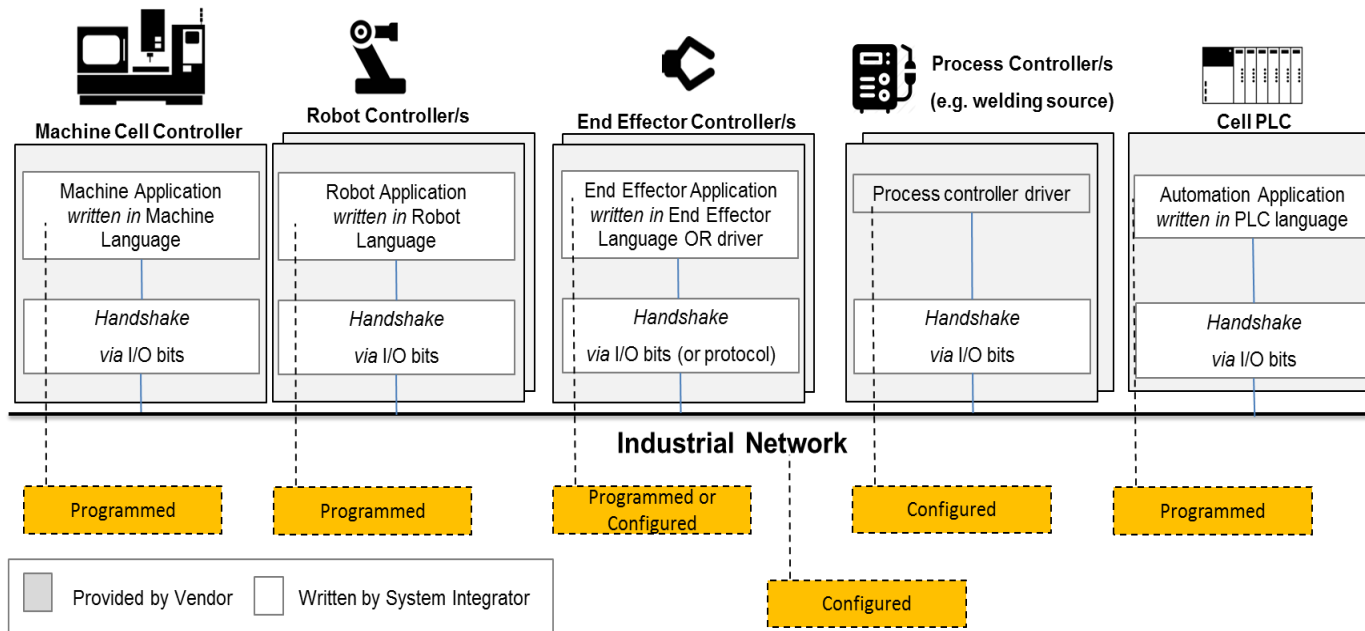


Multi-Robot, Multi-Machine Interoperability

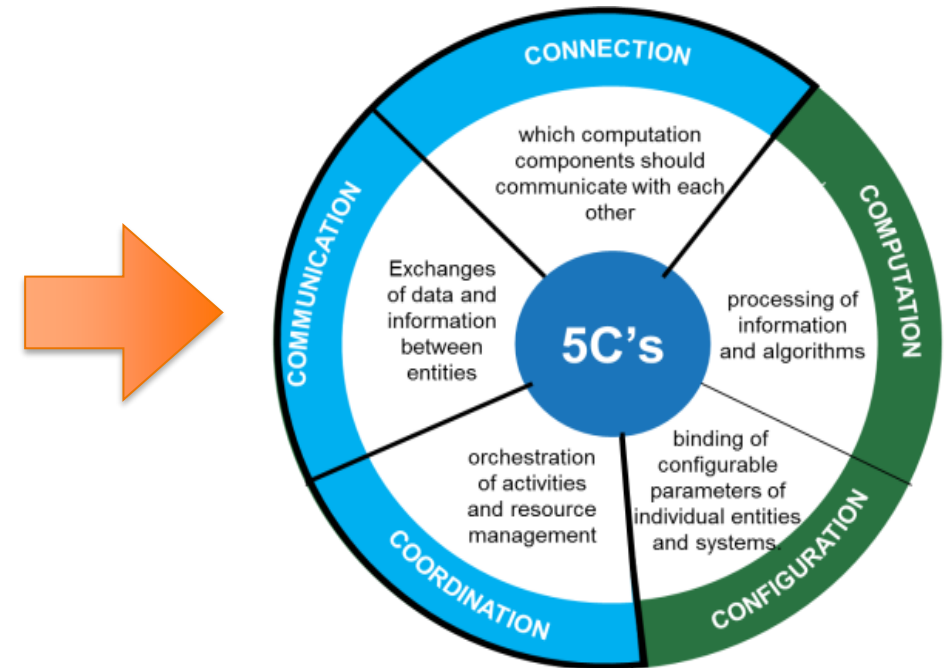
ROS-Industrial Consortium Americas 2021 Annual Meeting

The Interoperability Problem

Current Landscape for Robot Systems in Manufacturing



Dimensions to achieve **Interoperability**

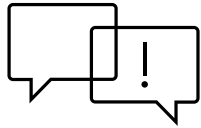


In blue, the focus of this project.

