Leveraging OPC UA for Interoperability in Shop Floor Machine Integration

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Presenters Bio

Vinh V. Tat

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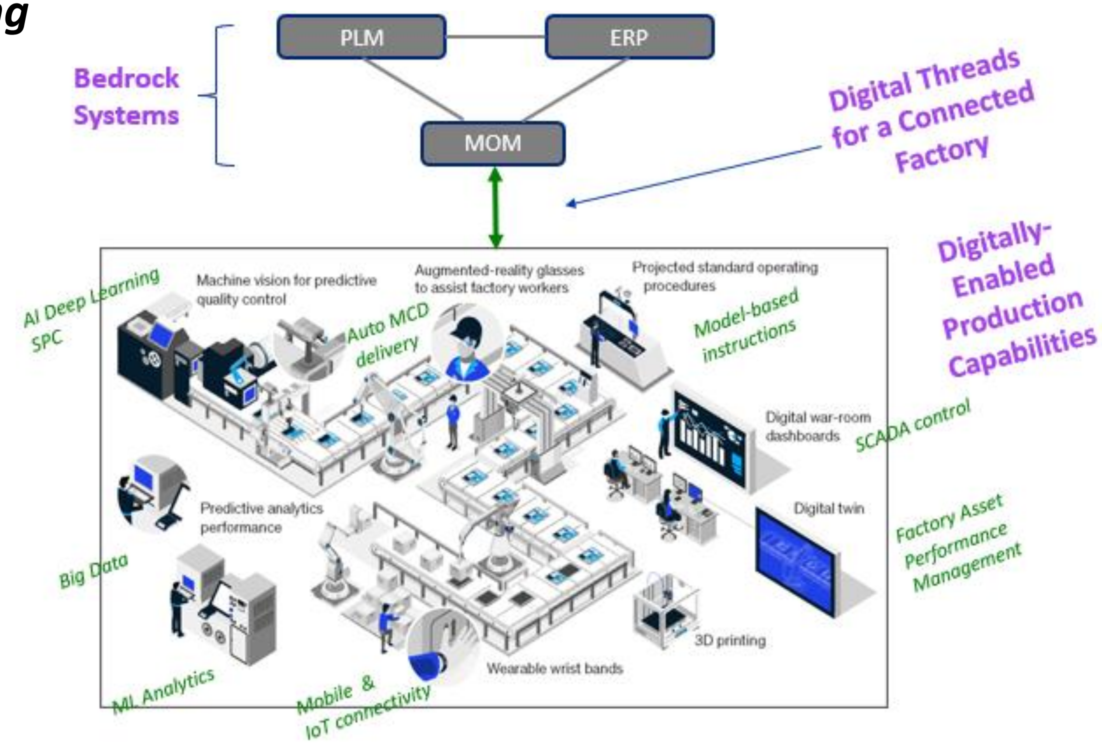
- Experience in Engineering, Manufacturing, Information Security
- Prior position at NASA Langley Research Center.
- Interest: HIIT workout, hiking, biking, DIY, stock trading, ballroom dancing, working on bikes, and machine learning projects
- M.S., Aerospace Engineering, University of Illinois, Urbana Champaign
- M.I.S., Computer Science, Carnegie Mellon University

Business Drivers

- Competitive landscape:
  - Customer's expectation to demonstrate ***smart manufacturing***
  - Emergent needs to improve & scale factory operations
- Drive effort to modernize and propagate digital technologies to factories
- Key enabler:
  - ***Digital Thread*** from engineering to shop floor, connecting factory automation equipment
- Realize a range of business capabilities:
  - Factory asset performance management
  - Automated MCD delivery
  - Mobility and IoT
  - SCADA control
  - Machine learning/AI



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Business Challenges

- Significant progress in IT and OT technologies (Big Data, IIoT)
  - Have means to realize data-driven smart manufacturing
- Technical challenges:
  - Most PLC are neither interoperable nor vendor-independent [1] → can lead to custom programming
- Business challenges:
  - Cost and schedule
  - Sustainability - workforce turnover, lack IT and vendor support

