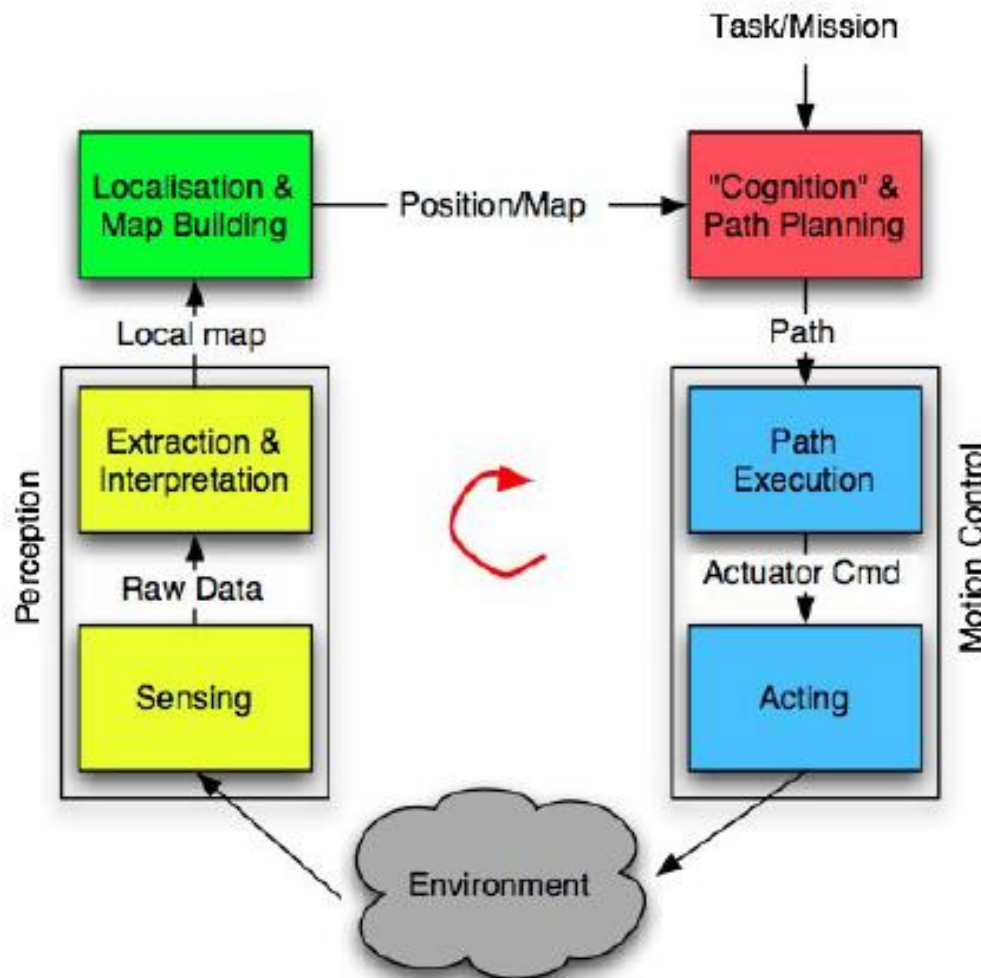
Reflection and Sharing



- Why do we need autonomous robots in Singapore now and in the future?
- Will autonomous systems pose a threat in any way?
- Can humans be replaced by autonomous robots?
- What are the ethical, safety and security considerations we need to have with autonomous robots?



System overview (RECAP for MTech students)





Contextual Autonomous Capability (ALFUS Model)



Environmental Difficulties

- Static: Terrain, soil
- Urban, rural, climate
- Operational: Threats, decoy

Mission Complexity

- Subtasks, decisions
- Organization
- Performance
- Situational awareness
- Knowledge requirements

Independence from Human Control

- Supervisory control, trust
- Experience, skills
- % of decisions/time
- Operator to Unmanned System ratio and comm.types

https://www.japcc.org/wp-content/uploads/JAPCC_Journal_Edition-20.pdf



Top 5 Requirements for Autonomous Vehicles



1. Greater computing power

- Approximately 1 GB of data will need to be processed each second
- This data will need to be analyzed quickly enough that the vehicle can react to changes in its surroundings in less than a second

2. A reliable supply chain

- The past story of LiDAR

3. A centralized approach

- Currently, new technologies added to the car often come with their own computer and software
- With each new addition, more challenges for the automaker to manage so many disparate systems

