



Industrial-Scale Environments With Bounded Uncertainty: A Productivity Maximisation Challenge

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What Ocado Technology does

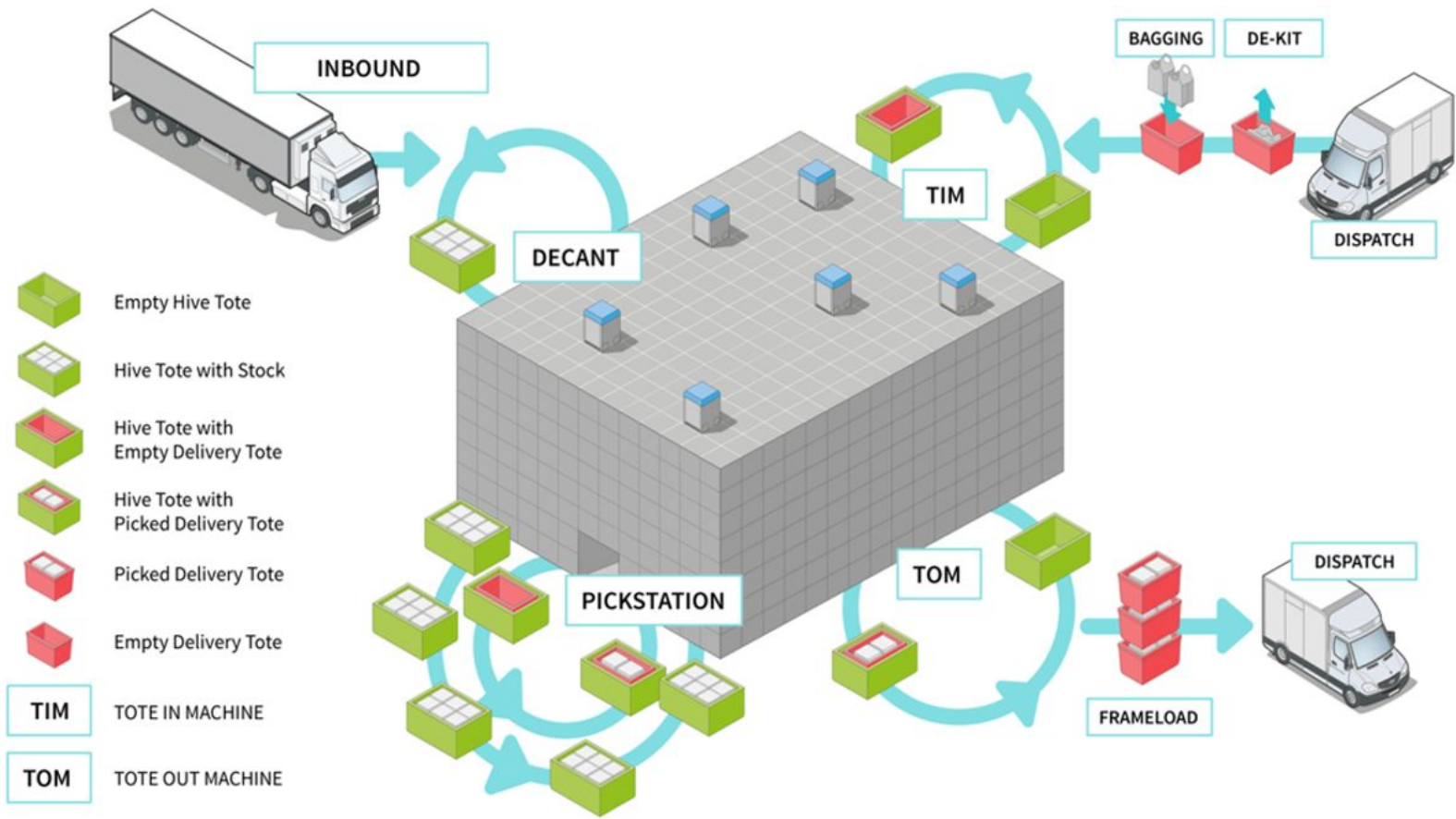
- Provide end-to-end e-commerce logistics platform
- Tech powers 4 automated warehouses in the UK
- Expanding to other retailers in **Canada**, **France**, **Sweden**, **USA**
- Fulfil online grocery orders for Ocado's retail arm and Morrisons
- Grocery deliveries come with several constraints
 - Temperature regime - chilled, ambient, frozen
 - Hard shipping deadlines, 24/7 operation
 - Shelf-life / freshness requirements
 - Storage / handling requirements
 - Low profit margins demand high efficiencies