Different tag names unstructured data

A buffet of PLC communication protocols* [1]

EtherNet/IP

PROFIBUS

EtherCAT

CANopen

Modbus

PROFINET

DF1

Fieldbus

Goal:

- Rapid connection to many automation equipment from different vendors without custom programming

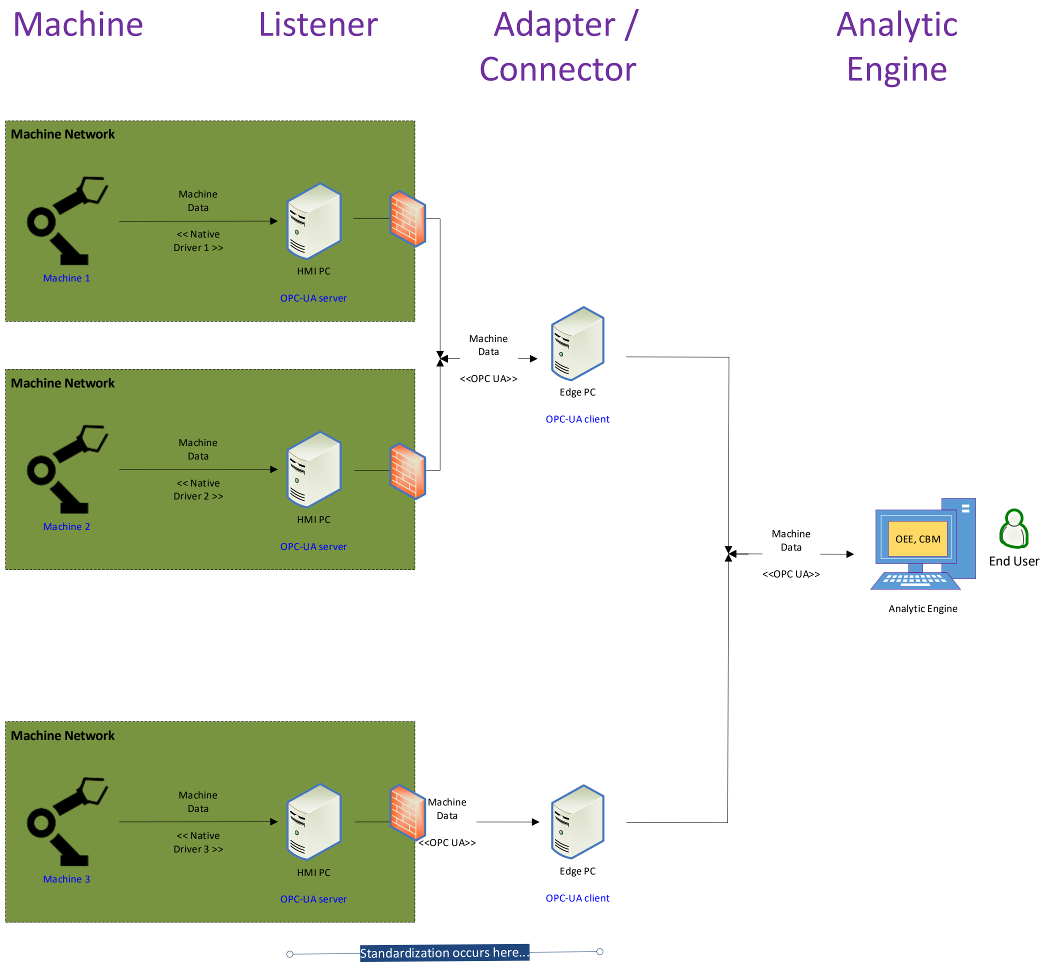
* *Industrial communication protocols developed meet harsh operating environment – real-time control, vibration, temperature, determinism*

