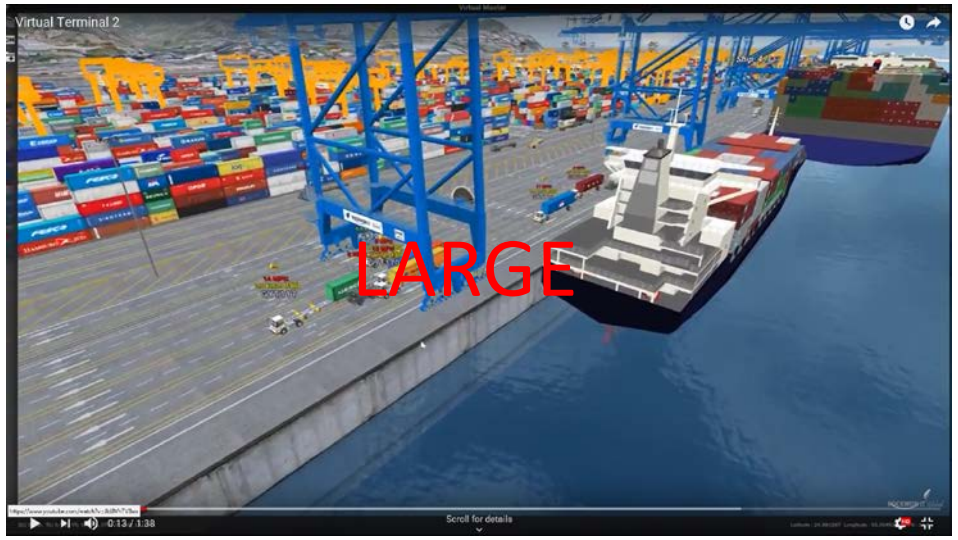
Assessment of Digital Twin manufacturing frameworks

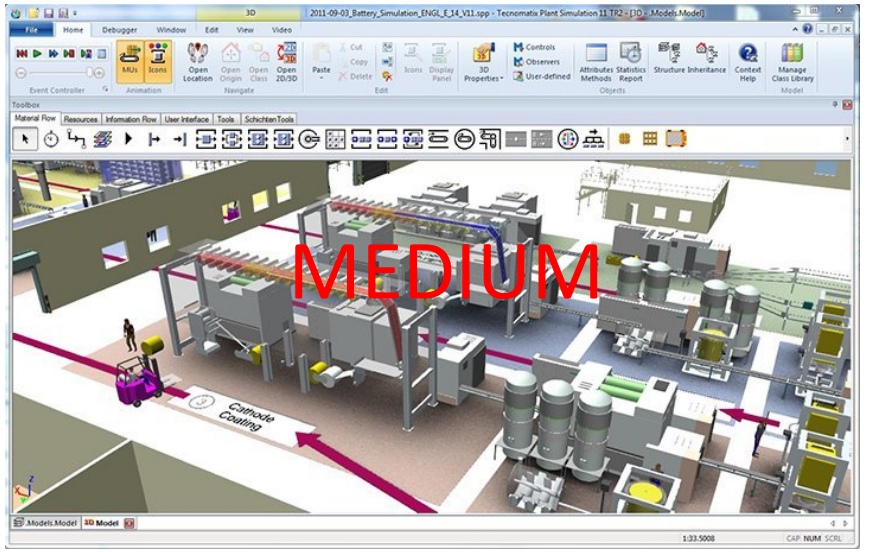
Dr. Martin Hardwick
Convener WG15 Digital Manufacturing
President STEP Tools, Inc.
Troy, NY USA