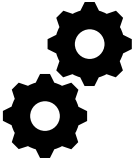
Why is Interoperability between Automation and Robotic systems difficult?



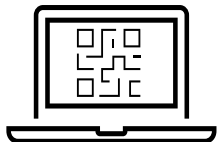
- **Custom Integration Software upfront cost can be 2x to 5x the hardware costs**
 - Small/midsize manufacturing companies may opt out from investing altogether



- **Communication protocol bridging is challenging (or even impossible)**
 - Introduces a high risk from the beginning



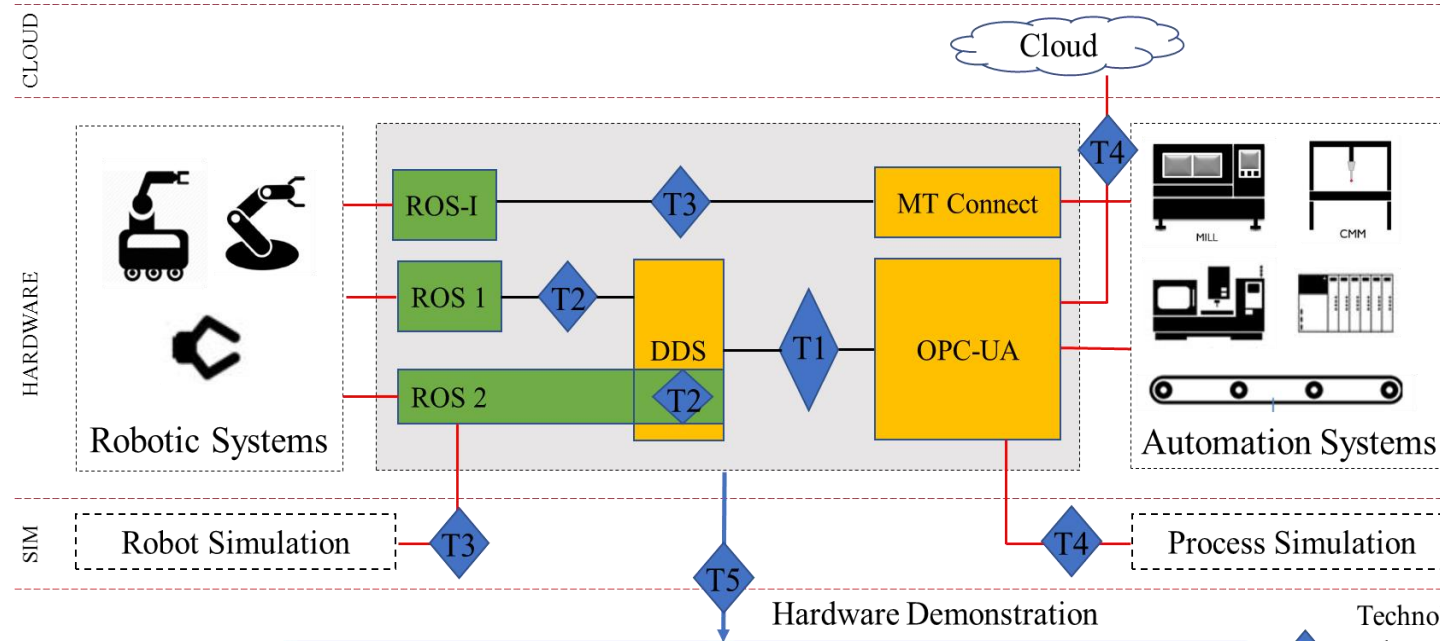
- **Every integration is a custom one-off solution**
 - Resulting in Non-Recurring Engineering costs every time
 - Only experience itself is reusable



- **Technology can be very intimidating**
 - Small/midsize manufacturing companies may lack the internal technical resources to take on the tasks
 - Software is not plug&play, lacks documentation and extended support

Source: <https://www.youtube.com/watch?v=hnDKqr-g3t4&t=1s>, MTConnect Institute

ARM 18-01-F-25 Seamless Multi-Robot, Multi-Machine Interoperability



- Technology integration, enhancement and demo in this project & associated task name
- Vendor specific drivers
- Gateway between robotic and automation systems
- Tech module transferable to ARM members**