4. A small, low-power solution

- The processors in tomorrow's cars must deliver increasing computing power, and must do so as efficiently as possible

5. Security and privacy

Conclusion

- For self-driving vehicles, it remains critical that the growing volumes of data transmitted to, from, and within the vehicle are safe
- The vehicle will need to rely on its data and the source of that data to make quick, accurate decisions



Basic Physical Ecosystem of an Autonomous Vehicle



- **Cameras** – Provide real-time obstacle detection to facilitate lane departure and track roadway information (like road signs).
- **Radar** – Radio waves detect short & long-range depth.
- **LIDAR** – Measures distance by illuminating target with pulsed laser light and measuring reflected pulses with sensors to create 3-D map of area.
- **GPS** – Triangulates position of car using satellites. Current GPS technology is limited to a certain distance
- **Ultrasonic Sensors** – Uses high-frequency sound waves and bounce-back to calculate distance. Best in close range.
- **Central Computer** – “Brain” of the vehicle. Receives information from various components and helps direct vehicle overall.
- **DRSC-based Receiver** – Communications device permitting vehicle to communicate with other vehicles (V2V)

*DRSC = Dedicated short-range communications



Robotic Flow Process (RFP) Design



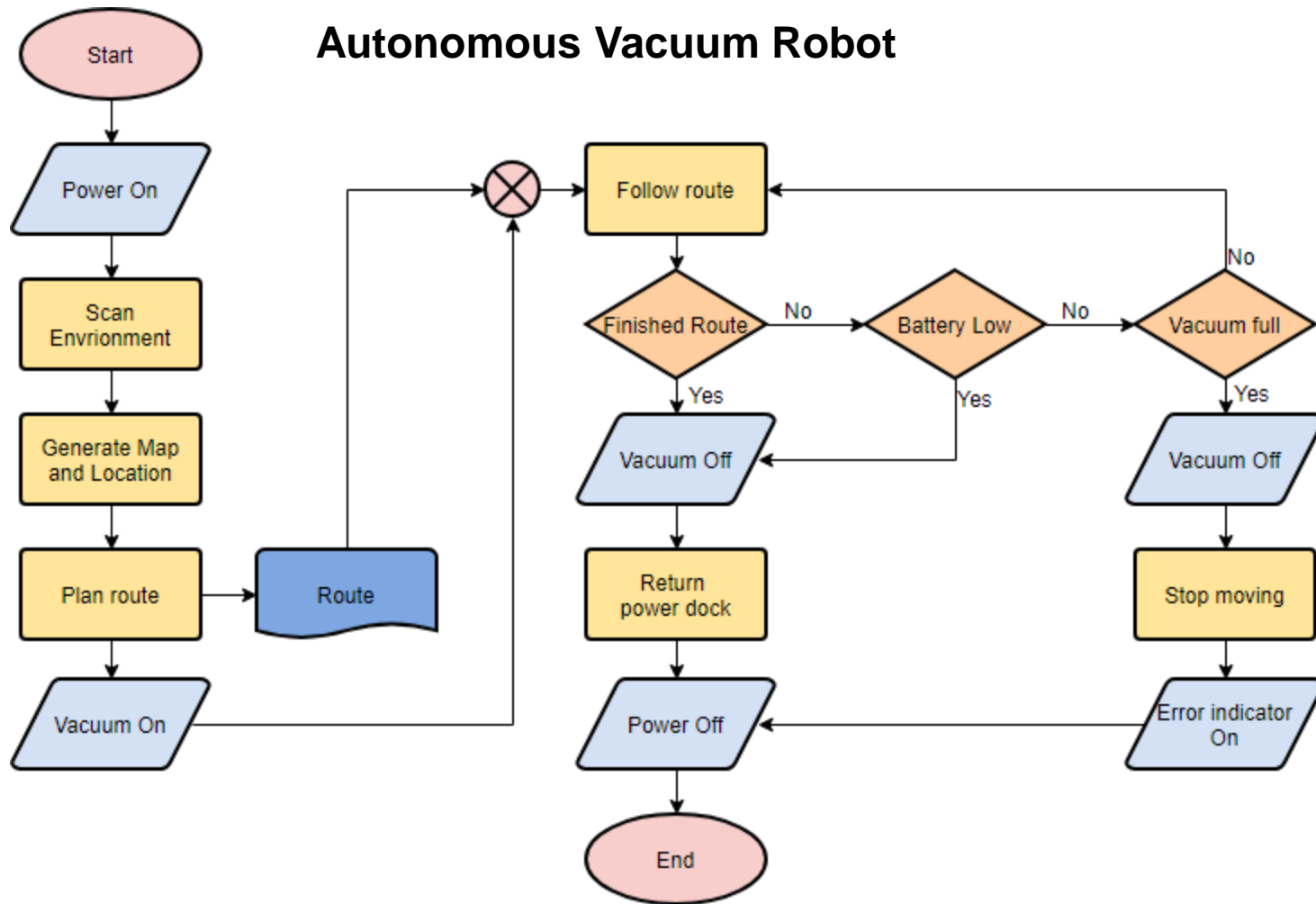
- **Design of robotic automation algorithm** is an important aspect for AI engineer
- Applicable for robots, intelligent systems and other “behavioral” and “rule-based” systems
- Provide developers and users the **transparency and control to understand and alter behavior and decision making processes** in autonomous systems