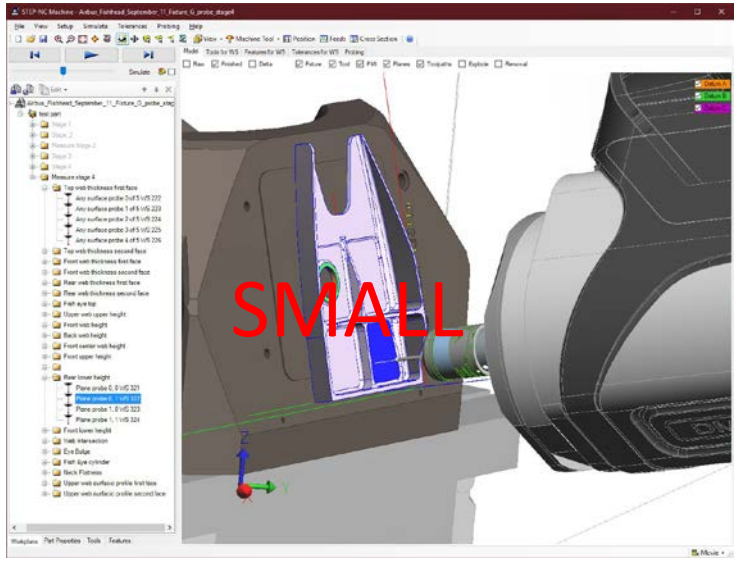
Background

- In 2017 our team issued a call for Digital Twin manufacturing framework examples.
  - 10 examples were received from 4 countries
- We classified the examples and used them as input for a new ISO 23247 standard.
- The author then extended the classifications and used them to measure the performance of a small scale digital twin framework.
- The team results are shown on slides 3 and 4, and the rest describe the authors results.

Framework classifications







Level of Detail	Physical Element
- material/component level (production item)	Personnel
- process level (production line)	- Equipment
- site level (many processes)	- Material
- enterprise level (supply chain)	- Process Definition
- regulatory level (industry sector)	- Product Definition
Communication styles	Application Paradigm
- closed loop adjustment	- real time control
- collision prevention	- off line analytics
- visualization	- preventative maintenance
- off line analysis	- health check

