University of Nottingham
Centre for Aerospace Manufacturing

Common Shared System Model for Evolvable Assembly Systems

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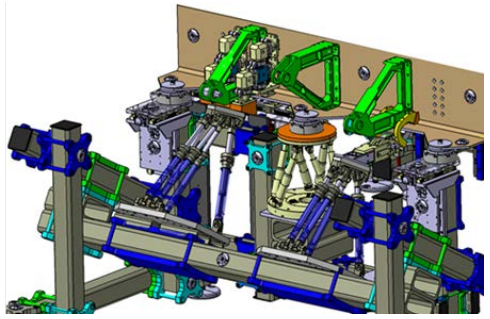
UoN Institute for Advanced Manufacturing

- Advanced Manufacturing Global Priority Research Theme
- Bringing together critical mass from a range of science, business and engineering disciplines
  - 422 members of staff and PGR students
- Current Manufacturing Research Portfolio
  - £49M including £32M EPSRC, £4M InnovateUK, £7M EU, £6M Industry
- Research excellence measured by quality outputs, delivering impact via strategic corporate partnerships
  - Centre for Aerospace Manufacturing established in 2010, now current portfolio in excess of £10M
- Investment in world-class research and teaching infrastructure
  - £7M – research facilities (2006-2014)
  - £24M – new state of the art IfAM building

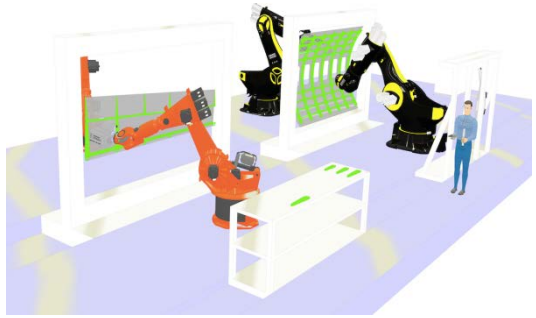
Research Strategy

Research Strategy - Automated Assembly Systems, Tooling and Fixturing

(1) Advanced Tooling and Fixturing	(2) Automated Assembly Systems	(3) Digital Factory
End Effector Tooling & Processes	Robotics Development & Implementation	Systems Integration
Smart Jigs, Fixtures & Work Cells	Sensing & Metrology	Smart Factories



Gripping, Handling & Joining of Components

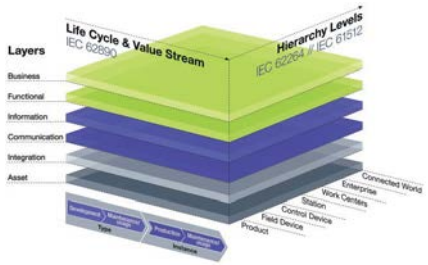


Identification, Location, Handling and Assembly of Component Structures

Final Assembly of Products

Informatics-Enabled Smart Factories

- Business drivers:
  - Improve global competitiveness
  - Dramatic reduction in production cost
  - Improve productivity
  - Upskilling of labour
  - Retaining capability to manufacture complete products in the UK
  - Improved quality and in-service support



- Product focus:
  - High value, high complexity products
  - Variable volumes
  - Trend towards product customisation
- Evolution:
  - Product
  - Process
  - System

EAS: Evolvable Assembly Systems

EP/K018205/1 Evolvable Assembly Systems:
Towards Open, Adaptable and Context-Aware Equipment and Systems

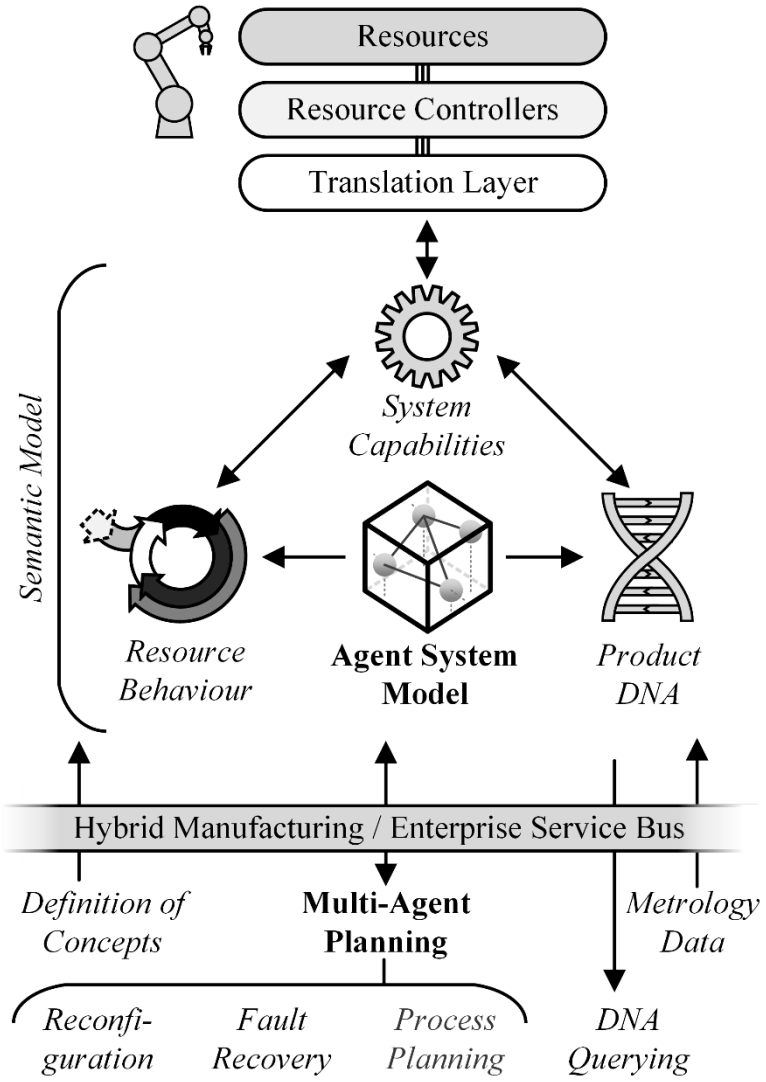
Part of EPSRC Flexible and Reconfigurable Manufacturing Systems Panel