<https://www.weforum.org/agenda/2017/03/audio-a-glimpse-into-the-future-autonomous-systems-ca69fb46-705b-4e73-bf4a-ed10208b30f1/>



Example of a RFP



<https://www.visual-paradigm.com/tutorials/flowchart-tutorial/>



Flowchart Symbols



Terminator

The terminator symbol represents the starting or ending point of the system.



Process

A box indicates some particular operation.



Document

This represents a printout, such as a document or a report.



Decision

A diamond represents a decision or branching point. Lines coming out from the diamond indicates different possible situations, leading to different sub-processes.





Flowchart Symbols



Input or output of Data

It represents information entering or leaving the system. An input might be an order from a customer. Output can be a product to be delivered.



On-Page Reference

This symbol would contain a letter inside. It indicates that the flow continues on a matching symbol containing the same letter somewhere else on the same page.



Off-Page Reference

This symbol would contain a letter inside. It indicates that the flow continues on a matching symbol containing the same letter somewhere else on a different page.



Delay or Bottleneck

Identifies a delay or a bottleneck



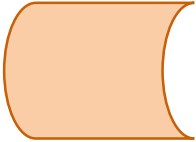


Flowchart Symbols



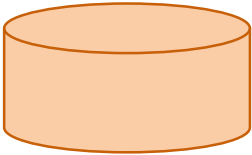
Stored Data

It represents information that has been stored in the system

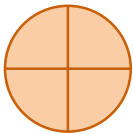


Database

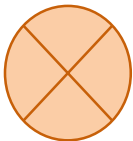
It represents information that is stored in a database



OR Operation



AND Operation



- There are 2 questions in total
- Take ~30 mins to complete this tutorial
- The presenters will be chosen randomly (2 for each question; total 4 presenters)



Applications and Use Cases

300 cleaning robots to roll out in Singapore by March 2020



<https://www.straitstimes.com/singapore/300-cleaning-robots-to-roll-out-by-march-2020>



<https://www.bloomberg.com/news/features/2018-09-16/singapore-s-changi-airport-is-partly-run-by-robots>

- LionsBot International
- Deployed around SG
- Size – 63cm wide and can navigate tight spaces
- Currently launched at the National Gallery Singapore and Jewel Changi
- Monthly fee rental ranging from \$1,350 to \$2,150



Autonomous Systems in SG



<https://govinsider.asia/digital-gov/how-will-robots-help-run-singapores-hospitals/>

- Changi General Hospital has started by automating logistics
- Move documents, drugs, specimens and linen
- Next plan to use robots to move heavier objects, like patient beds



An Autonomous Container Trailer (ACT) baggage robot on the tarmac at Changi Airport



<https://www.bloomberg.com/news/features/2018-09-16/singapore-s-changi-airport-is-partly-run-by-robots>



Service and Hospitality



<https://vulcanpost.com/675764/robot-workers-singapore/>

- Tray-return robots found at some food courts, coffeeshops and hawker centres
- Follows a fixed route around eateries
- Increase ease of returning trays
- Automatically stops if there is an obstacle



Social Receptionist Robot



<https://vulcanpost.com/675764/robot-workers-singapore/>

- Pepper the robot
- Manufactured by Softbank Robotics
- Works alongside human staff to greet customers and answer some of their general queries
- At AIA's Finlayson Green service centre



Customer Service



<https://vulcanpost.com/675764/robot-workers-singapore/>

Singtel uses a roving live bot to assist customers at their recently opened 24-hour unmanned store, UNBOXED