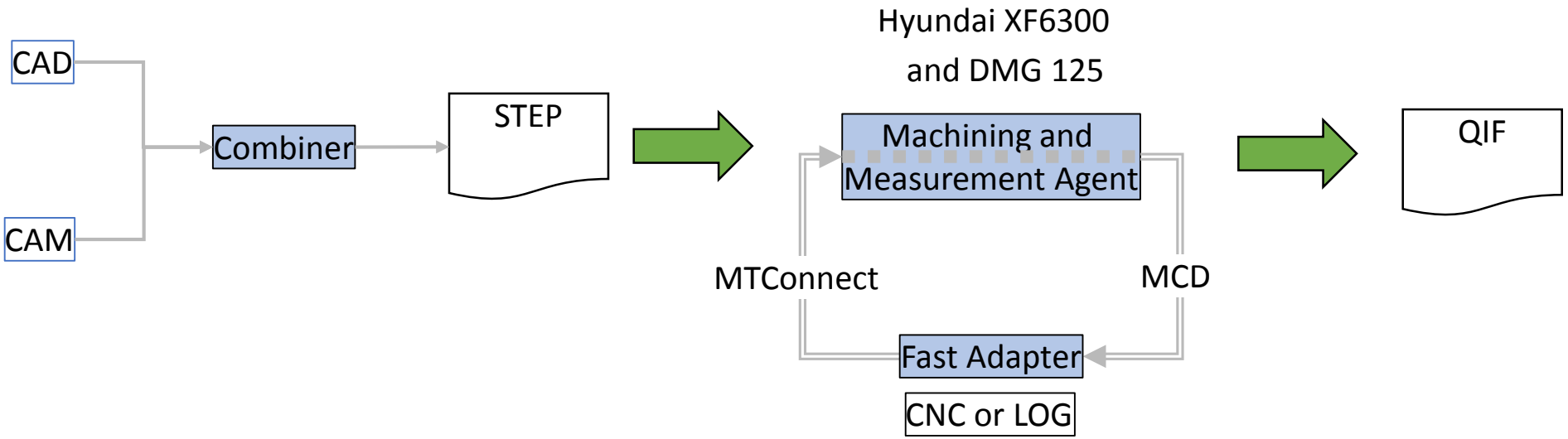
Framework benefits

- Owner/Operators
  - Want to know real time comprehensive status of their manufacturing/production
  - Want to drive optimization and production efficiency to maximize profit
- Production/Machinist/Operators
  - Want a more intuitive user interface
  - Want to prevent mistakes
- Engineers
  - Want more comprehensive view to understand the true value of their efforts
  - Want to eliminate non-value add tasks such as data re-entry
- Maintenance
  - Want insight to why equipment is failing
  - Want windows of opportunity to do preventative maintenance
- Subcontractors
  - Want access to information so they can bid more easily and accurately
  - Want ability to share manufacturing processes
- Equipment suppliers and builders
  - Want to make it easier to implement and integrate their products
  - Want to efficiently monitor equipment performance for improved performance
- IT developer / integrator
  - Want to be certain organizational security and access control protocols are being followed