5 Year Project: 1st Feb 2013 – 31st Jan 2019

Total Budget: £2.66 million

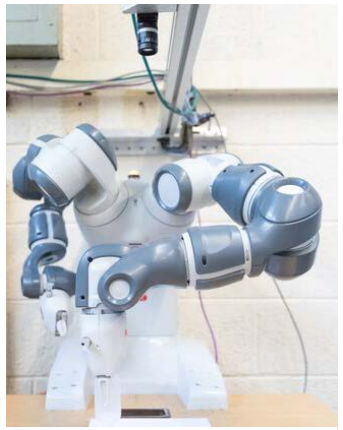
ABB
AIRBUS AN EADS COMPANY
BAE SYSTEMS
DE-STA-CO
GE Measurement & Control
Hyde Group
mtc Manufacturing Technology Centre
midlands aerospace alliance
SIEMENS
TQC

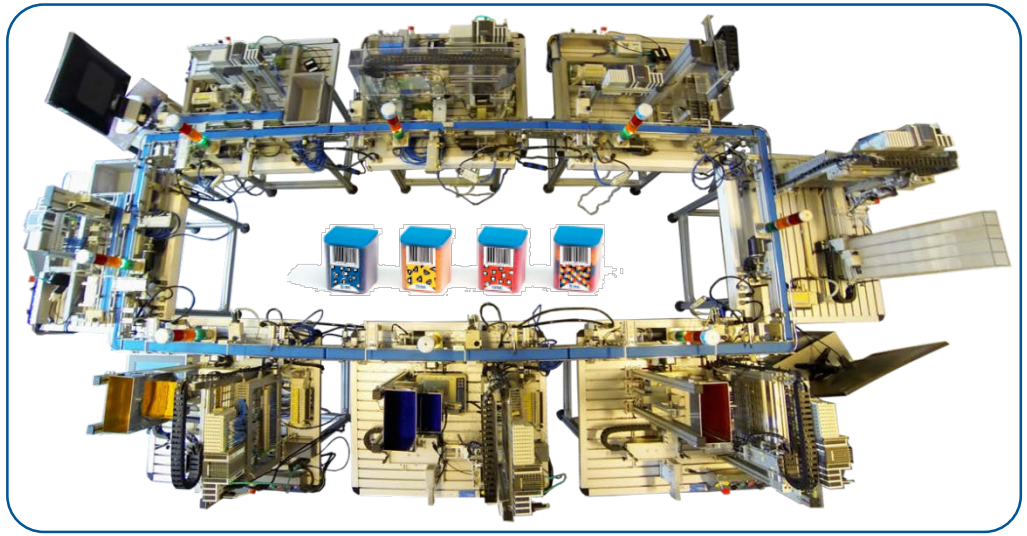
Shared System Model

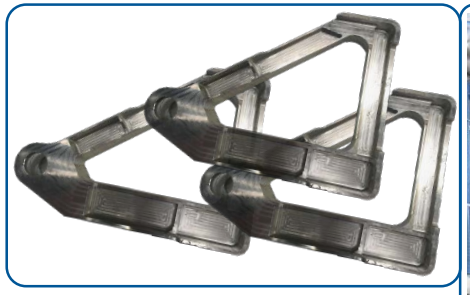


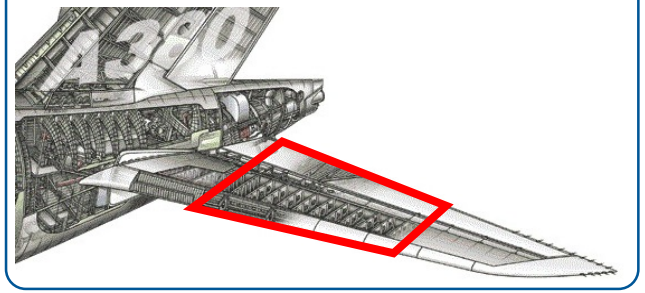
- Behaviour
  - How will the system react to disruption?
  - How do we guide system behaviour to achieve goals?
- Capabilities
  - What is the system topology?
  - What can the whole system do?
- Products / Parts
  - What happened to <*PartY*>?