Room Service in Hotels



<https://vulcanpost.com/675764/robot-workers-singapore/>

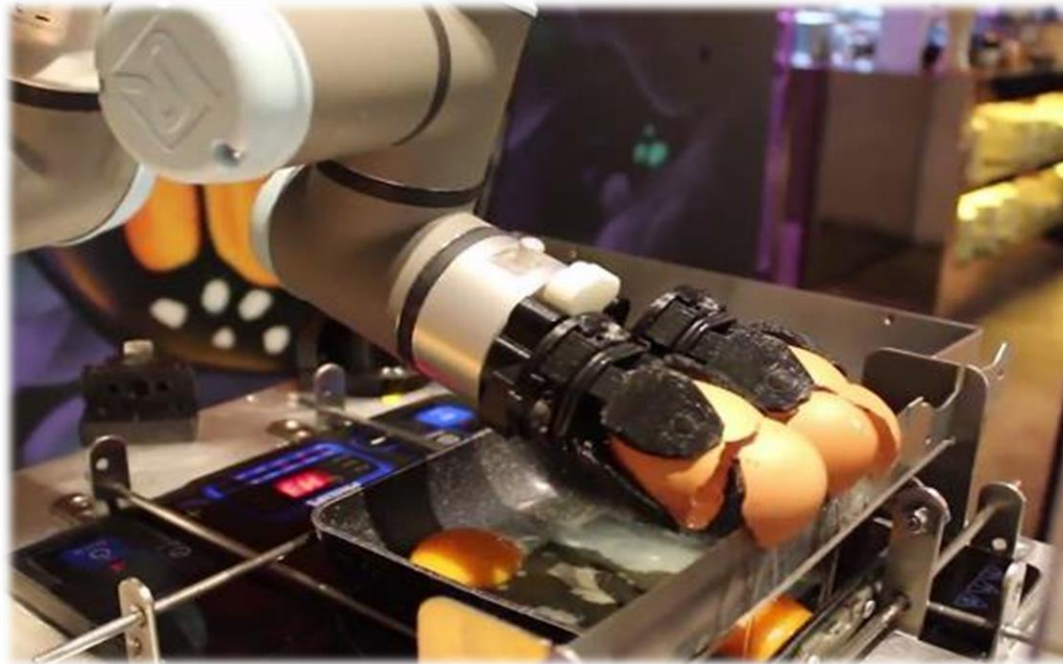
- Deliver room service orders like food and toiletries to guests' rooms
- Transport dirty linens out and replace them with fresh sheets
- Hotel Jen, Park Avenue Rochester Hotel, Sofitel and The Millennium Group



Autonomous Systems in SG



Cooking Food



<https://vulcanpost.com/675764/robot-workers-singapore/>

- At M Social, AUSCA (Automated Service Chef Associate) helps to whip up the perfect sunny-side-ups and omelettes
- Guests just have to select their choice and give the robot an empty plate
- Good for live food stations during catering events



Cooking Food



<https://www.youtube.com/watch?v=N9-gtnHAilw>



Transport



<https://vulcanpost.com/675764/robot-workers-singapore/>

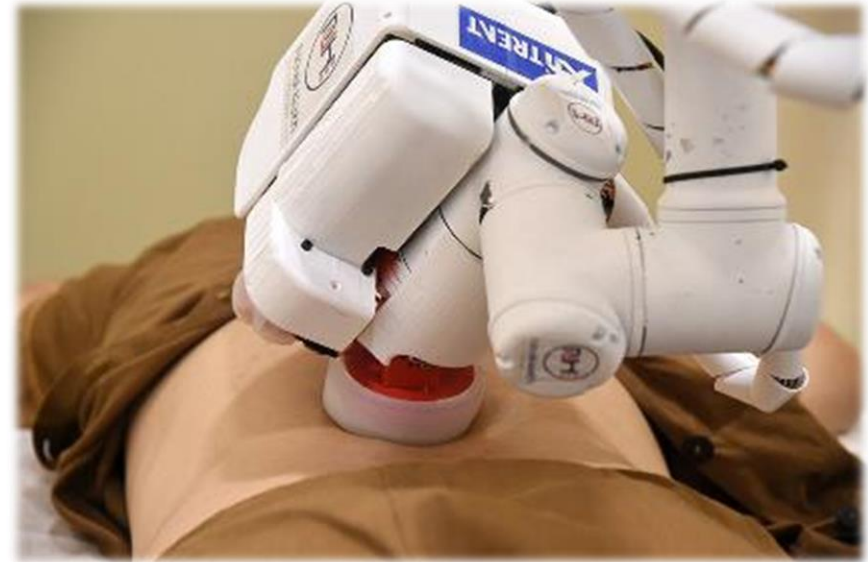
- NTU, Volvo and the Land Transport Authority (LTA) jointly launched a full-sized autonomous electric bus in March 2019
- Can carry 80 passengers and travel 25km on a full charge