  - Want system to robust, flexible, fault tolerant, accurate, scalable and wherever possible non-prescriptive
- Regulatory agencies
  - Want to prove that a process has been followed
  - Want a standardized interface into product information
- Software vendors
  - Want a consistent, reliable, affordable interface to external data, tools and systems
  - Want to make it easier to deploy their solutions
- Standards Development Organizations (SDO's)
  - Want to promote their standards
  - Want to enhance their value by becoming part of an eco-system

Two Digital Twin qualities

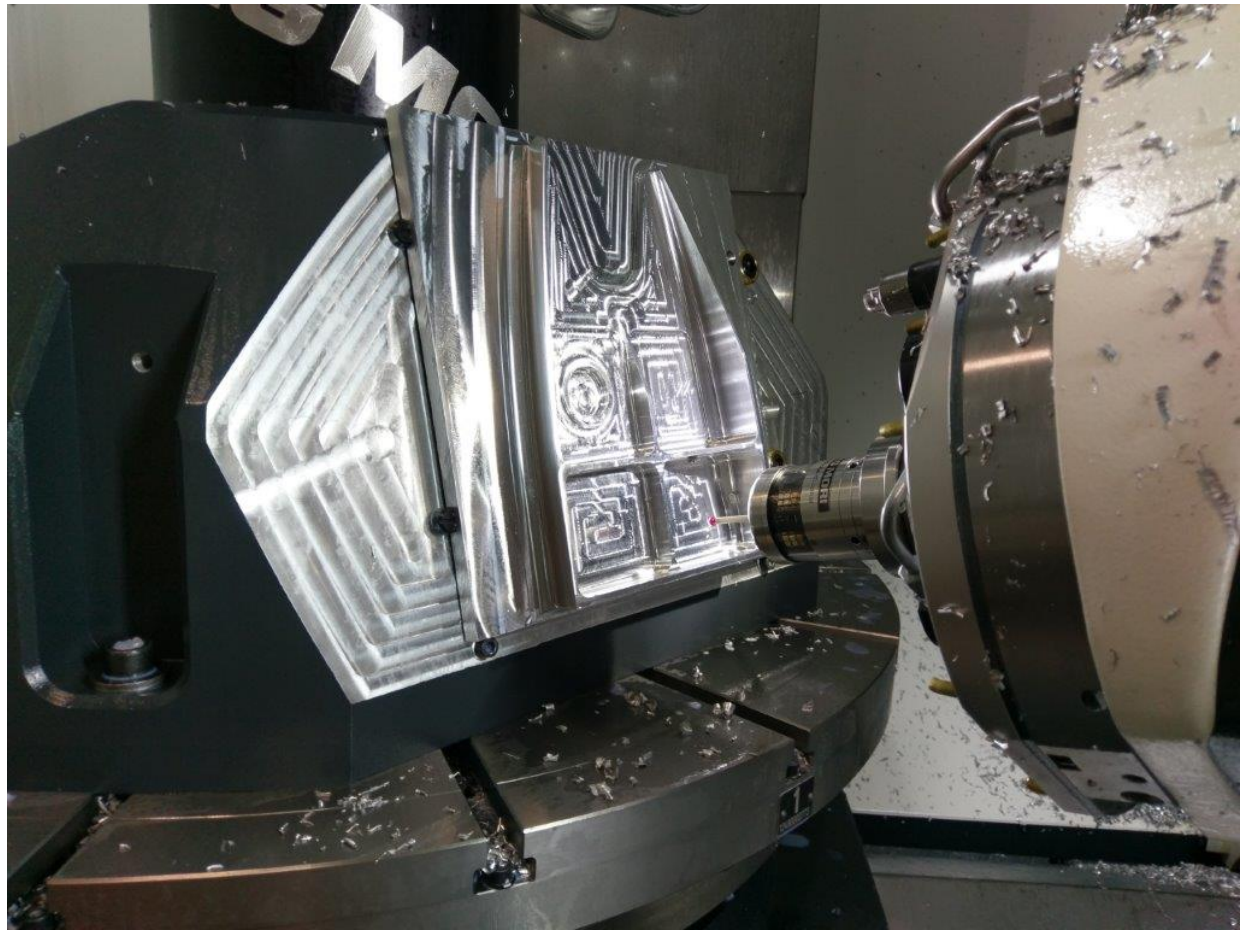
- Observable
  - A digital twin is a model of something that is observable in the real world.
  - Describes one or more aspects of the real world phenomenon.
  - Makes it easier to understand, use, control, or operate.
- Measurable
  - The digital twin is “meaningful” to measure.
  - Will learn something about the physical twin.
  - Will not get the same result for every twin.