Leveraging OPC UA for Interoperability

- **OPC UA** – **standardization** at **device communication level**
- Abstraction layer to analytic engine
- Implement standardization at the middle layer - between listener & adapter

Outcome **within 1 ½ year**:

- Securely connect 16 types of machines
  - OEM-provided OPC UA server. Installation easy.
  - Third-party OPC UA server. Occasional struggle.
  - COTS products for OPC UA client and analytic engine
- We created 3 different types of analytic dashboards (see next slide)
- Partnership of **business, IT and industry**

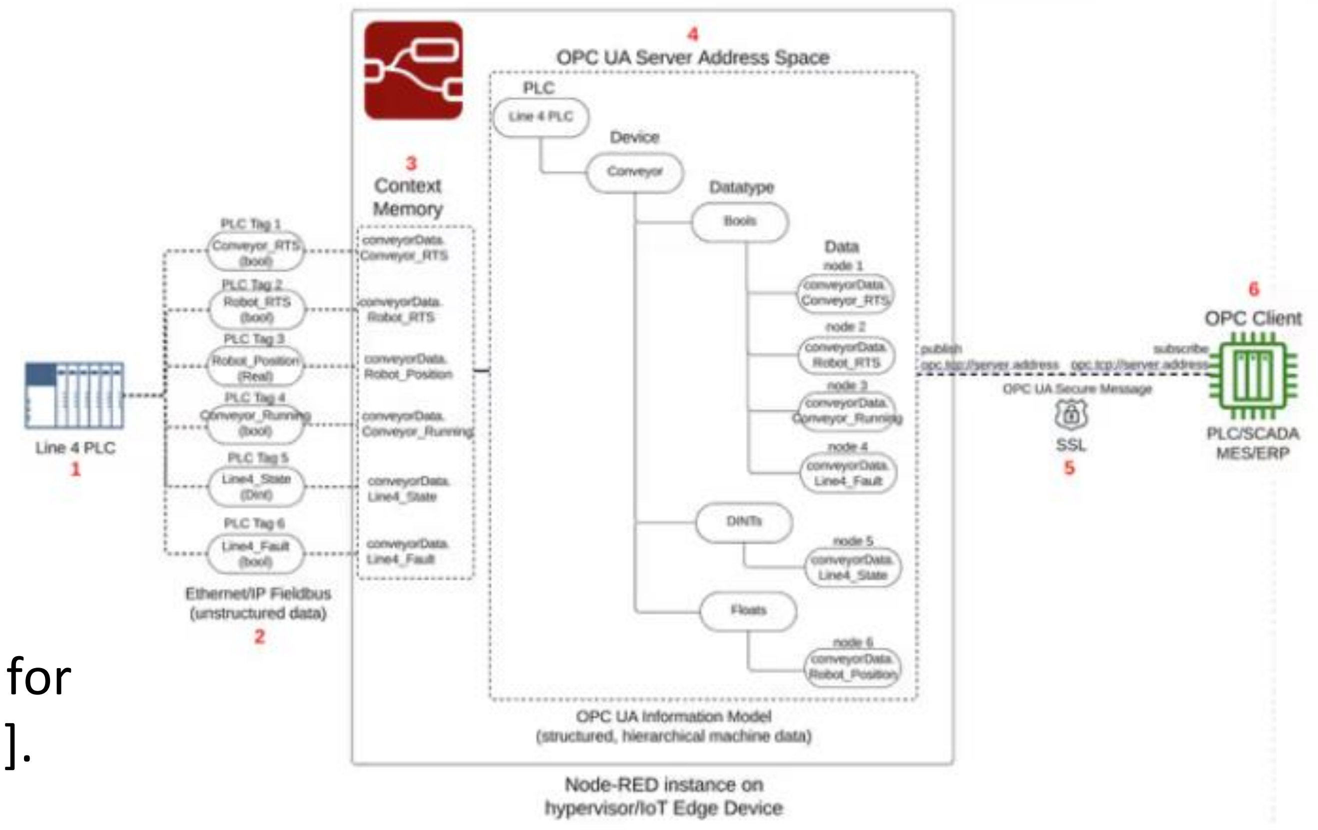


Leveraging OPC UA for Interoperability

- We created analytic dashboards for:
  - Asset utilization
  - Condition-based maintenance
  - Process optimization