Healthcare



<https://vulcanpost.com/675764/robot-workers-singapore/>

At the pharmacy in Tan Tock Seng Hospital, a system of robots speeds up the time taken to dispense medication with accuracy



<https://vulcanpost.com/675764/robot-workers-singapore/>

Emma (Expert Manipulative Massage Automation) can be found giving acupressure massages at Traditional Chinese Medicine (TCM) and sports therapy clinics



Robot at Pharmacy in TTSH



<https://www.youtube.com/watch?v=B1EHyRcCXcc>



Autonomous Systems in SG



Security



<https://vulcanpost.com/675764/robot-workers-singapore/>

- Singapore Police Force deploys autonomous security robots to help them patrol areas, especially during the 33rd ASEAN Summit and the Trump-Kim Summit
- Transmit a 360-degree view of their surroundings back to the police command posts,
- Video analytics capabilities to detect suspicious activity on their own



Future of Autonomous Systems

Missions

- Replace humans (in certain tasks)
 - Unattended exploration (e.g., space, undersea, hazardous environment)
 - Unattended monitoring (situational awareness)
- Assist humans
 - Overcome handicaps
 - Repetitive boring tasks (non-intelligent to human)
 - Requires robust human-machine interface
- Augment/Enhance human capabilities
 - Requires robust human-machine interface

Inspiration


- Biology/nature inspired (biological organisms)
- Science fiction inspired
 - Example: book called Lock In: Humans have robots that interact for them