Example Scenarios – Batch Size of One

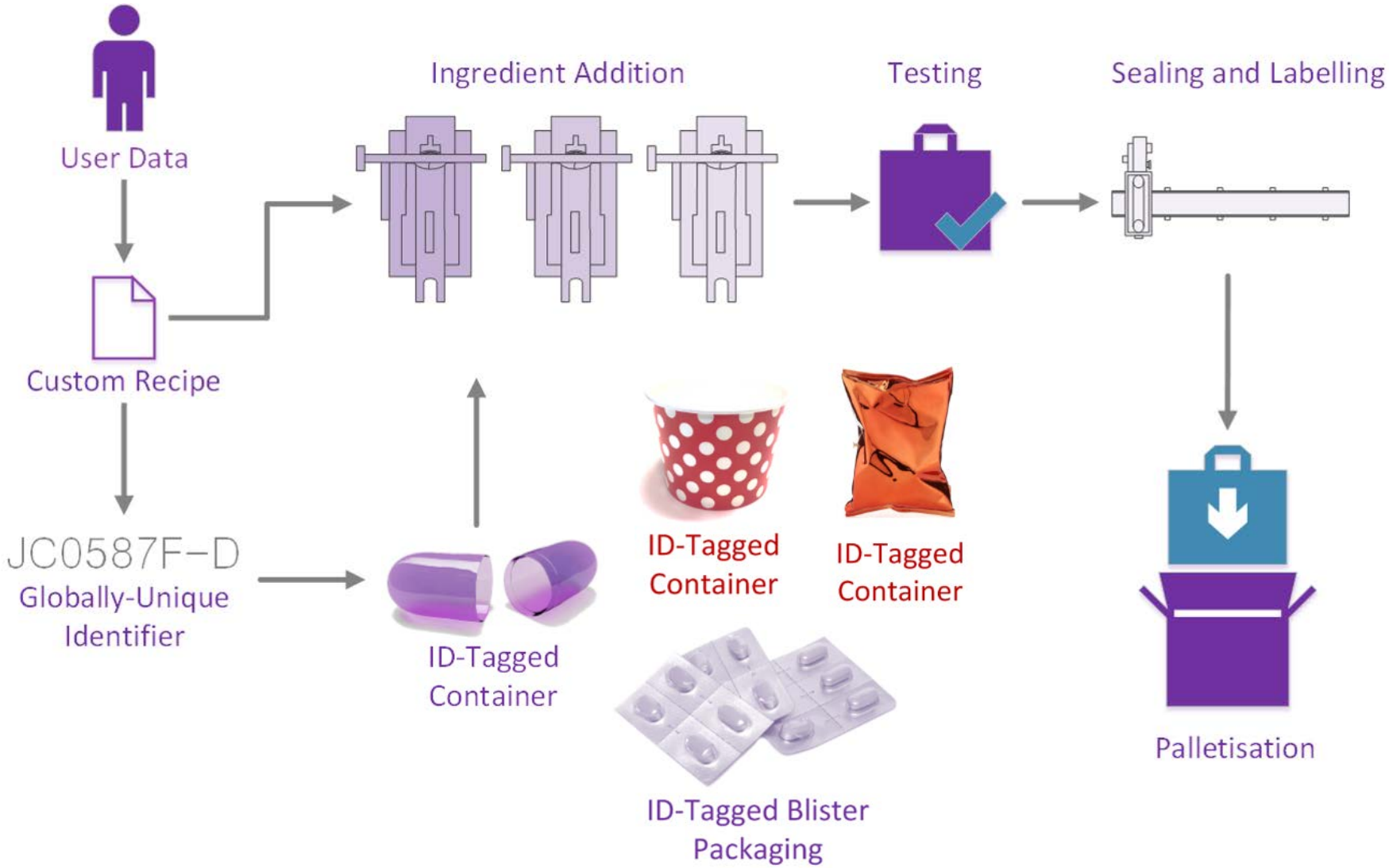




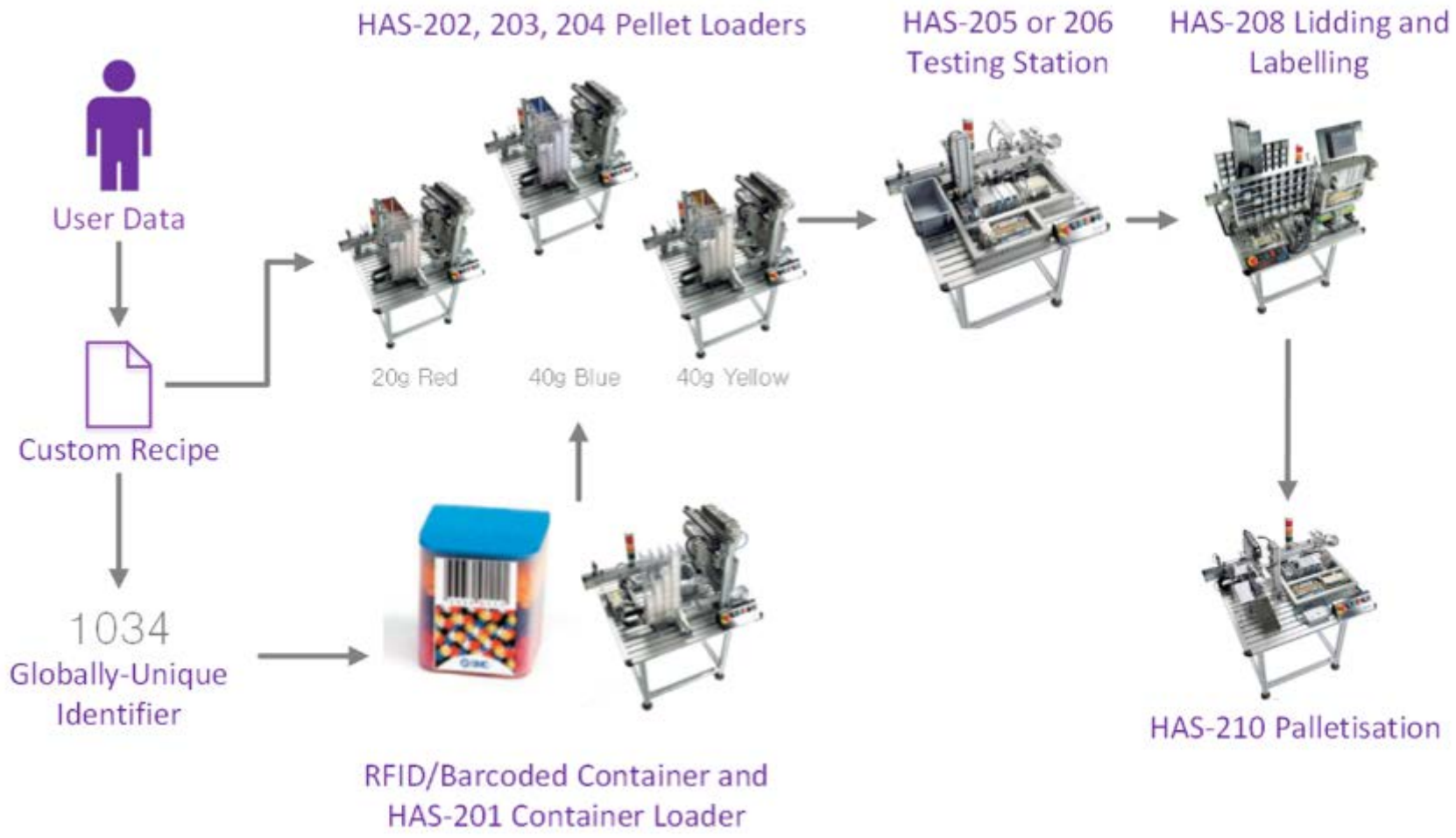




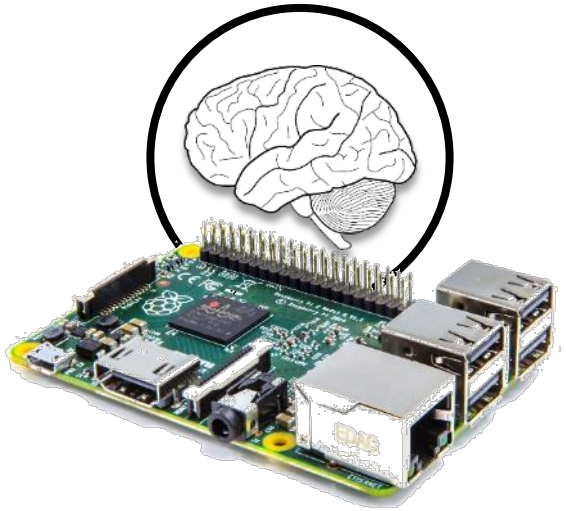
Batch Size of One Scenario – Customisable Pharma/Food