OSP video

<https://www.youtube.com/watch?v=iogFXDWqDak> (Ocado Tech)

<https://www.youtube.com/watch?v=EeMTZd68fOU> (Ocado Tech)

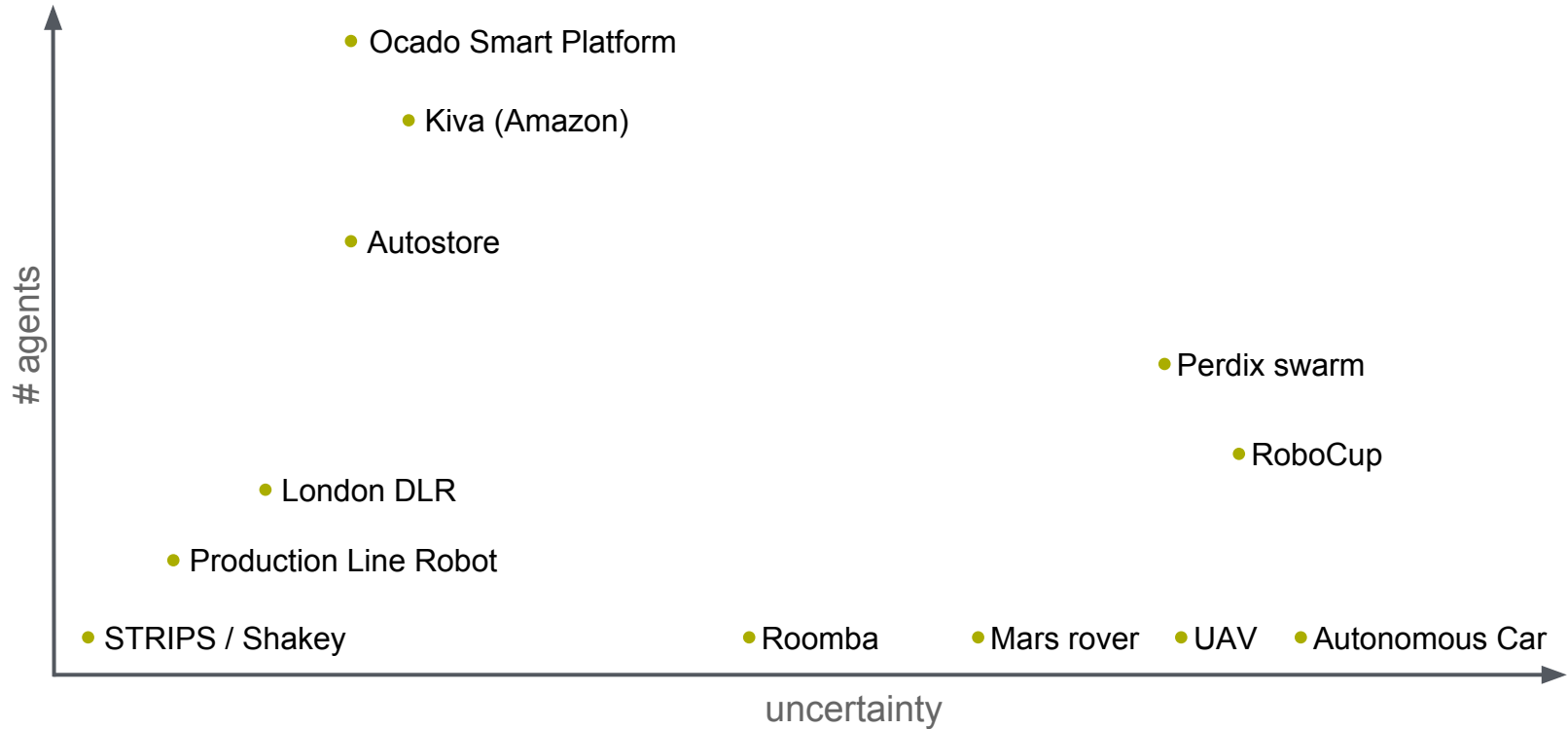
https://www.youtube.com/watch?v=4DKrcpa8Z_E (Tech Insider)



Warehouse automation

- Warehouse is artificial, controlled environment
- Large numbers of robots, conveyors, lifts - high redundancy
- Several sources of uncertainty
 - Mechanical wear and tear
 - Manufacturing variations
 - Human performance (and human errors)
 - Radio communications performance
 - Dirt and contamination
- Uncertainty limited to these known categories
- No single point of failure