Key Contributions



OPC UA / DDS Gateway

- Initial implementation
- Uni-directional comm.
- Linux



- Robustified implementation
- Bi-directional comm.
- Linux and Windows

DDS and ROS2 Interoperability

Partial ROS2 ↔ DDS Interoperability



Freedom to Mix and Match ROS2 and DDS applications

MTConnect High-level Task Coordination

- Rigid MTConnect Implementation
- HTTP Transport



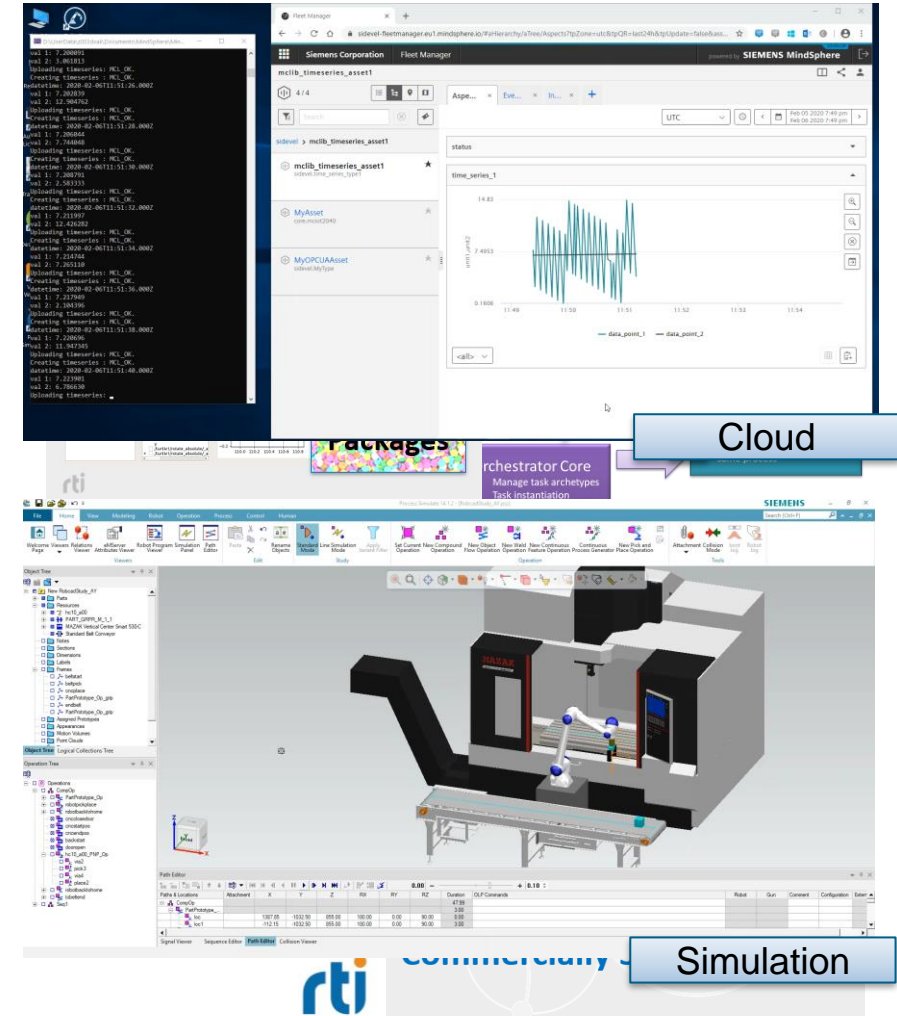
- Flexible standalone MTConnect Python package
- DDS Transport

Cloud and Simulation (OPC UA)

- Cloud Plug&Play devices collect OPC UA and proprietary protocol signals
- Industrial Simulation Software uses OPC UA external signals