SMART Demonstrator



EAS Intelligent Agent Control



High-Level Commands

Low-Level Control

Capability Instantiation

High-Level Decisions

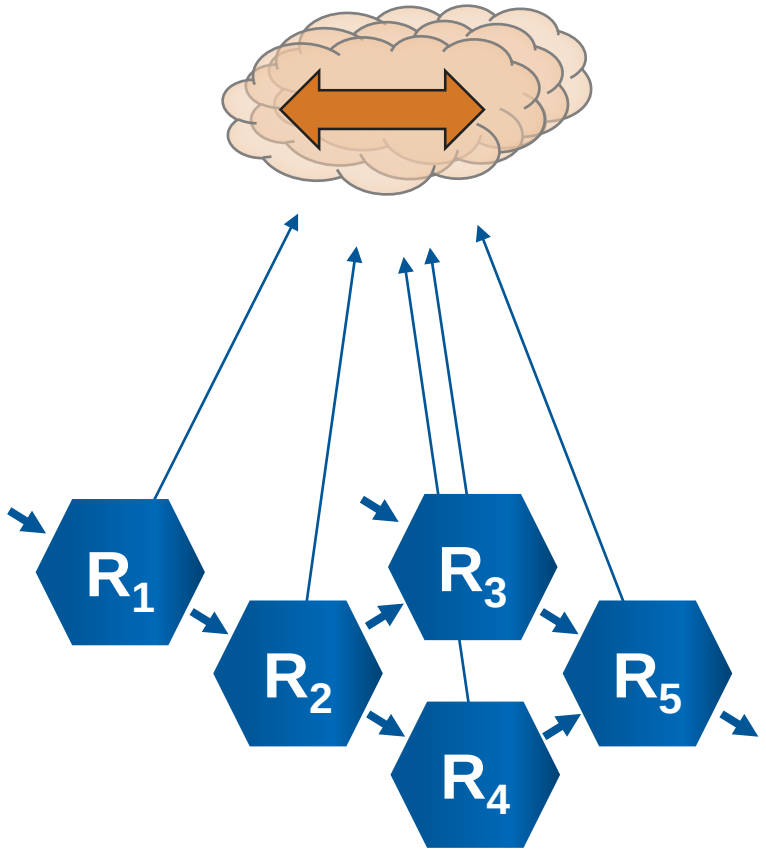
Processed Data

Raw Data

Data Distribution Service

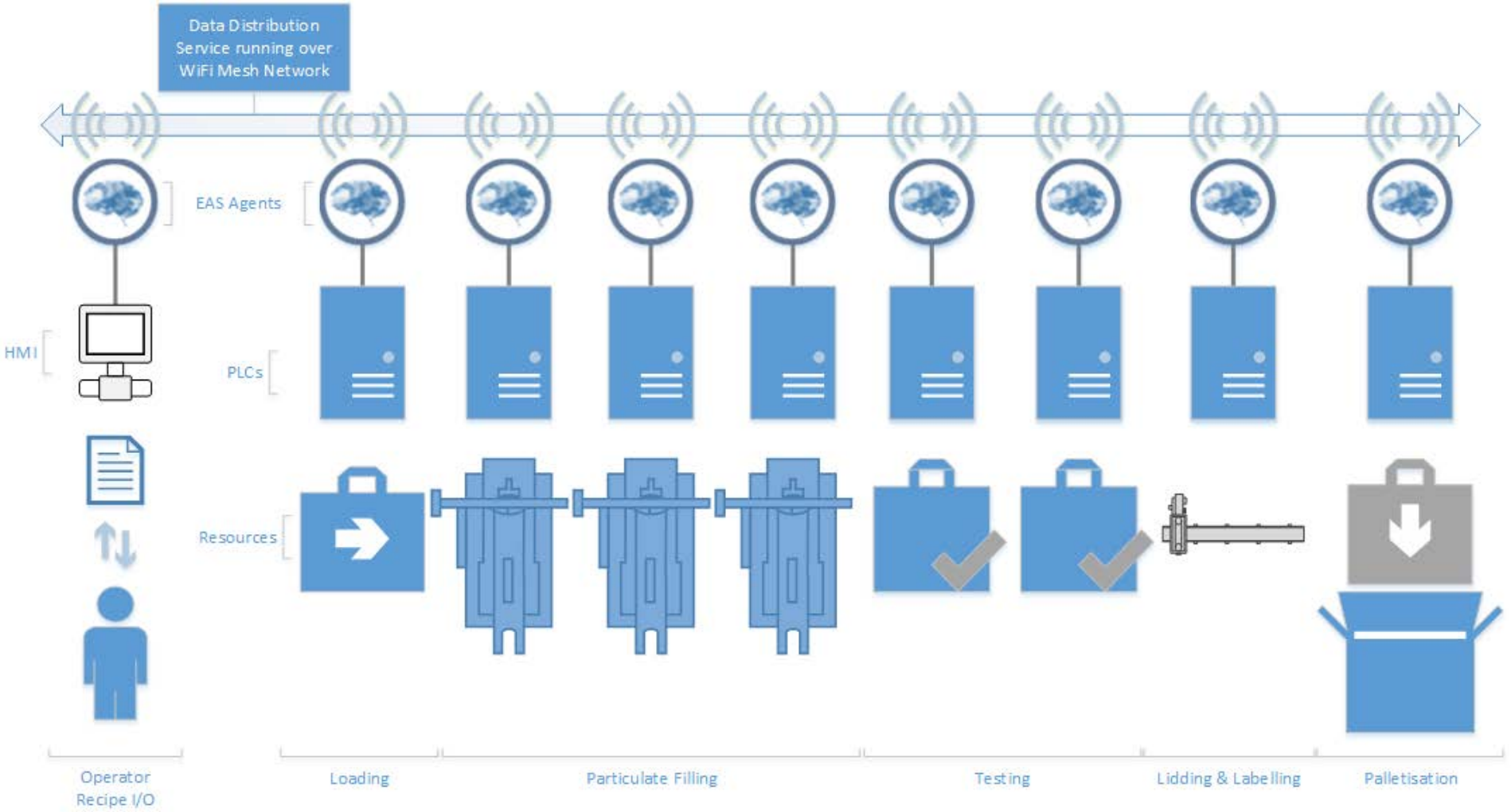
- Data Distribution Services promote a **decoupled, data-driven** communication strategy
- Nodes **publish** and **subscribe** to topics without concern for the origin/consumer node
- The topics and nodes form a **Shared System Context** – a single canonical view of all data
- Resources need only take from this Context what they require to make **intelligent decisions**