Autonomous Domestic Workers



Tesla Bot




**WORLD BUILT BY HUMANS,
FOR HUMANS**

FRIENDLY

**ELIMINATES DANGEROUS,
REPETITIVE, BORING TASKS**

HEIGHT 5'8"	CARRY CAPACITY 45 LBS
WEIGHT 125 LBS	DEADLIFT 150 LBS
SPEED 5 MPH	ARM EXTEND LIFT 10 LBS

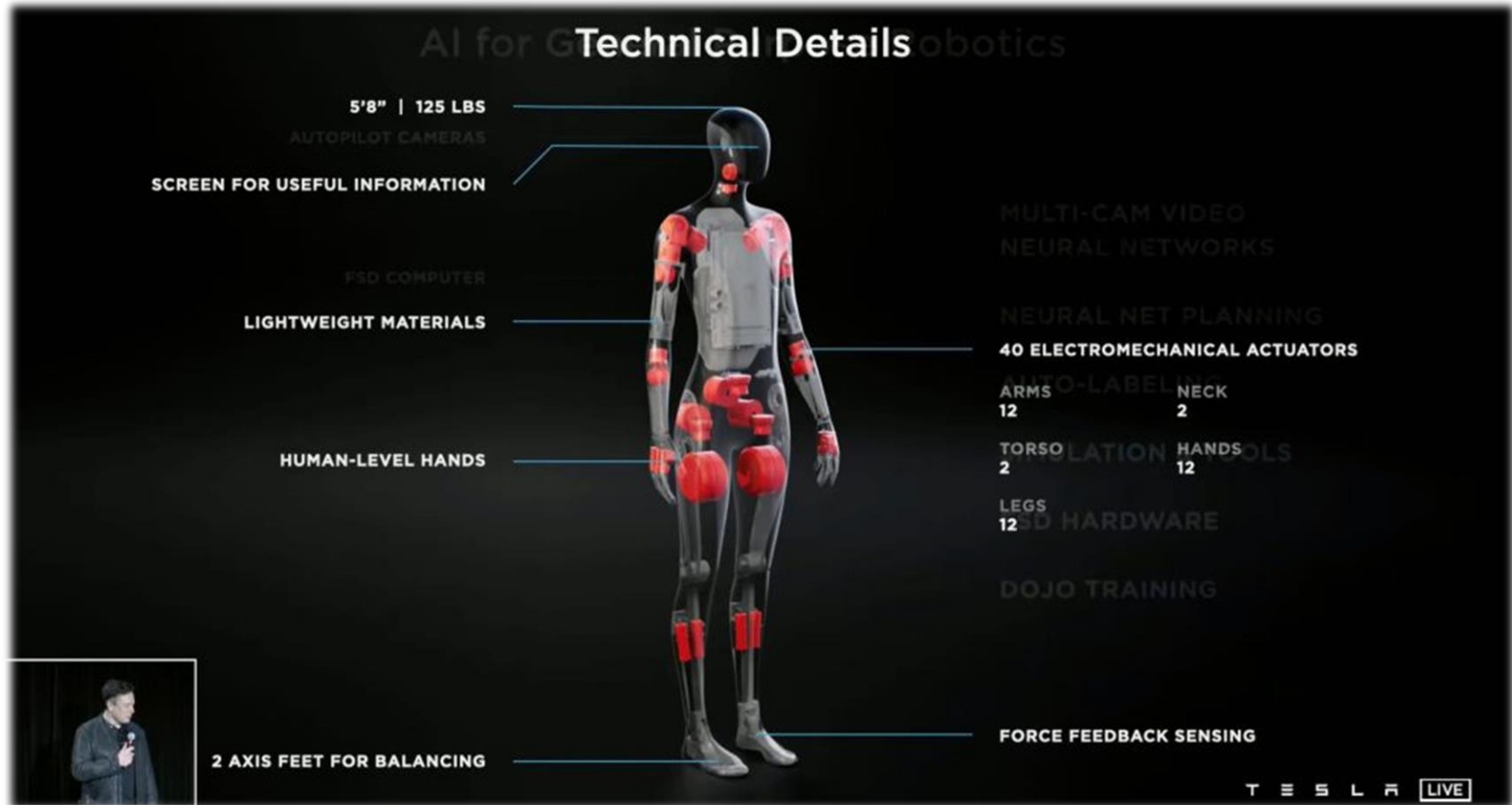


T E S L A **LIVE**

<https://www.bloomberg.com/news/articles/2022-06-03/musk-says-tesla-may-have-optimus-robot-prototype-within-months>