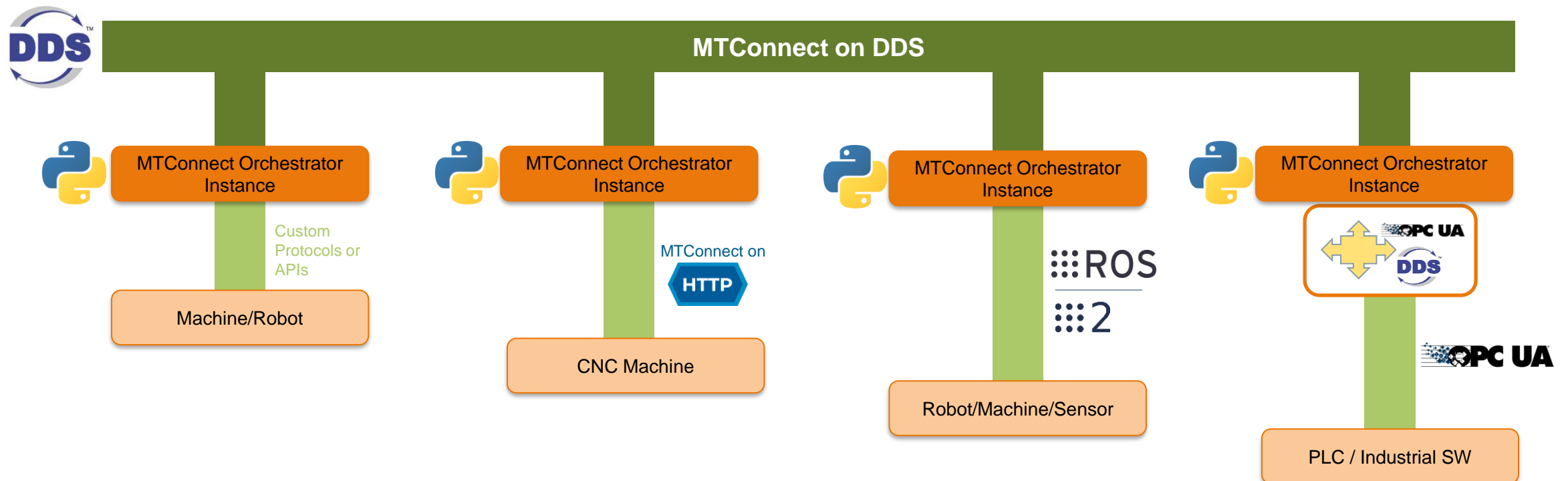


- Cloud Plug&Play field devices collect OPC UA and DDS signals
- Industrial Simulation Software uses OPC UA and DDS external signals.



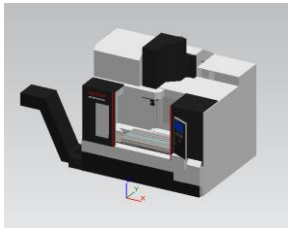
Integration under MTConnect Orchestration

