Common Shared System Model for Evolvable Assembly Systems

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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 - Automated Assembly Systems, Tooling and Fixturing

<table>
<thead>
<tr>
<th>Research Area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Advanced Tooling and Fixturing</td>
<td>End Effector Tooling &amp; Processes, Smart Jigs, Fixtures &amp; Work Cells</td>
</tr>
<tr>
<td>(2) Automated Assembly Systems</td>
<td>Robotics Development &amp; Implementation, Sensing &amp; Metrology</td>
</tr>
<tr>
<td>(3) Digital Factory</td>
<td>Systems Integration, Smart Factories</td>
</tr>
</tbody>
</table>

- **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
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

User Data → Custom Recipe → JC0587F-D (Globally-Unique Identifier)

Ingredient Addition → Testing → Sealing and Labelling

ID-Tagged Container → ID-Tagged Container → ID-Tagged Container

ID-Tagged Blister Packaging → Palletisation
SMART Demonstrator

User Data → Custom Recipe → 1034 Globally-Unique Identifier → RFID/Barcoded Container and HAS-201 Container Loader.

HAS-202, 203, 204 Pellet Loaders → HAS-205 or 206 Testing Station → HAS-208 Lidding and Labelling → HAS-210 Palletisation.
EAS Intelligent Agent Control

High-Level Commands

Low-Level Control

Capability Instantiation

Raw Data

High-Level Decisions

Processed Data
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**.
## Recipe Tracking

### To-Do List

<table>
<thead>
<tr>
<th>Recipe ID</th>
<th>Identifier</th>
<th>Action ID</th>
<th>Action</th>
<th>Arguments</th>
<th>Pre-requisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>0000 0001</td>
<td>3</td>
<td>Fill Yellow</td>
<td>1</td>
<td>1,2</td>
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</table>

### Referenced Recipes

<table>
<thead>
<tr>
<th>Recipe ID</th>
<th>Action ID</th>
<th>Action</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>1</td>
<td>Load</td>
<td>Complete</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Fill Blue</td>
<td>Complete</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Fill Yellow</td>
<td>Claimed</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Test</td>
<td>Claimed</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Lid/Label</td>
<td>Claimed</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Palletise</td>
<td>Claimed</td>
</tr>
</tbody>
</table>
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

1. loadPallet; loadRib
2. pickRib
3. applySealant
4. scanSealant
5. sealantOK ?
6. sendToNext
7. sealantNotOK ?

sendToNext
storeRib
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

Domain: Recipe 0001

Topic: pickRib

Task Status: Complete

Location:
104.6X 205.4Y 67.1Z
56A 78B 104C

Time Completed:
2018/01/01
14:56:12

RFID Part ID:
6D000000000001

What data is important for others to know?

Should I be applying sealant yet?

Publish

Subscribe

Slave Robot

Master Robot
## Industrialisation of Fundamental Research

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

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