Shared System Context

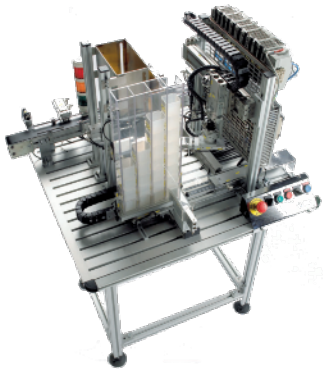


Production Line

SMART Network



Recipe Tracking



Fill Yellow

To-Do List

Recipe ID	Identifier	Action ID	Action	Argu-ments	Pre-requisites
0001	0000 0001	3	Fill Yellow	1	1,2

Referenced Recipes

Recipe ID	Action ID	Action	Status
0001	1	Load	Complete
	2	Fill Blue	Complete
	3	Fill Yellow	Claimed
	4	Test	Claimed
	5	Lid/Label	Claimed
	6	Palletise	Claimed

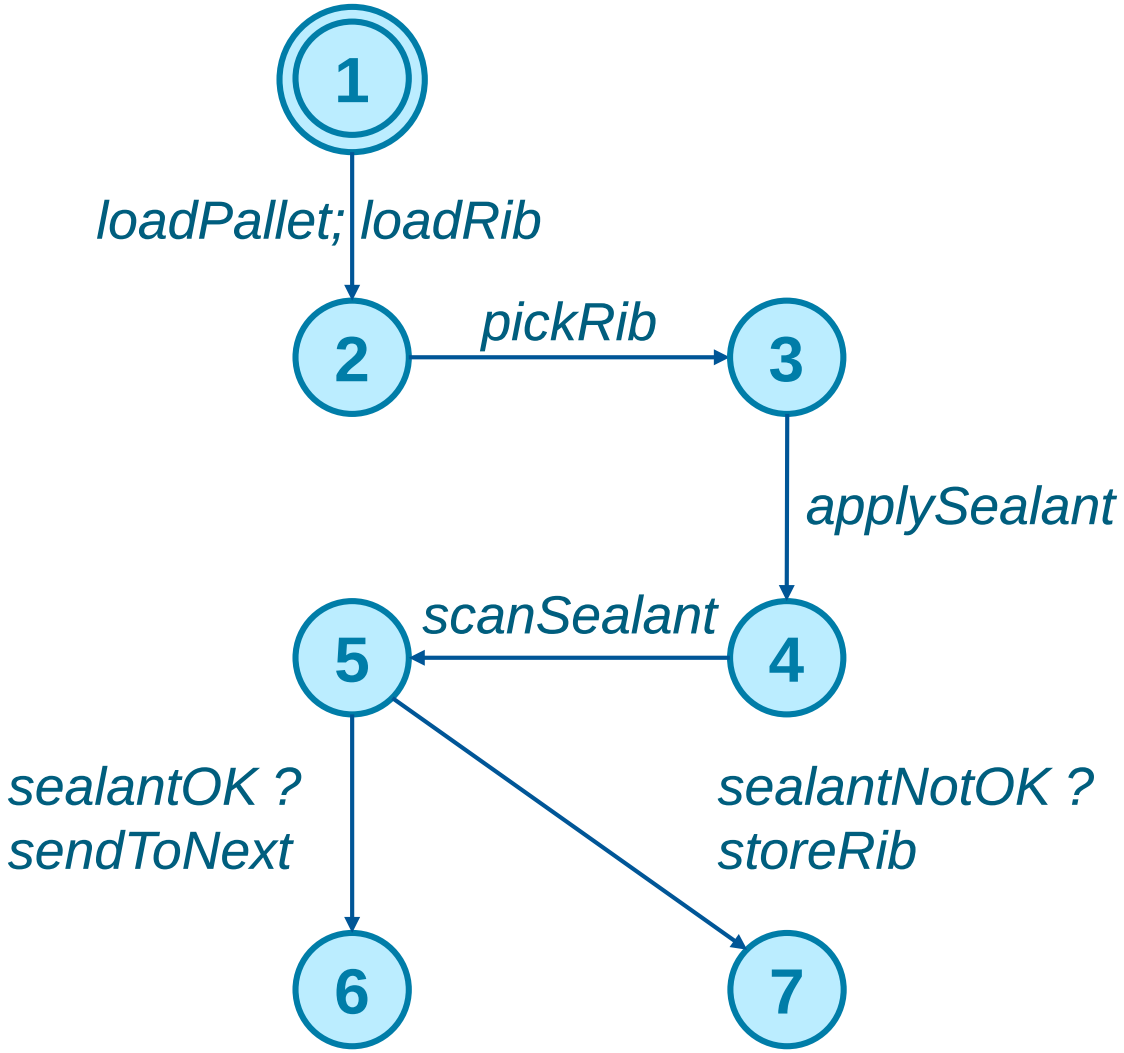
Video

YouTube Link

Robotic Assembly Scenario

- Automatically apply and verify sealant application to multiple unique rib components
  - Each rib unique – but not immediately obvious to operator
  - Recipe-driven automation
- Rib components to be assembled as part of larger structure
  - Requires information about quality of sealant to achieve tight tolerances
- Automated cell, but decisions must be scrutinised if necessary
  - Requires complete data logging