Digital Twin machining experiment

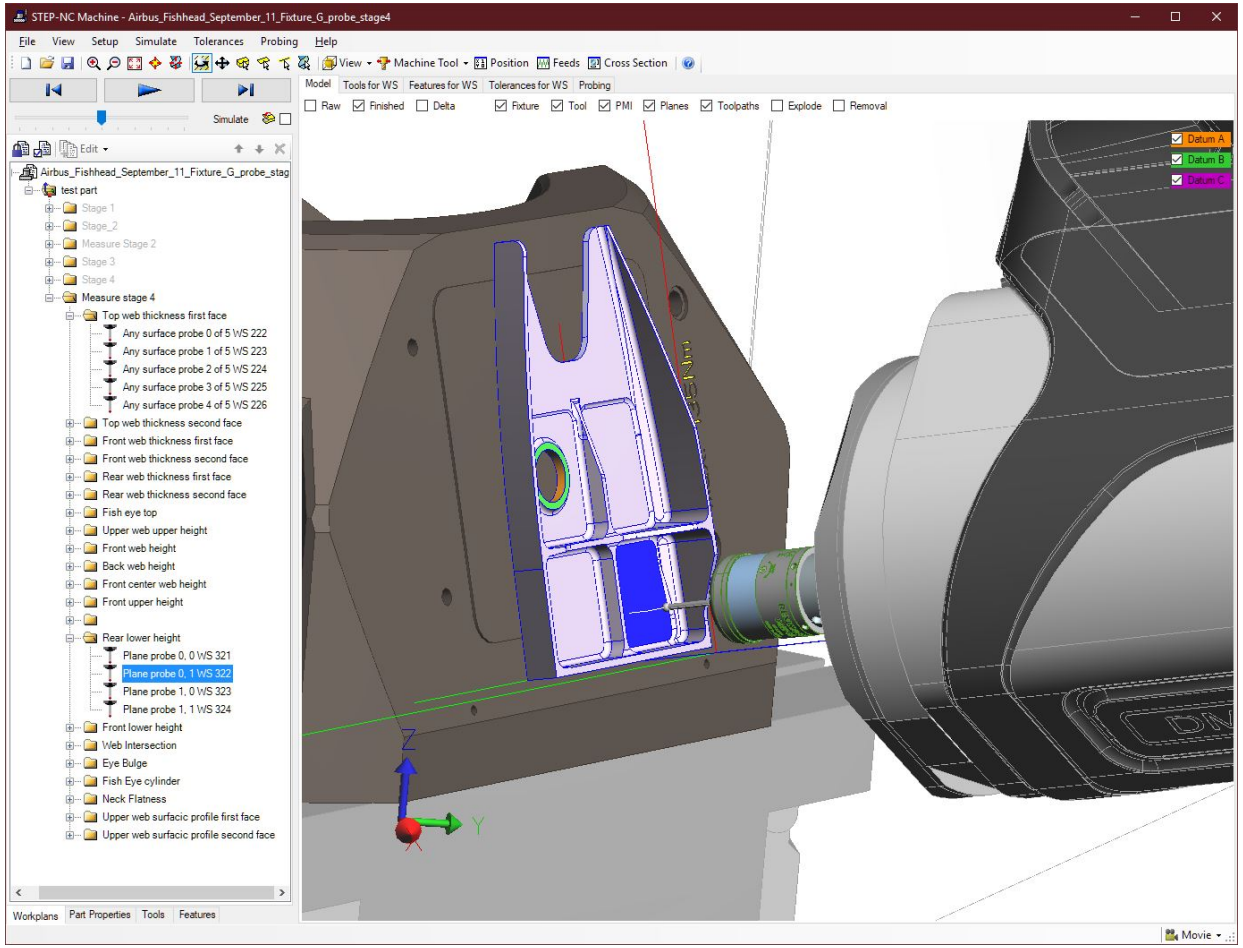


- Small scale framework (one agent)
- Shown on two five axis machine tools at IMTS 2018
- Twin performance measured after the show from log files