How Interoperability is Enabled

- **Transport interoperability**: OPC protocol for field, control and supervisory communication
  - Client/Server: Transport (**OPC TCP, HTTPS**), Encoding (**OPC JSON, Binary, XML**)
  - Pub/Sub: MQTT, AMQP
- **Semantic interoperability**:
  - Exposes a hierarchical **information model** of tags that is discoverable for machine data collection. Used tool like UaExpert to navigate
  - Tags can be further standardized via **Companion Specs** which can add metadata about data
- Demand for standardized, detailed semantics for different domains; e.g., NDI, machine vision [2].
  - Leader VDMA - 3200 European mfg. companies.

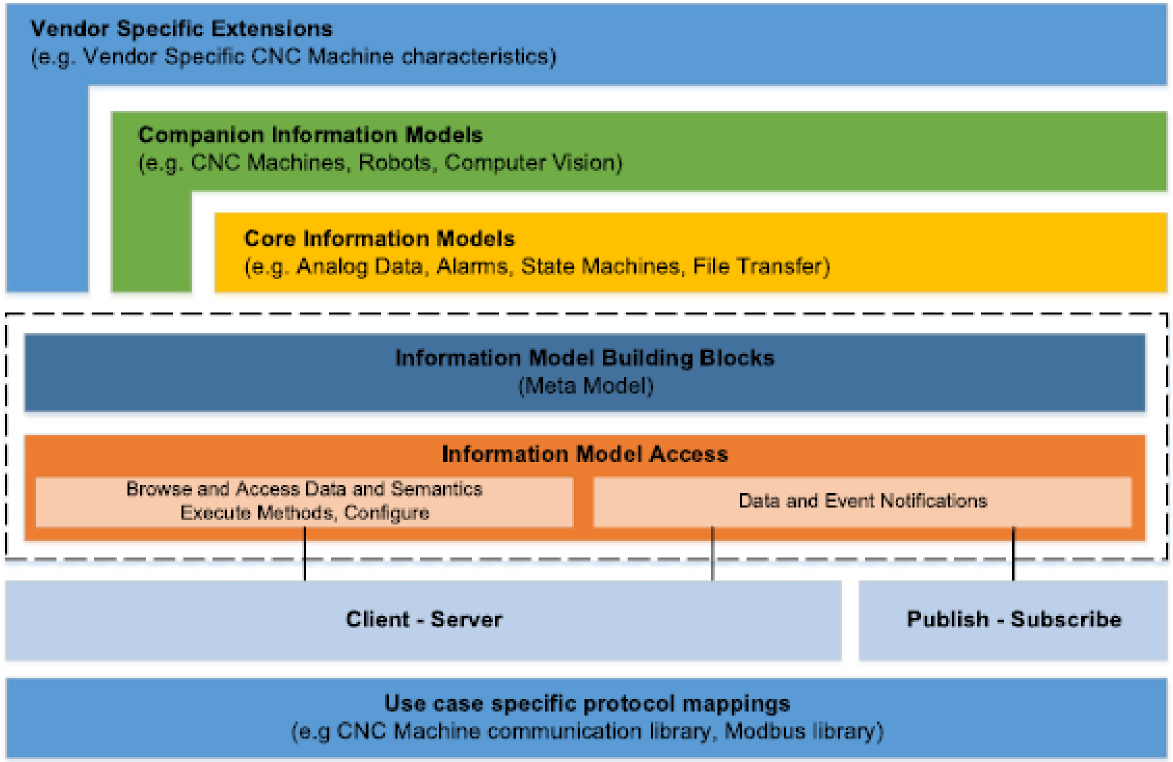


OPC UA Server Address Space [3]