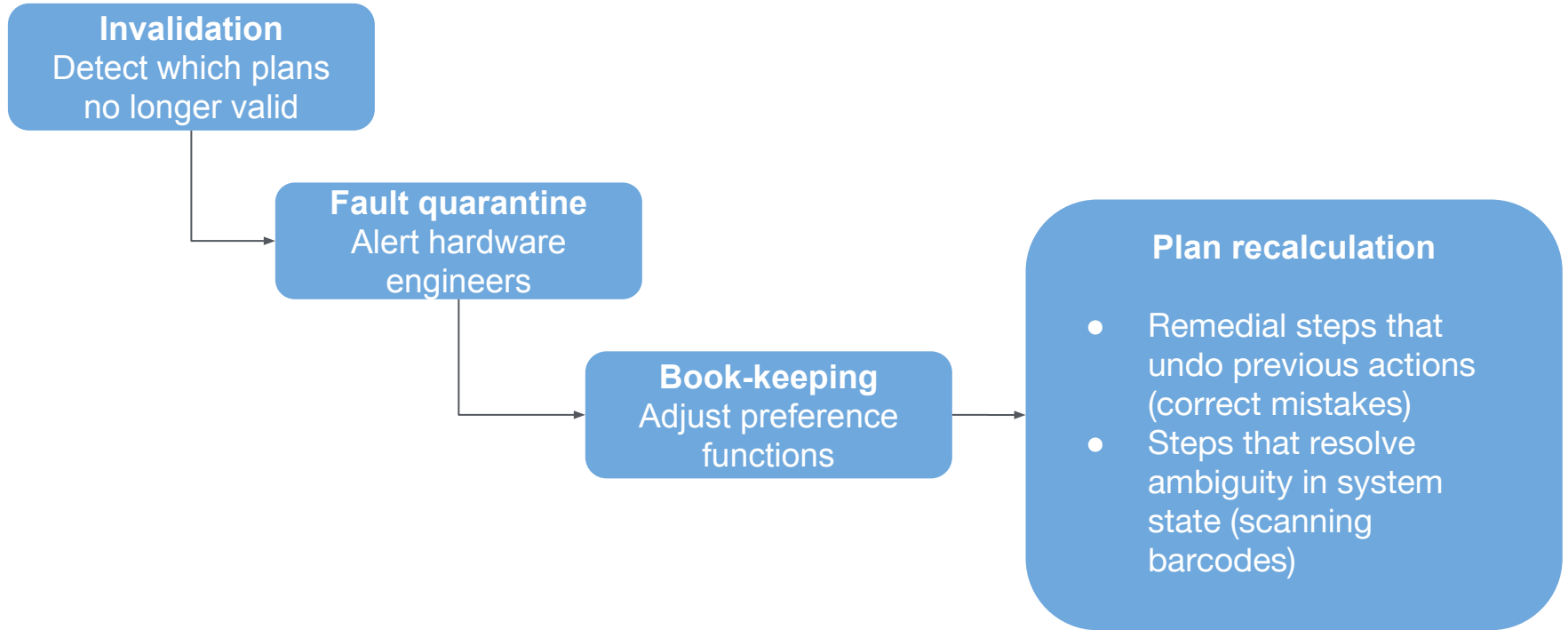
A Comparison



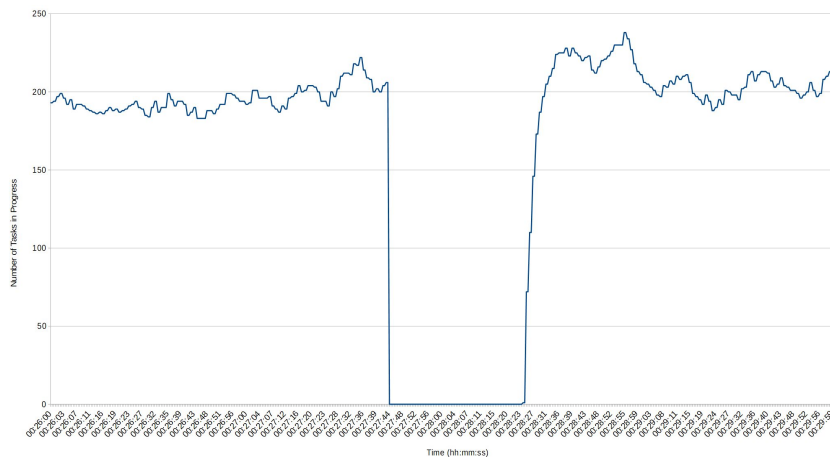
Coping with uncertainty

- Warehouse control systems allocate work to robots/conveyors
 - E.g. move a storage container to specific location
 - New work arrives continually throughout the day
- Actuator assumed to operate within performance envelope without failures
- When failure occurs, one or more local plans are invalidated
- Failure and recovery is usually **localised** - majority of actuators can continue operating