Small Scale Framework



Physical Twin



Digital Twin

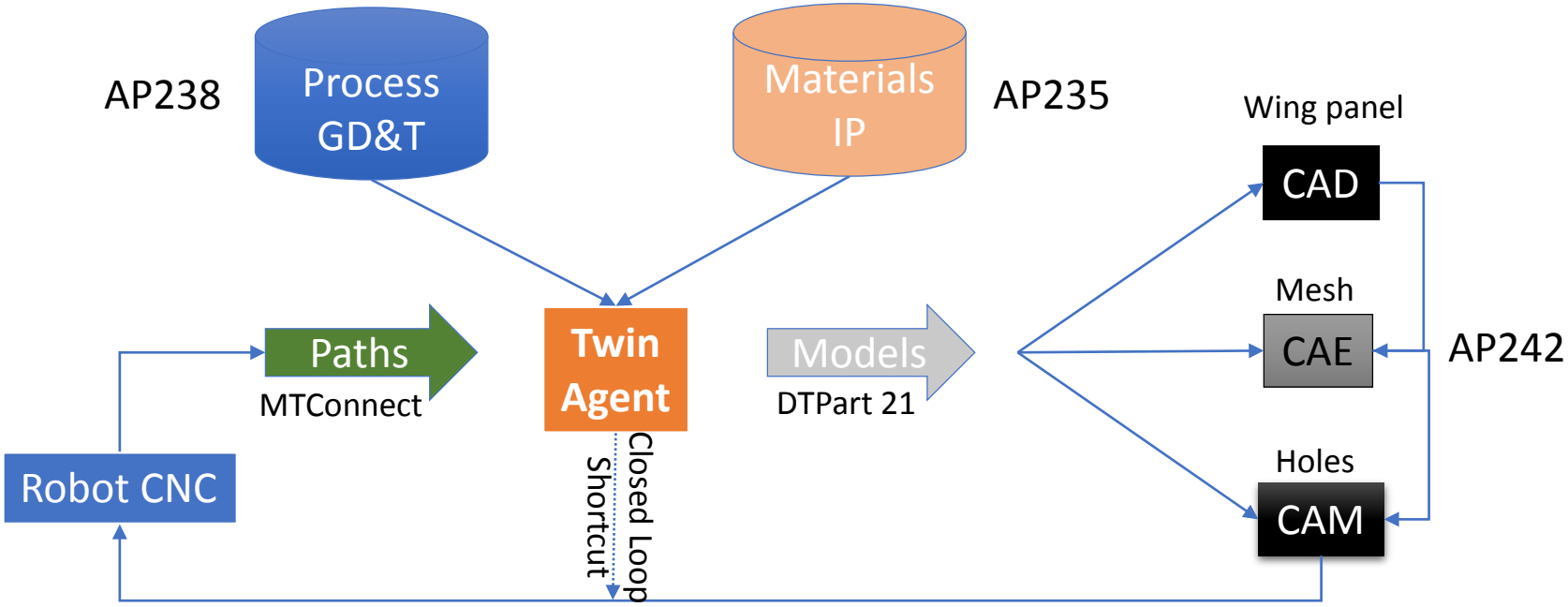
Experimental results

	Twitches	Changes	Points	Change %	Point %		Avg	Short	Long		Epsilon
Stage12Hyundai	711451	639789	5303	90%	0.75%		0.178	0.0009	49.38		1.00E-03
Stage12Hyundai	711438	567313	3699	80%	0.52%		0.226	0.0009	49.35		2.00E-03
Stage12Hyundai	711439	542266	2628	76%	0.37%		0.320	0.0009	49.66		5.00E-03

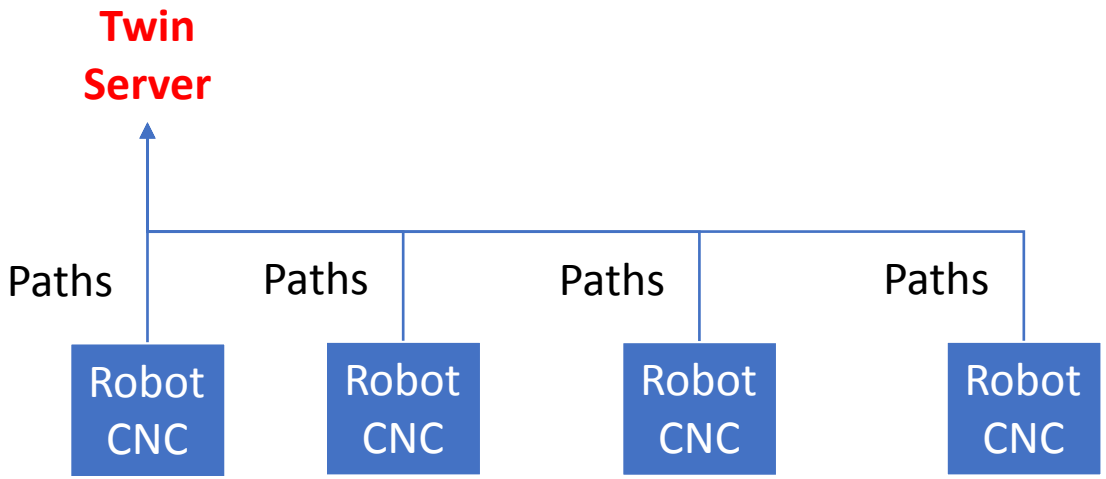
- Twitches are differences to the lowest significant digit of a value
  - Many twitches are roll overs
- Changes are new values in the tool location
  - Many changes are on the same path
- Points are locations where the direction of machining changes
  - These must be captured to make an accurate digital twin

Small Scale Framework

- Digital Twin Challenges
  - We can measure models in real time
  - Identify issues, optimize processes
  - Coordinate multiple operations
- Digital Twin Benefits
  - Stronger, lighter structures
  - Reduced tooling costs
  - Adaptive manufacturing