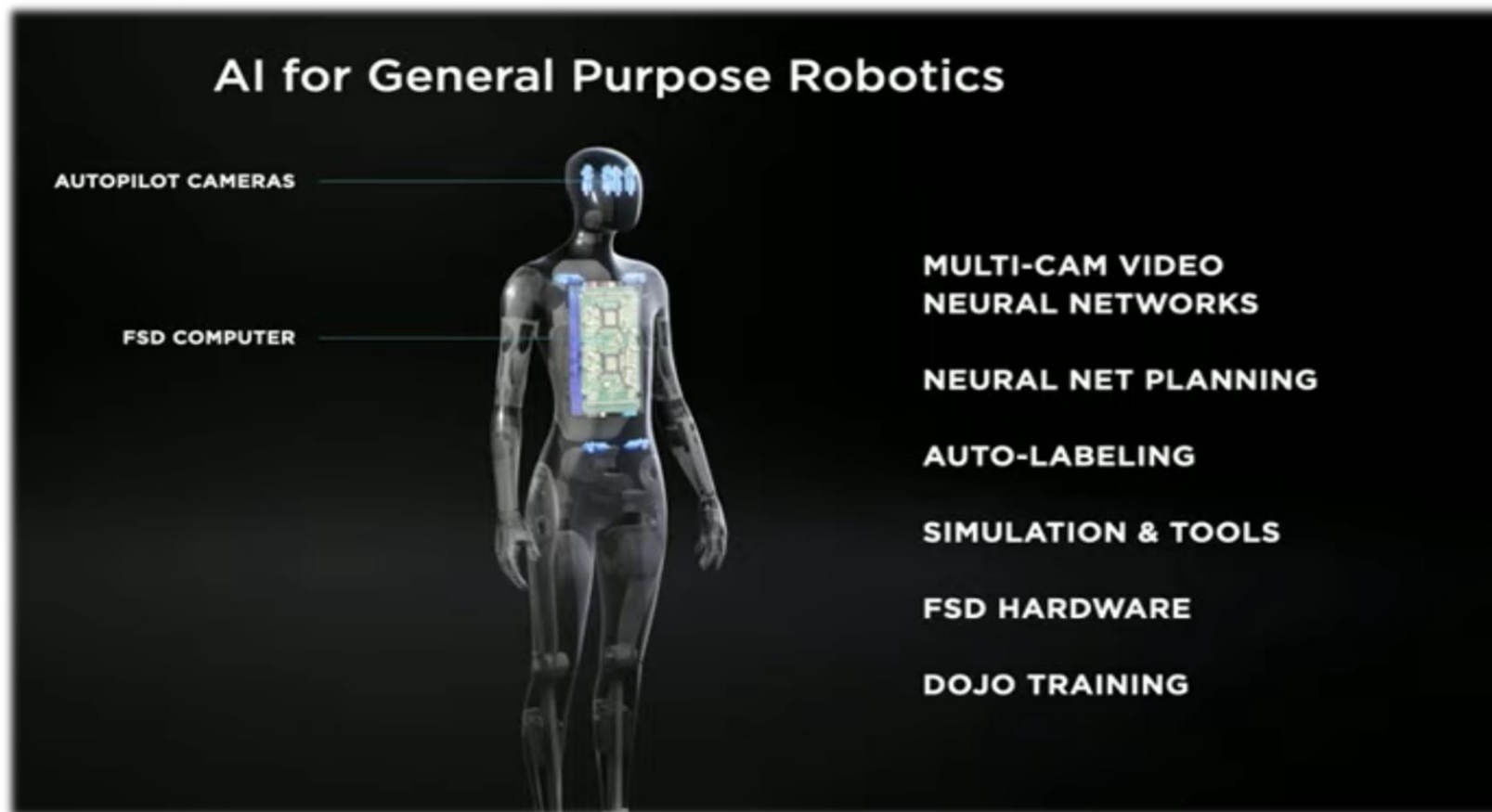
Autonomous Domestic Workers



<https://www.bloomberg.com/news/articles/2022-06-03/musk-says-tesla-may-have-optimus-robot-prototype-within-months>