Possible configurations under the MTConnect Orchestration scheme



Siemens Demo: Use Case

- Complex Industrial Environment



Industrial Simulation Software



Cameras and Sensors



Transportation Systems



Robotic Arms



Industrial Controllers

- Manufacturing Process



Raw material

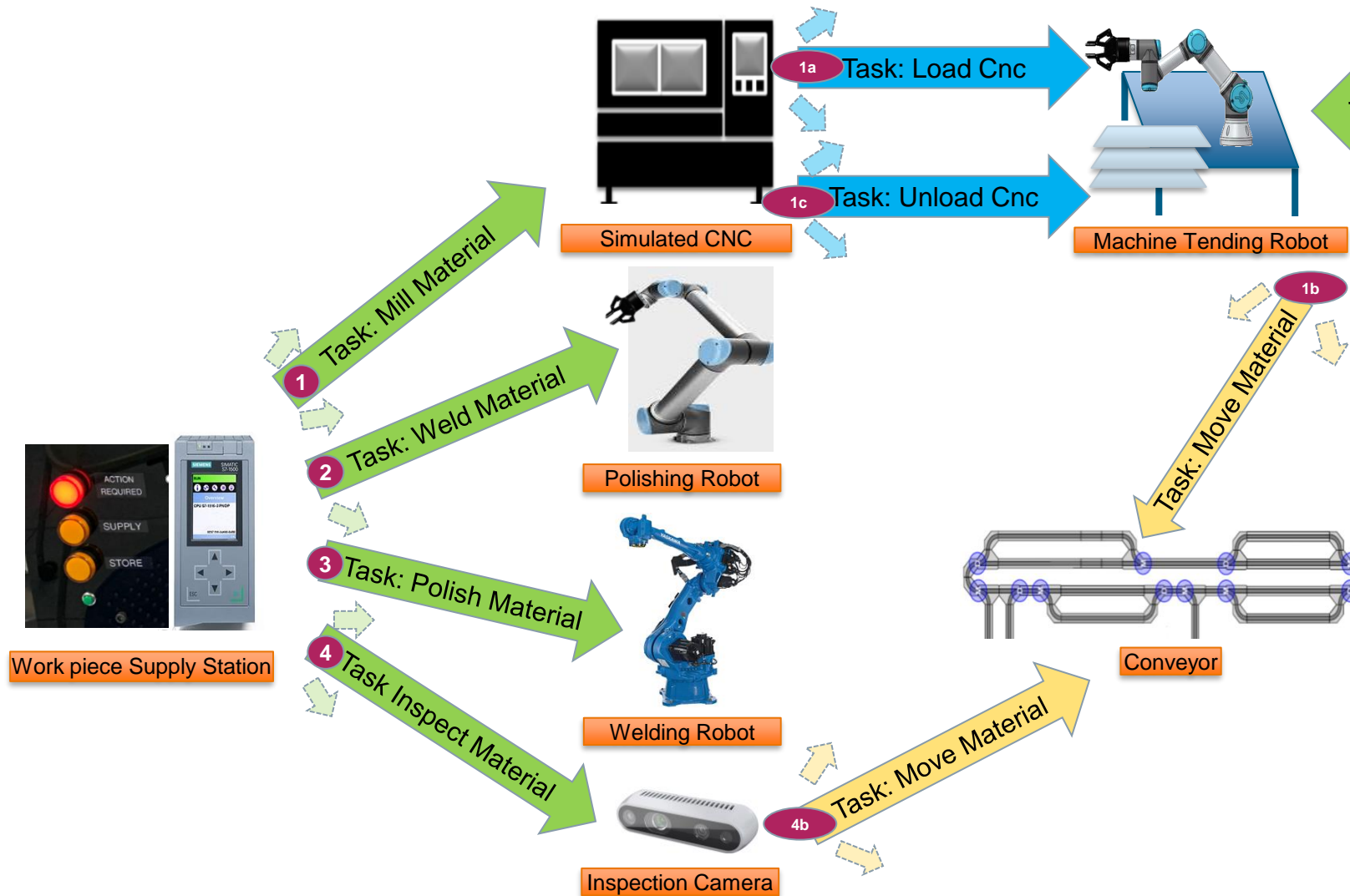


Finished material

Siemens FoA Lab Hardware Demonstration

Orchestration over MT Connect

SIEMENS
Ingenuity for life

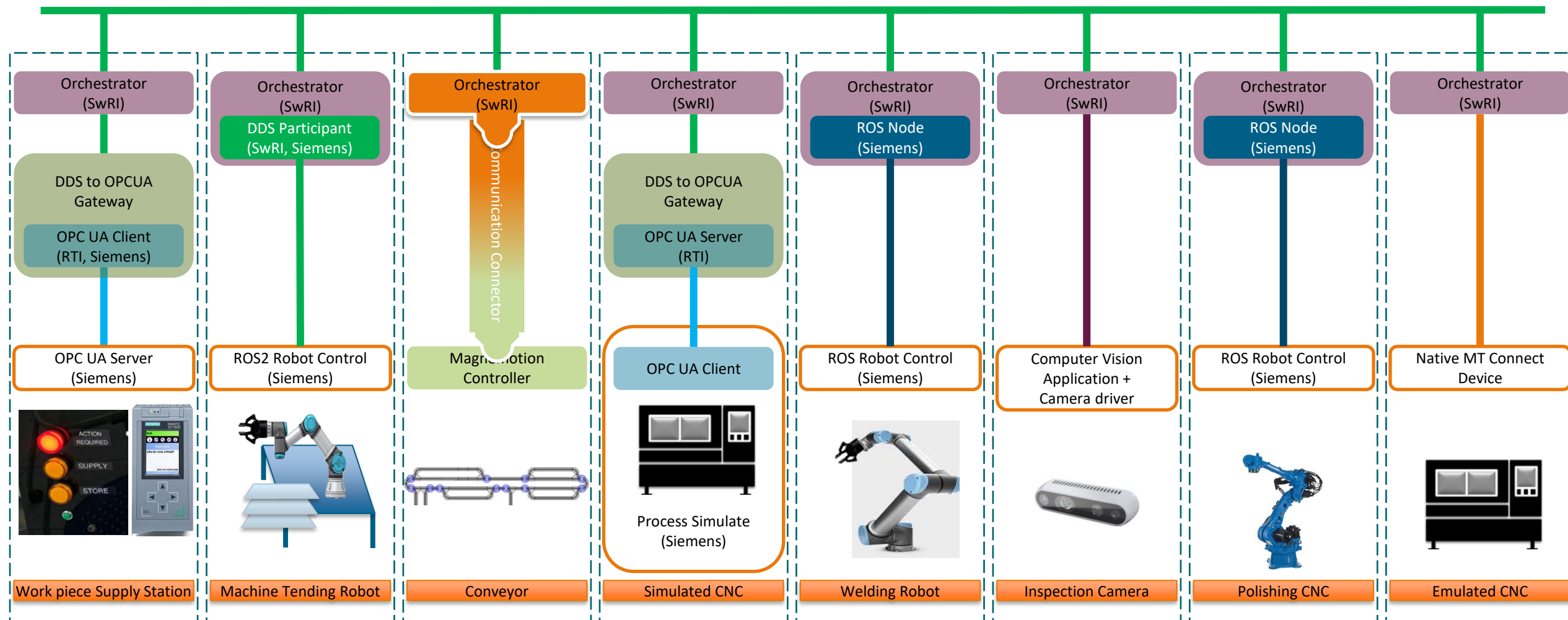


Legend	MTConnect Interface	Description
	ProcessItem	for tasks involving performing work such as milling
	MaterialHandler	for tasks involving material handling (e.g. load)
	MaterialTransport	for tasks involving moving objects between devices