Proposal for medium scale



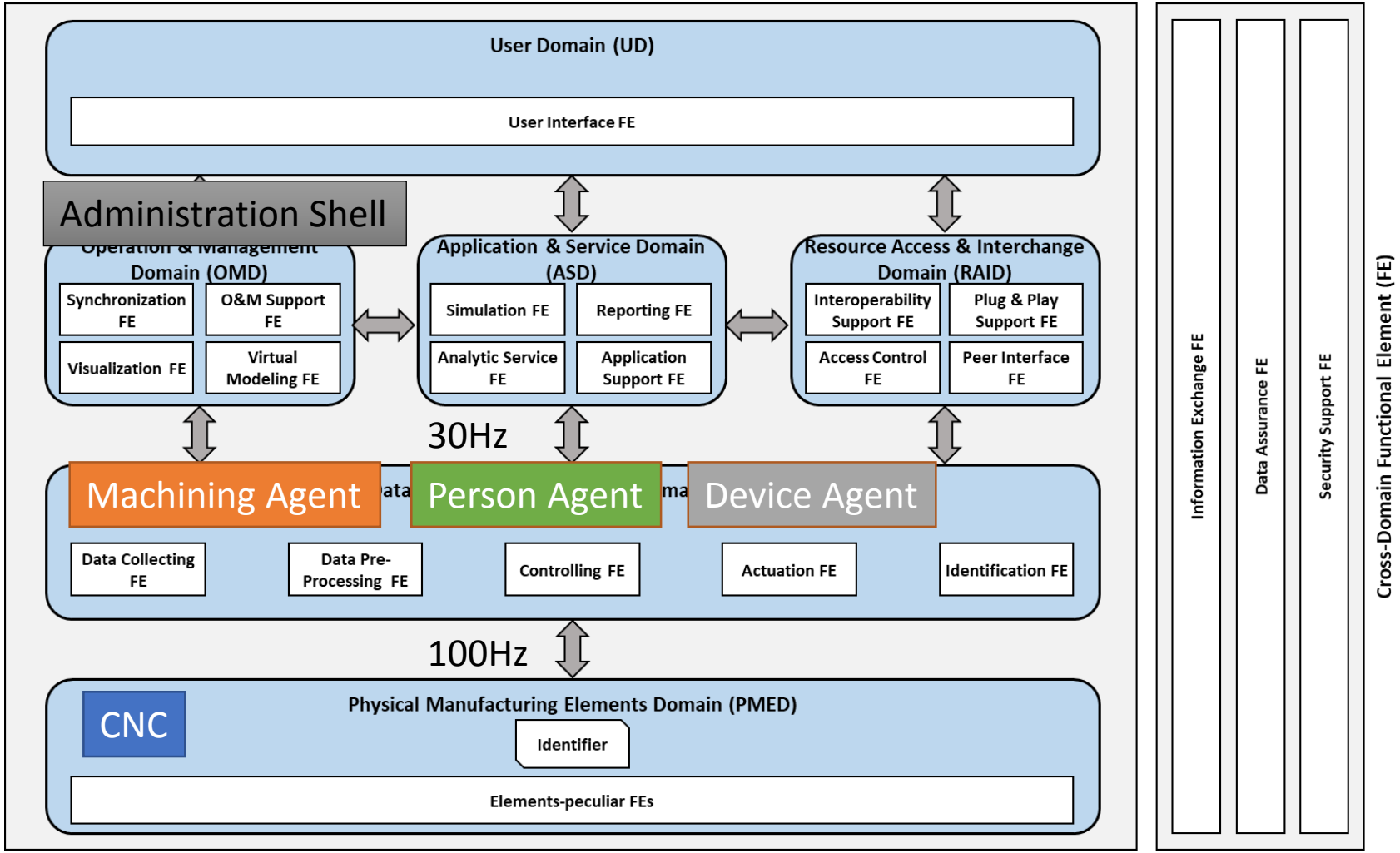
Twin Server

- Single large memory space
- Many cores (128)
- One core per agent

Applications

- Collision prevention
- Dynamic scheduling
- Accuracy management

Large Scale Framework



IoT Architecture (ISO 30141)

ISO 23247
Part 1 Overview
Part 2 Architecture
Part 3 Digital Representation
Part 4 Information Exchange

Complete automotive or aerospace plant

Conclusion

- A digital twin is a measurable model of a physical element that can be observed in the real world.
- A digital twin agent processes messages streamed from sensors and uses them to synchronize the current state of digital twins with that of their corresponding physical elements.
- A small scale framework manages one agent. A medium scale framework manages multiple agents in a shared memory space. A large scale framework manages multiple levels of agents distributed between many memory spaces.