OPC UA – Architecture, Key Features and Mission

- **Open Platform Communications – Unified Architecture** by OPC Foundation, 2008 [4, 5]
- Architecture & data exchange protocol (IEC 6251)

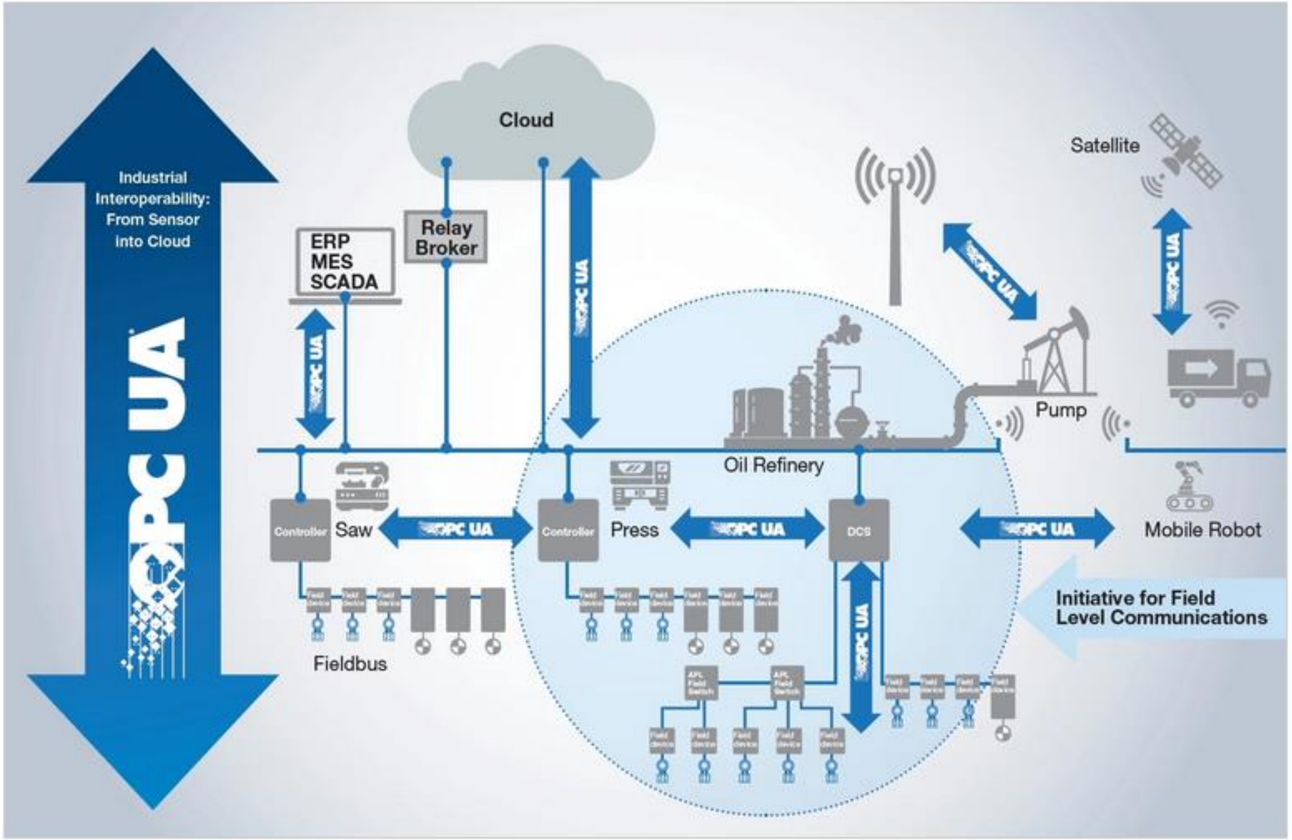
Classic OPC	OPC UA
Windows	Windows, Linux, Mac
OLE	Information Model (Address Space – hierarchical and discoverable)
DCOM	SOA and Pub/Sub
	Object – Method (invocable by OPC UA client)
	x.509 – SSL



OPC UA Framework [6]

The OPC Foundation sets out to develop a single client/server specification that would allow any vendor to develop software and applications that share data in a fast and robust way and, at the same time, eliminate the proprietary schemes that made these vendors duplicate their development efforts.