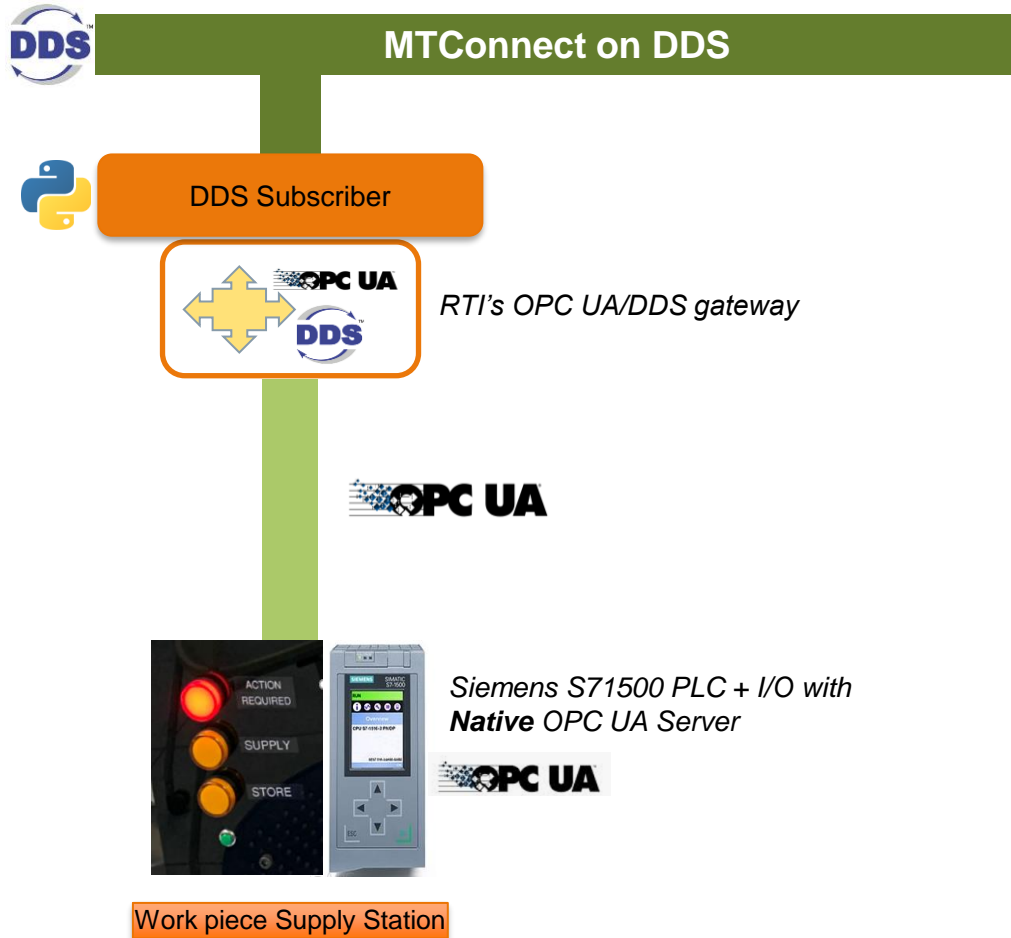
Siemens FoA Lab Hardware Demonstration Architecture



DDS MTConnect Orchestration Channel



Live Demo: Supply Station (PLC)



Demo: Welding Station (Berkeley, CA)