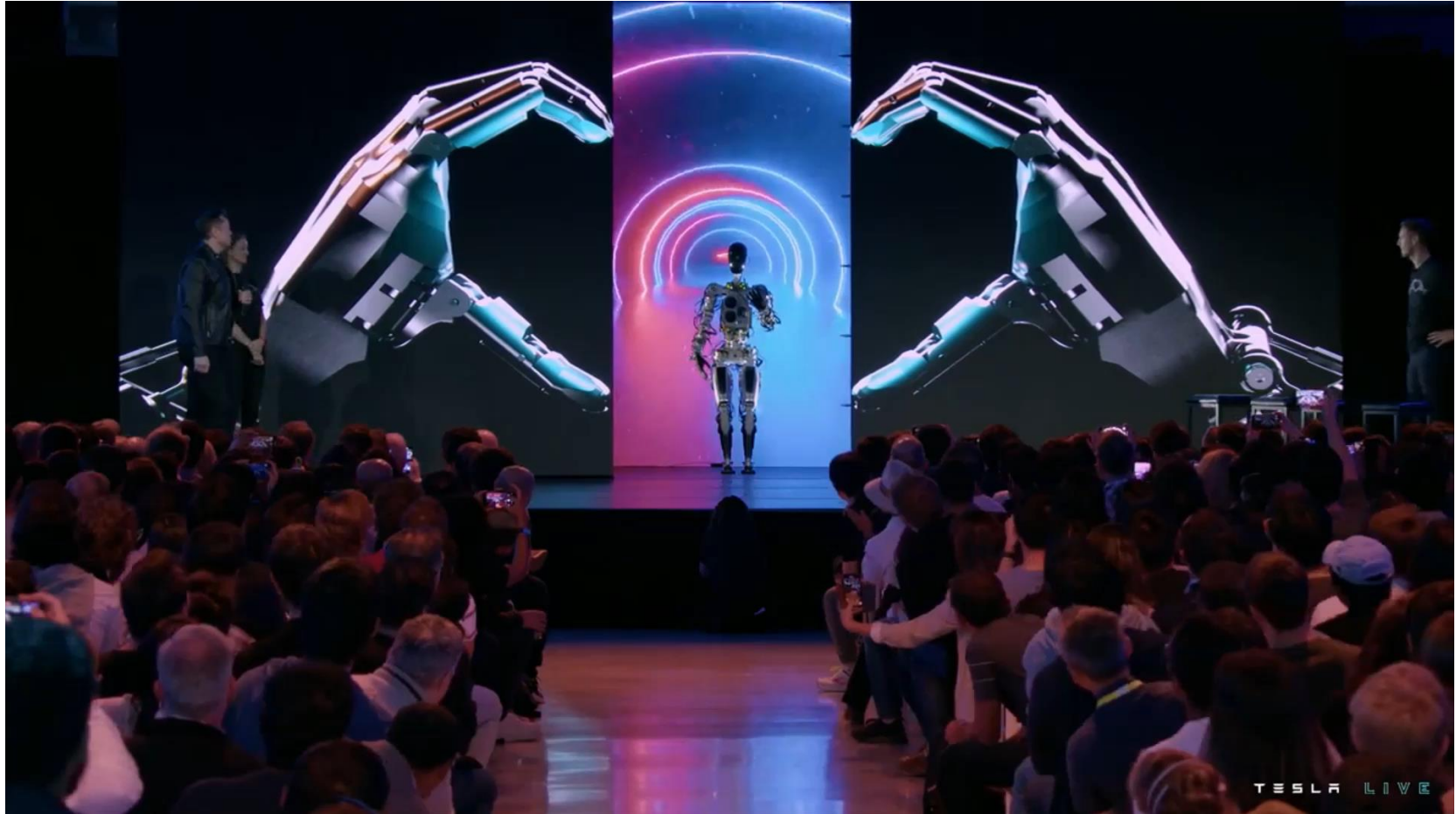
Autonomous Domestic Workers



<https://www.bloomberg.com/news/articles/2022-06-03/musk-says-tesla-may-have-optimus-robot-prototype-within-months>



Extra: Tesla Bot



Source: https://www.youtube.com/watch?v=ODSJsviD_SU

SELF-FLYING PLANES ARE HERE; AUTONOMOUS AIRCRAFT ARE THE FUTURE.

Home - Blog - Self-Flying Planes Are Here; Autonomous Aircraft Are The Future.

✈ Industry: **Materials & Chemical Processing**

I find it interesting how people get more comfortable with a concept, like self-flying planes, the more they understand the level of autonomy in modern planes.

You could consider modern planes as self-flying, in that they can autonomously execute a flight plan created by pilots. However, these aircraft cannot think for themselves; they will follow the flight plan until it's changed

For example, when pilots take off the seat-belt sign, chances are you're in a self-flying plane. With this information — and given the number of successful flights every day — the concept of autonomous aircraft starts to sound like a safe, feasible innovation.

In commercial aircraft, pilots input the flight plan into the flight management system (FMS) when the aircraft is still on the ground. The pilots usually activate this autopilot a few minutes after takeoff. The autopilot typically remains engaged until a few minutes before landing.

However, this isn't always the case. In low visibility, if the aircraft and runway are certified for autonomous landings, the plane can



<https://fluidcodes.com/news/self-flying-planes-are-here-autonomous-aircraft-are-the-future/>



Autonomous Bicycles



<https://www.youtube.com/watch?v=LSZPNwZex9s>

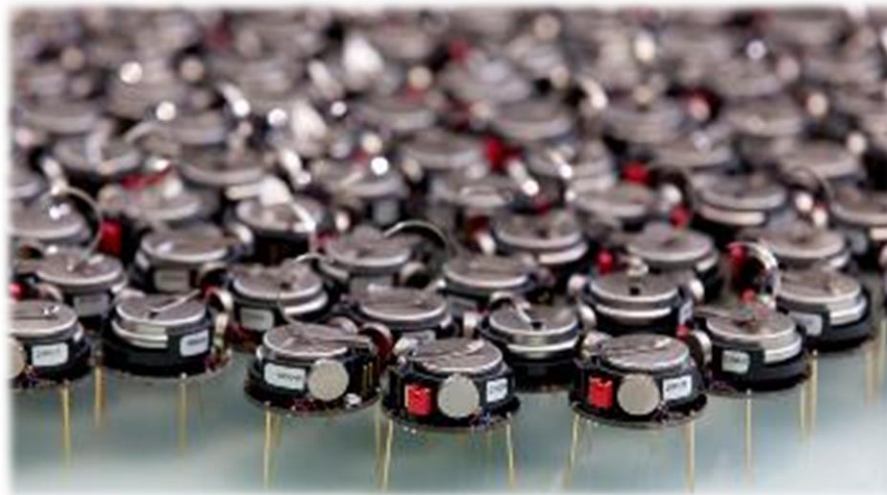


Autonomous Motorbikes



<https://www.youtube.com/watch?v=VaZITsoj0Hc>

- **Swarms: Collection of autonomous systems with distributed communication and control**
 - Biological inspiration from ant colonies and bird flocking behaviors
 - Advantage of robot teams: efficient convoying and V2V, faster search and rescue operations, wider coverage
- **Distributed computing and communications between individual agents and high-level human control**
- Robustness: adaptation, learning, and reconfigurability



<https://www.theengineer.co.uk/sheffield-robot-swarm-exhibits-turing-learning/>



End of Module 1