Key Usages and Adoption

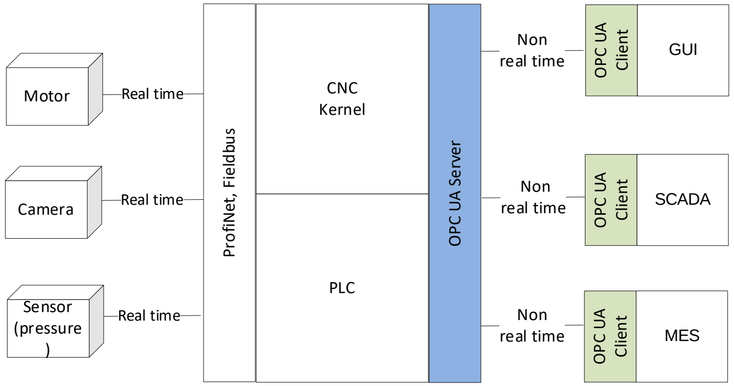


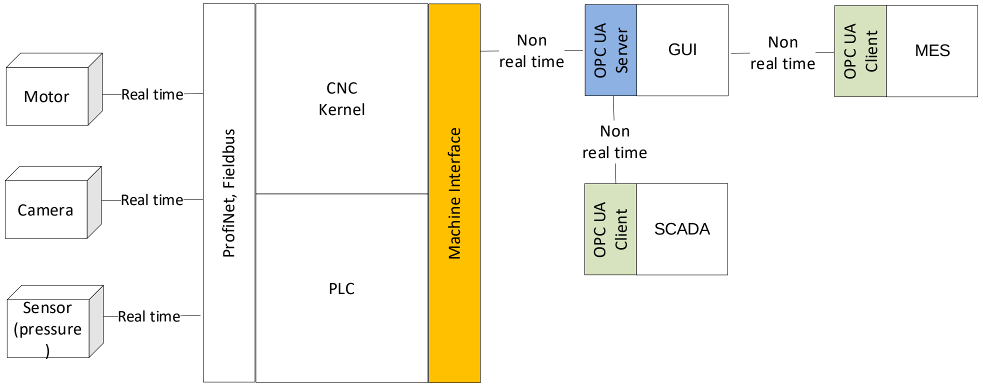
OPC UA Field Level Communication System Architecture
(courtesy OPC Foundation)

- Survey of 500 participants – 70% have OPC UA implemented and 60% using Companion Specs, their own or hybrid
  - Over ½ of modern equipment in our factory have OPC UA servers
  - Hybrid
- "Remarkable OPC UA becomes such a prominent standard" [6].
- Key uses of OPC UA [6]
  - System architecture
  - Middleware
  - Information model
  - Interoperability
  - Data collection

Different ways OPC UA can be realized

- Applicability
  - **Machine-to-machine**
  - **Machine-to-business network**
- OPC UA server built into the
  - Controller
  - HMI PC
  - Edge PC
- OPC UA client is typically installed on
  - SCADA layer
  - Manufacturing Execution System
  - PLM
  - Cloud