SIEMENS
Ingenuity for Life



MTConnect on DDS

Domain 1

PulseSecure VPN

Domain 0

MTConnect on DDS



MTConnect Orchestrator

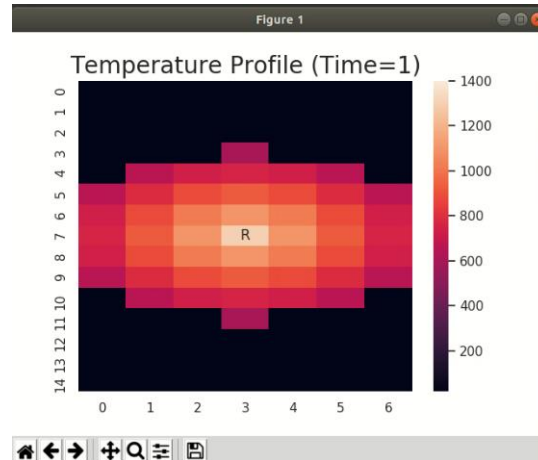
Welding Path Optimizer
+
Robot Control

TCP/IP

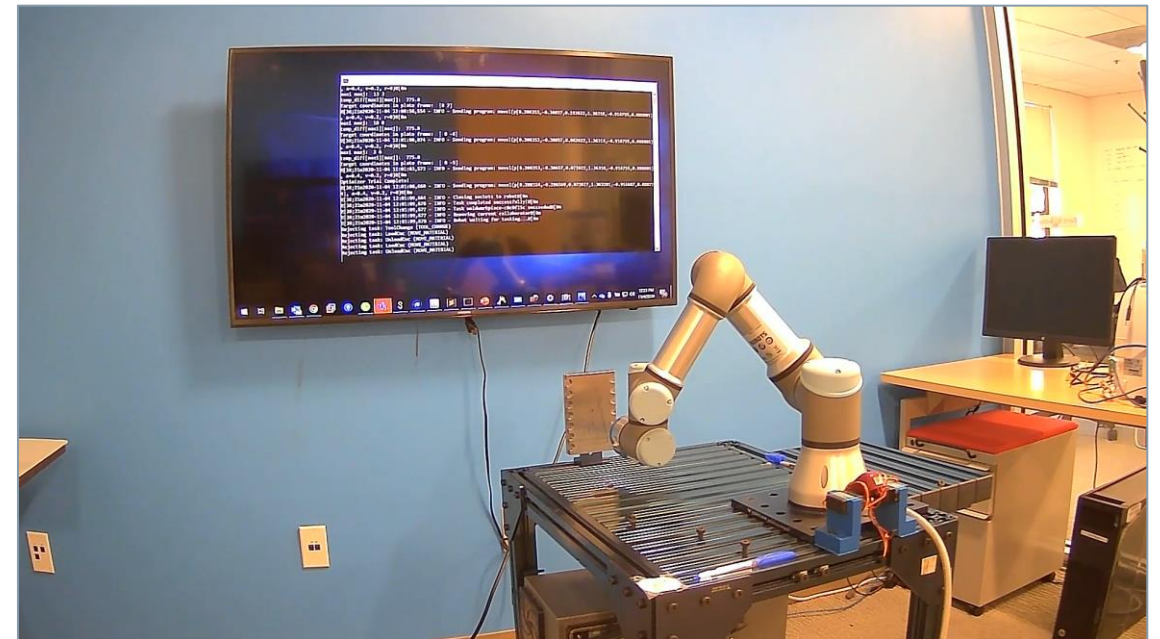
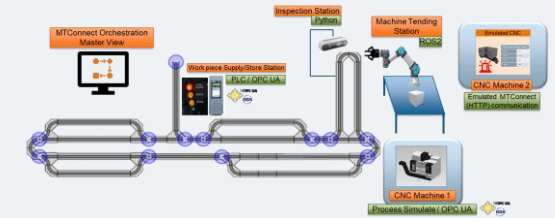


UNIVERSAL ROBOTS

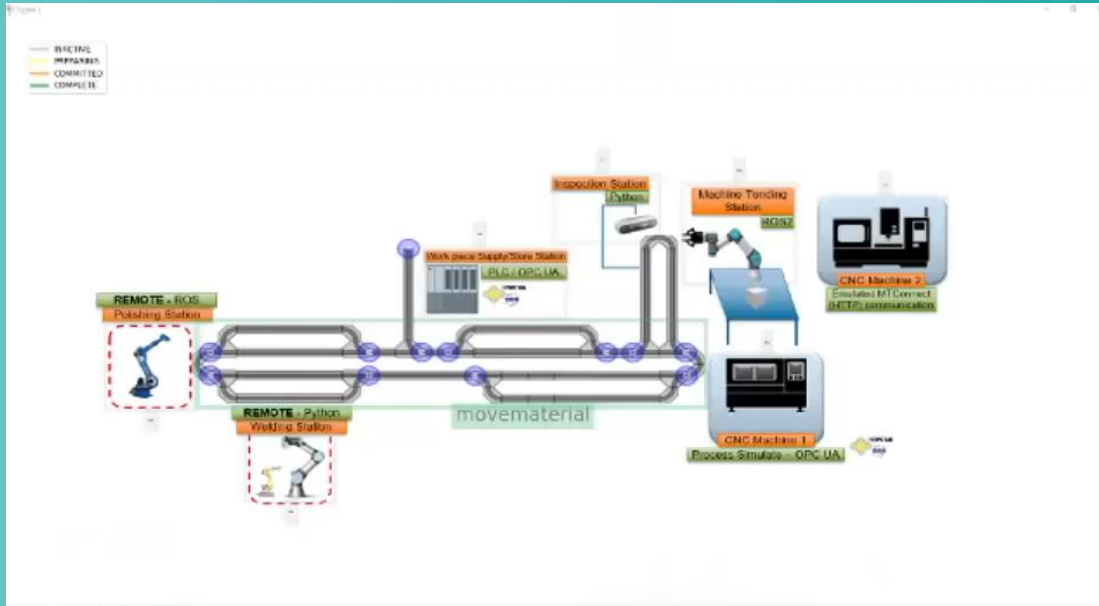
Optimizing the robot motion to maintain uniform temperature profile on the surface with simulated sensory input



To be deployed on FANUC robot



Recorded DEMO



A screenshot of the Siemens SIMATIC Energy Manager interface. The main window displays a 3D model of the factory floor layout, showing the robot cell and material flow system. On the left, there is a 'BIAAS M-Connect Link' panel with several input fields. Below the 3D model, a log window shows a list of events, including 'Received supply done', 'Received supply done', and 'Received supply done', with corresponding status indicators like 'False' and 'True'.