Recovery process

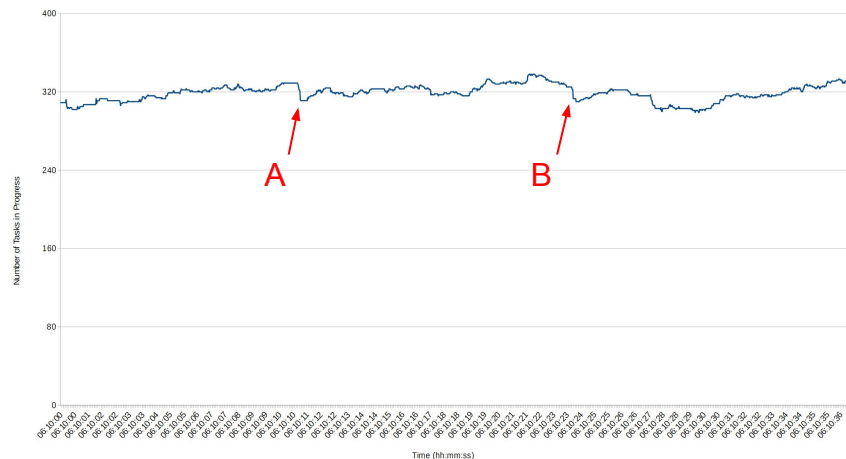


Results (i)



Global Plan Reset

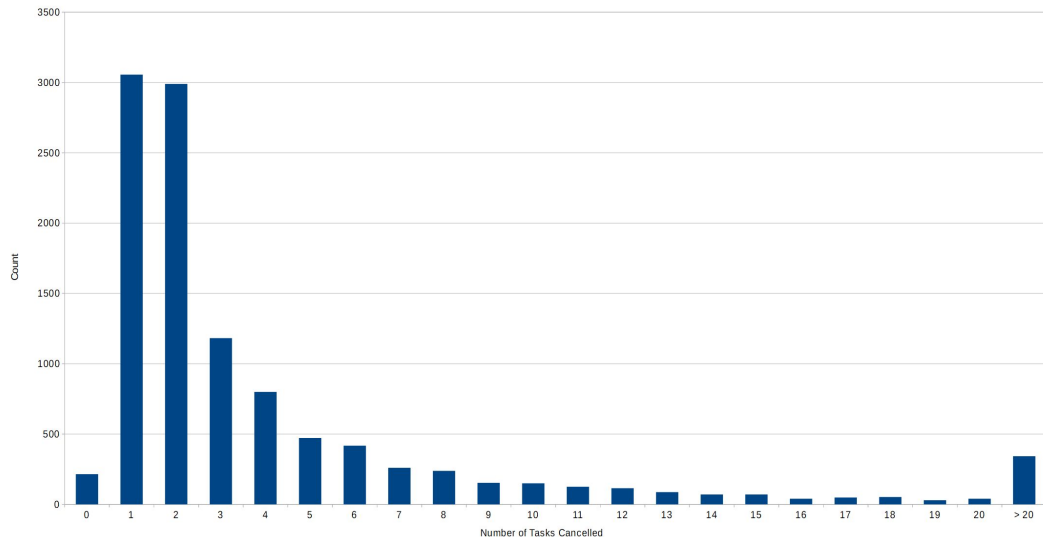
- Significant impact
- Quick recovery
 - Due to low-overhead planning



Local Plan Reset

- Minor impact
 - A: 18 tasks naturally complete
 - B: 11 tasks plans invalidated

Results (ii)



- Very few in-progress tasks cancelled at the same time
 - Typically <3%, but often < 1%
- Replanning comparable to natural planning for new work entering system

Summary

- Ocado OSP warehouses are an industrial-scale instance of a highly controlled environment
- “Planning for Failure” less critical in highly controlled environments
- “Just-in-time Planning” useful when unpredictable but continuous stream of work enters system
- Logistics is a rich domain with many challenging aspects
 - Many diverse constraints
 - Many degrees of freedom within which to optimise for throughput
 - Controlled environment allows us to consider it a perfect-information problem (with chance)
 - Doing it all in (near) real-time is critical



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Tack

P.S. We're hiring

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<http://www.ocadotechnology.com/join-us>