Implementation of OPC UA Servers and Clients

OPC UA – Where there are Gaps

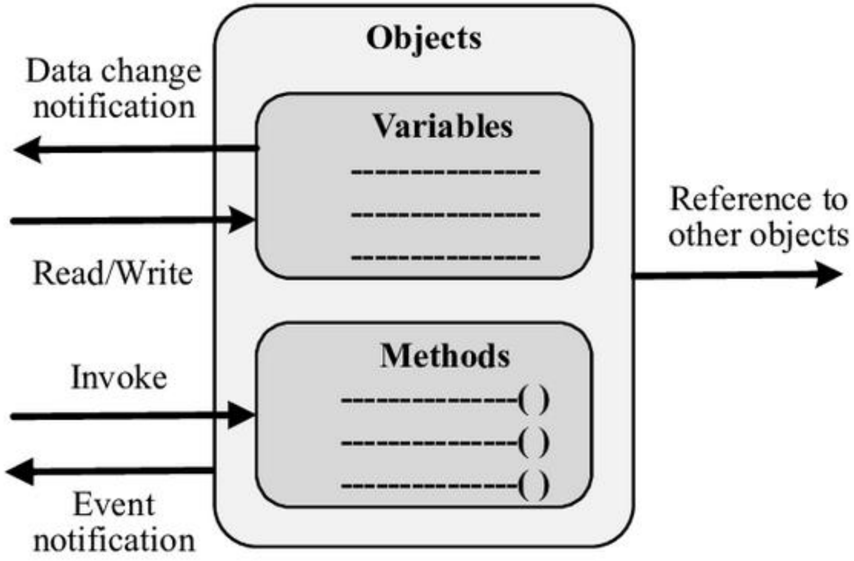
- Not all OPC UA servers subscribe to Companion Specs' tag convention
  - If you want common names on Analytic engine side, data mapping is required in OPC UA client
  - This takes up the most time, after machine connection

		OPC UA Server Exposes				OPC UA Client Exposes (data mapping)
Machine	**Controller**	**Node ID**	**Tag Name**	**Value**		**MachineState**
KRC Trim & Drill	Siemens 840D	/Bag/State/opMode	Operation Mode	(0, 1)	-->	(On, Off)
AGFM Ply Cutter	GFM CNC6000-GP	CNC2.CncTags.001	MachineOn	(True, False)	-->	(On, Off)
Taricco Autoclave	AB CompactLogix L63ERM	FANC	Fans On/Off	(True, False)	-->	(On, Off)
		BOLTLOCKS	Door Lock/Unlock	(True, False)		

- For custom controller that we built, we often have to develop our own OPC UA server
  - Challenge here: it is not always obvious which Companion Specs to use.

OPC UA – Security and Object - Method

- Security:
  - **TLS X.509 asymmetric-key security** over DCOM
  - Rigorous security review conducted [7]
  - Use *SignAndEncrypt*
- ***Object*** model has ***Method*** which enables injection of code fragment to perform mission-specific tasks
  - For example, starts a motor → motor started/not
- Usage:
  - Data conditioning
  - MCD clean up, post NC program execution
  - Advanced M2M communication [8] - orchestration
  - Product inspection – vision-based system



Lessons Learned

Business

- Leveraging industrial standards enabled rapid progress towards smart manufacturing
- Partnering of IT, business and industry is important to success
- Ensuring generation of business value through active business engagement is hardest part (chicken-and-egg problem)
- Enabling digital capability in one area becomes cultural steppingstone to other areas

Technical

- Needing education on Companion Specs & clarification to distinguish overlap → use cases will help
- Challenging to set up X.509 cert. for SignAndEncrypt mode, though easier than DCOM security
- Discovering many modern machines already come equipped with OPC UA servers
- Expecting difficulties with very old, legacy machines – some may not even have data out
  - Option: hardware technology that can sense current flow → simple machine ON/OFF states

Summary

- OPC UA advances state of art in interoperability for machine-to-machine and machine-to-enterprise
- Significant benefits in ease of machine integration for business
- Provides standard, very secure and flexible field communication protocol and architecture
- Area of improvement for OPC Foundation: Because OPC UA is so extensive and encompassing, it can be difficult to decipher

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