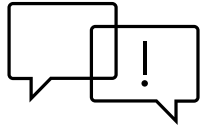
A screenshot of the SIMATIC Energy Manager Plant Overview dashboard. The dashboard is divided into several sections, each representing a different station in the factory. Each section contains a small icon of the station and a set of status indicators (ELECTRIC, DEFECTIVE, COMMITTED, COMPLETE) with corresponding text labels. The sections include: Supply/Store Station, Machine Tending Robot Station, CNC - Simulated, CNC - Emulated, Transport System, Quality Inspection Station, Welding Station, and Polishing Station.

Station	Transition to INACTIVE	Transition to COMPLETE	Transition to DEFECTIVE	Transition to PREPARING	Transition to COMMITTED
Supply/Store Station	True	True	True	True	True
Machine Tending Robot Station	True	True	True	True	True
CNC - Simulated	True	True	True	True	True
CNC - Emulated	True	True	True	True	True
Transport System	True	True	True	True	True
Quality Inspection Station	True	True	True	True	True
Welding Station	True	True	True	True	True
Polishing Station	True	True	True	True	True

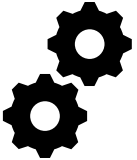
How have we lowered the bar for Interoperability of Automation and Robotic systems?



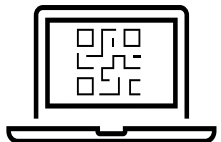
- **Developed/hardened Open-Source Software or based on Open Standards**



- **Successfully derisked OPC-UA / DDS / ROS / ROS 2 communication**

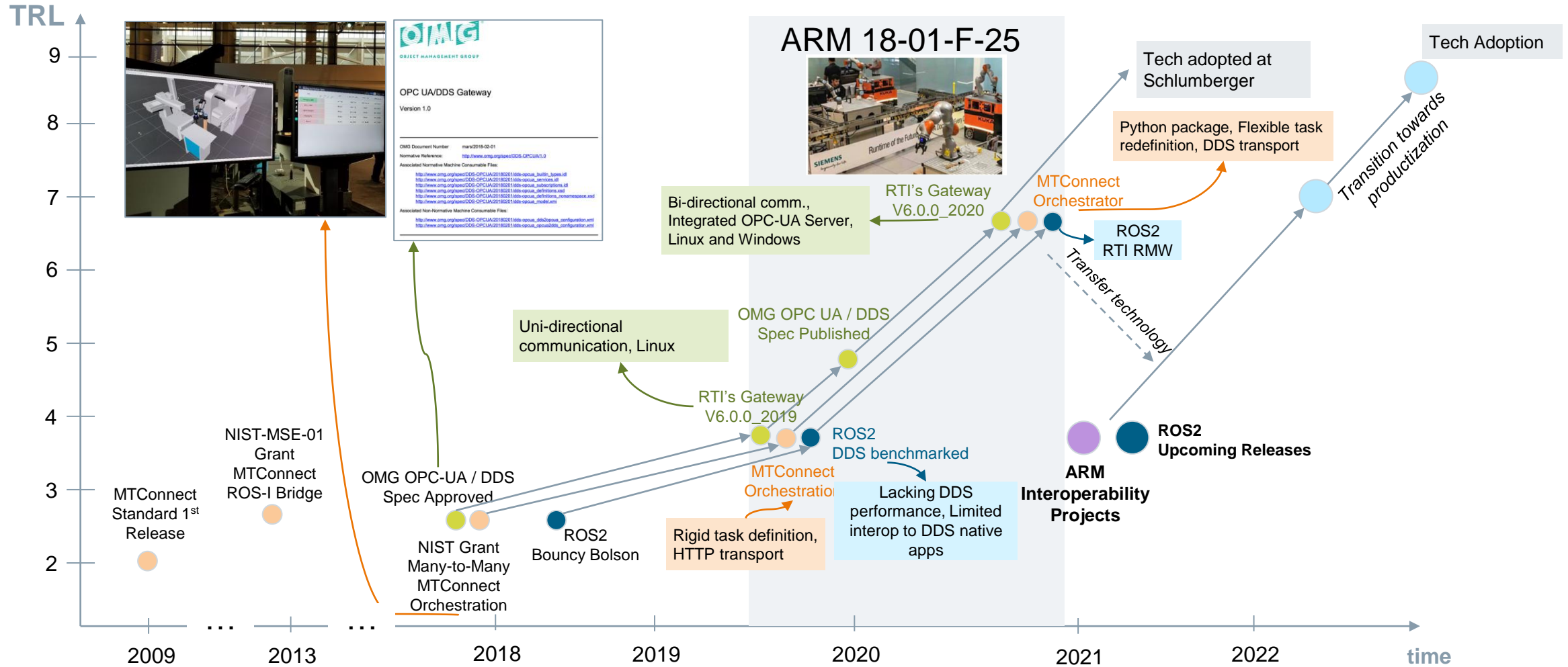


- **Developed reusable software (MTConnect Python Package, RTI OPC-UA / DDS Gateway)**



- **Plug&Play software accompanied by Tutorials, documentation, and samples for all core software contributions**

Technology Readiness Level Journey



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