Example Recipe



Cell Resources

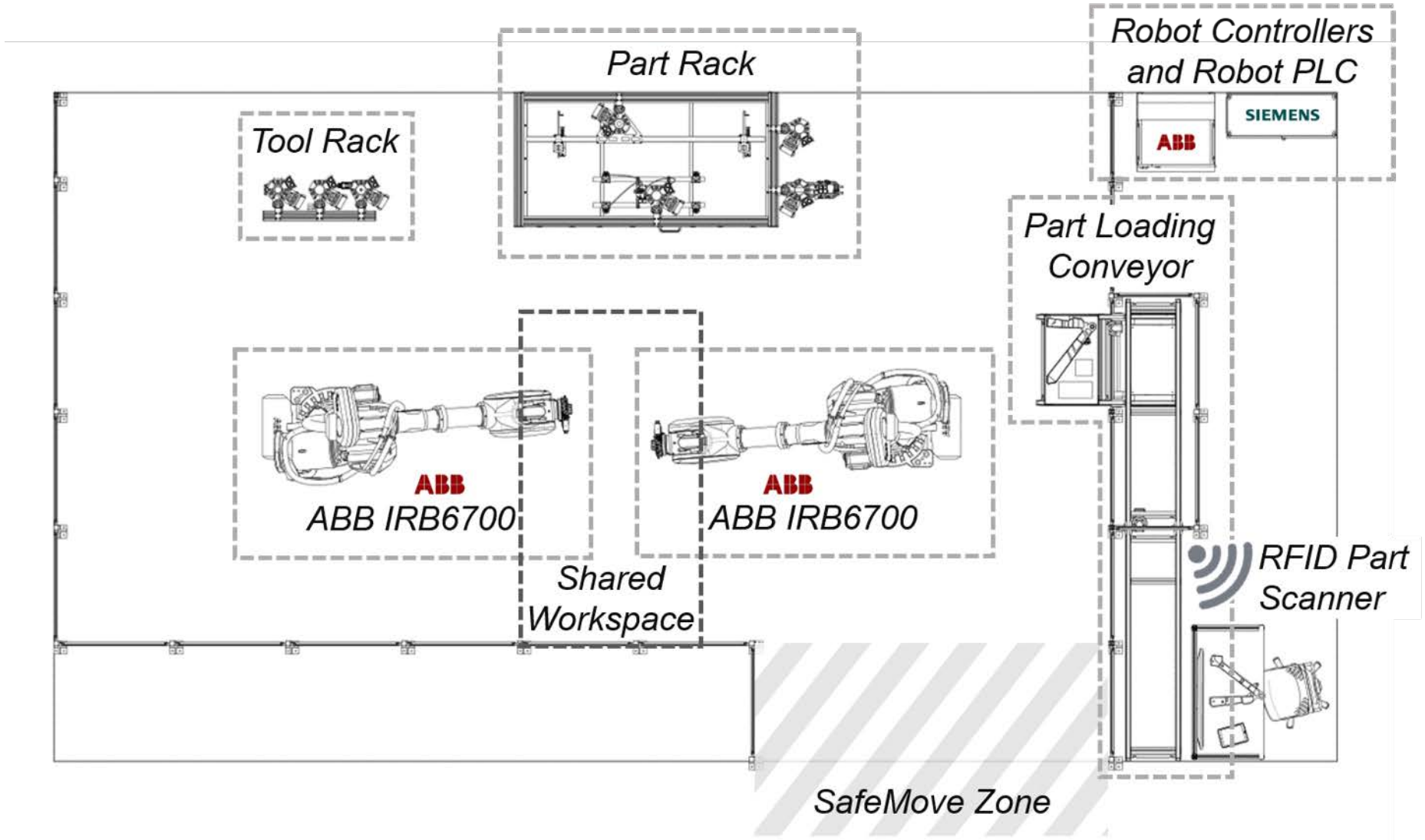
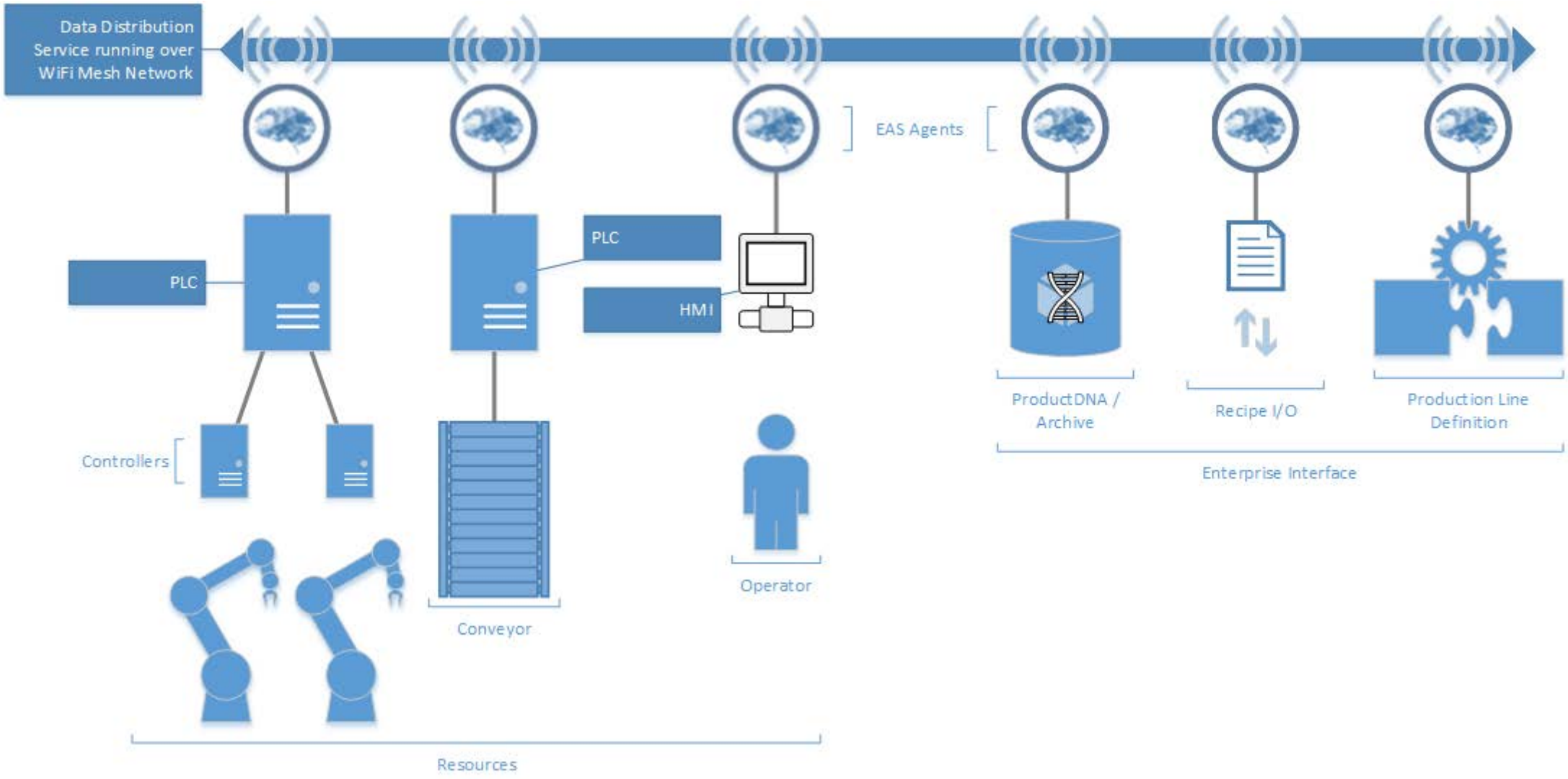
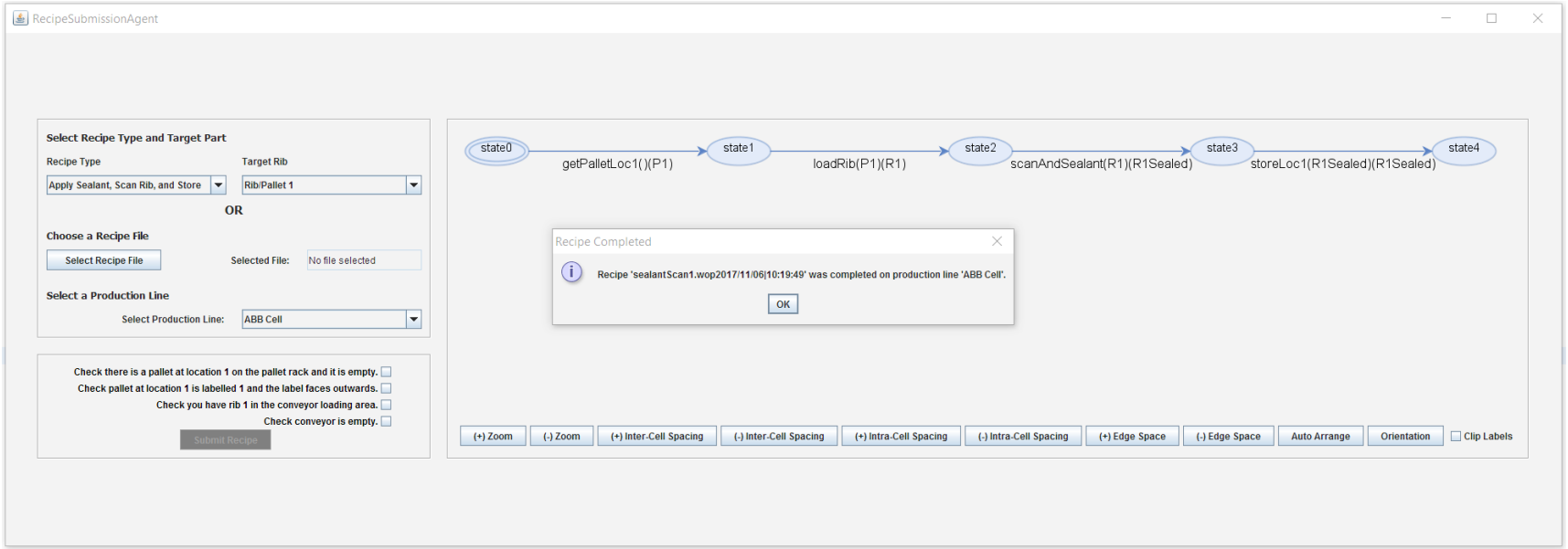


ABB Cell Network

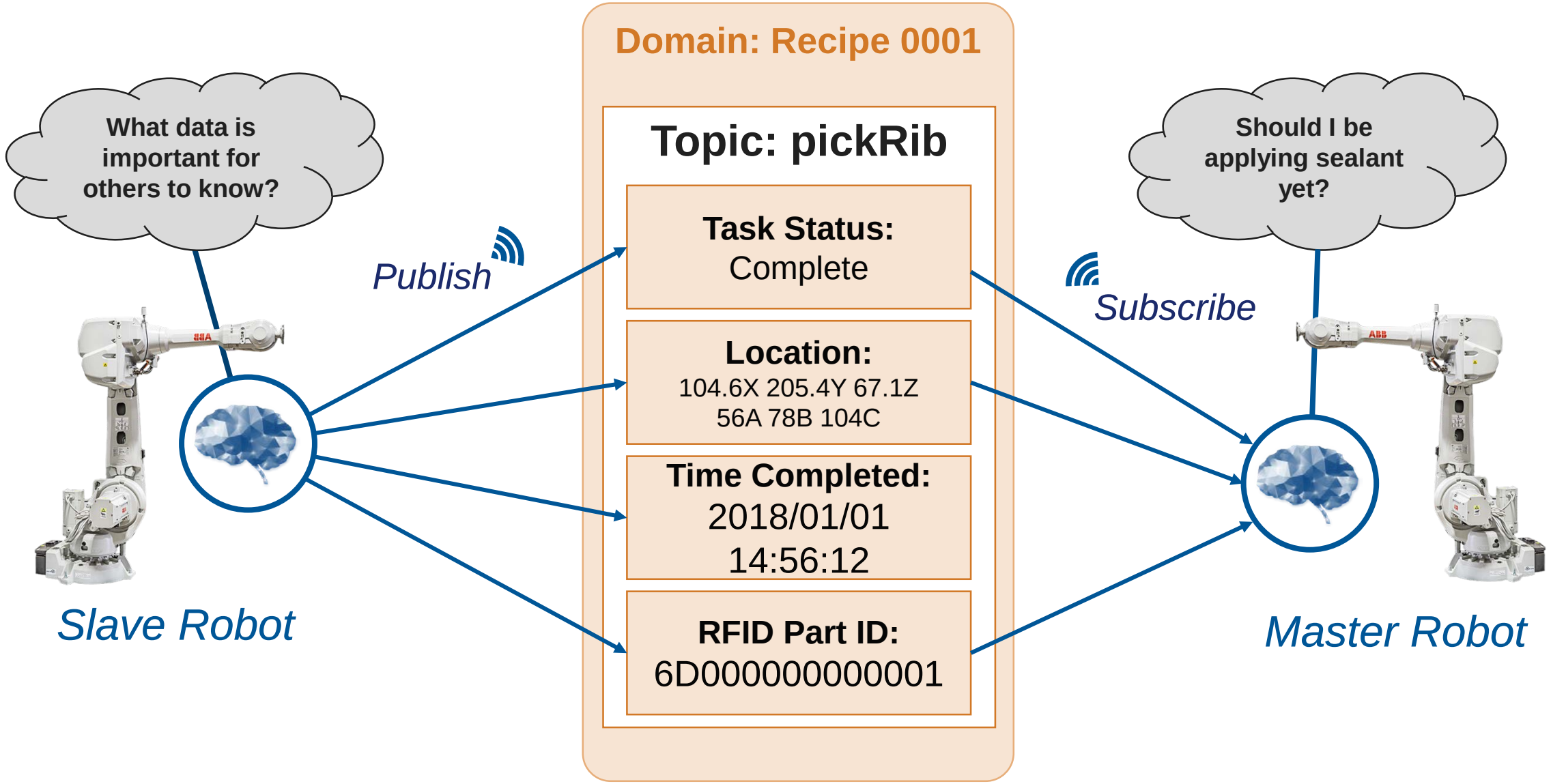


Batch Size of One Demonstration



- Recipes can be submitted to the system via user interface
- Agents collaborate to determine if recipe is possible, and what the execution plan is
- Shared system model allows per-recipe topics for agents to track multiple recipe progress

Recipe Tracking



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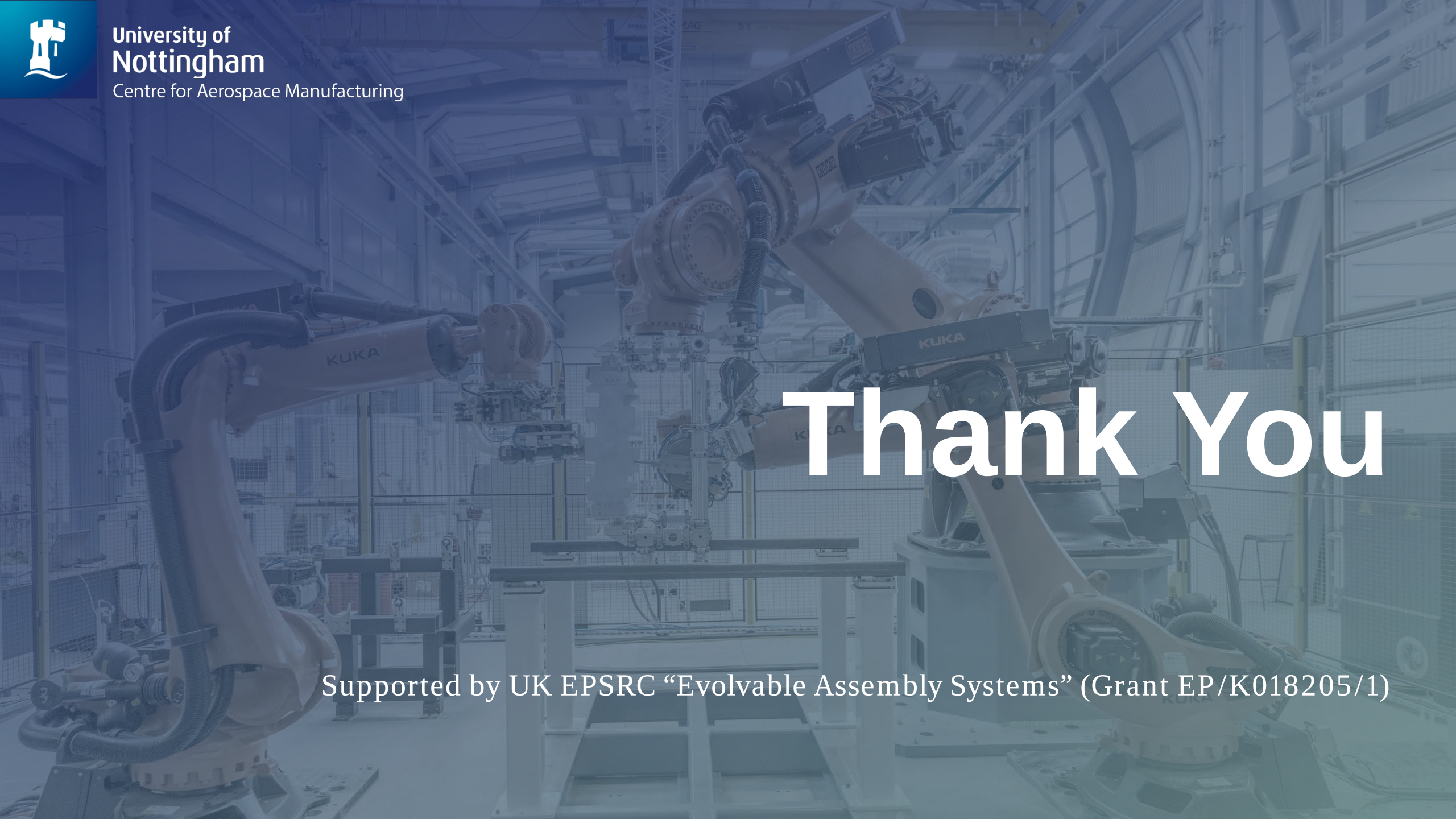
Industrialisation of Fundamental Research

Partners	Key Projects	Funding	Research Theme
AIRBUS	• Next Generation Composite Wing (NGCW) • Factory of Aircraft Future (FoAF) • Wing Lean Innovative Future Technologies (WingLIFT)	Direct Funding and Aerospace Technology Institute (ATI)	• Future Factory • Future Assembly Tooling • Current Production Tooling & Business Case
AIRBUS HELICOPTERS GE Aviation	• Advanced Wing Structure for Rotorcraft Additional Lift (ASTRAL)	Clean Sky 2, EU	• Design and Structural Optimisation • Cost Modelling for Composite Manufacturing and Assembly • Automated Assembly of 3m Demonstrator Wing *(UoN Core Partner & Coordinator)*
BAE SYSTEMS INSPIRED WORK	• Digital Factory • Assembly Philosophies • Assembly Demonstrator	Direct Funding and Aerospace Technology Institute (ATI)	• Future Assembly Tooling • Automated Assembly Processes • Future Factory Enablers *(Awarded 3 Chairman's Bronze Awards)*
GKN GE Aviation	• Validation and Integration of Manufacturing Enablers for Future Wing Structures (VIEWS)	Aerospace Technology Institute (ATI)	• Flexible Component Assembly Cell • Automated Sealant Application • Human Robot Collaboration
LEONARDO AIRCRAFT	• Variance Aware Determinate Assembly Integrated System (VADIS)	Clean Sky 2, EU	• Scanning of Aircraft Wing Skins (~10m) for Rib Holes and Interfaces *(UoN Coordinator)*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KUKA
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