PLM on the Edge

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GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2019

Presentation Outline

- **Impact of Disruptive Technologies on Future State PLM**
  - **Next Generation Internet of Things (IIoT)**
  - **Media Technologies**
  - **Distributed Ledger Technologies (DLT) and Blockchains**
  - **AI (ML and DL)**
  - **Edge, Fog, and Cloud Computing**
  - **Domain Specific Languages**
  - **Data Driven Design and Fabrication**

- **Impact of Disruptive Technologies on Design**
  - **Computational Design Optimization**

- **Conclusions**

Authors' bios

- **Sunil Elanayar**

Manager in Engineering Systems (Boeing IT.) His research interests include AI in Design and Manufacturing, PLM, Machine Learning, Optimization, and Model Based Engineering. He has held leadership positions in Dassault Systemes, PTC, and AutoDesk. He is currently an IT Manager in Engineering Systems, with responsibilities for Enovia /CATIA, Data Distribution and Product Standards. In the past, he has lead projects in Massive Model Visualization, New Wiring Systems, Aerodynamics, and Knowledge Based Engineering (KBE).

- **Gee Kim**

Joined Boeing in 2006 and work as a Boeing Software Developer for PLM MBE Services for Engineering Systems. She has past work experiences in MBSE, Product Standards, and data distribution system in 3-D rendering application.

Next Generation Internet of Things (IOT)

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6A's of IOT:

- Anything (Any device) transferred to
- Anyone (role/ user), located
- Anyplace (location) at
- Anytime (any context) from
- Any path (physical network) to provide
- Any service (capability)

6C's of IOT:

- Collect (heterogeneity of devices)
- Connect (ubiquitous),
- Cache (storage)
- Compute (advanced processing)
- Cognize (analytics & insights)
- Create (new interactions, services, business models)

Evolution of Internet of Things (IOT)

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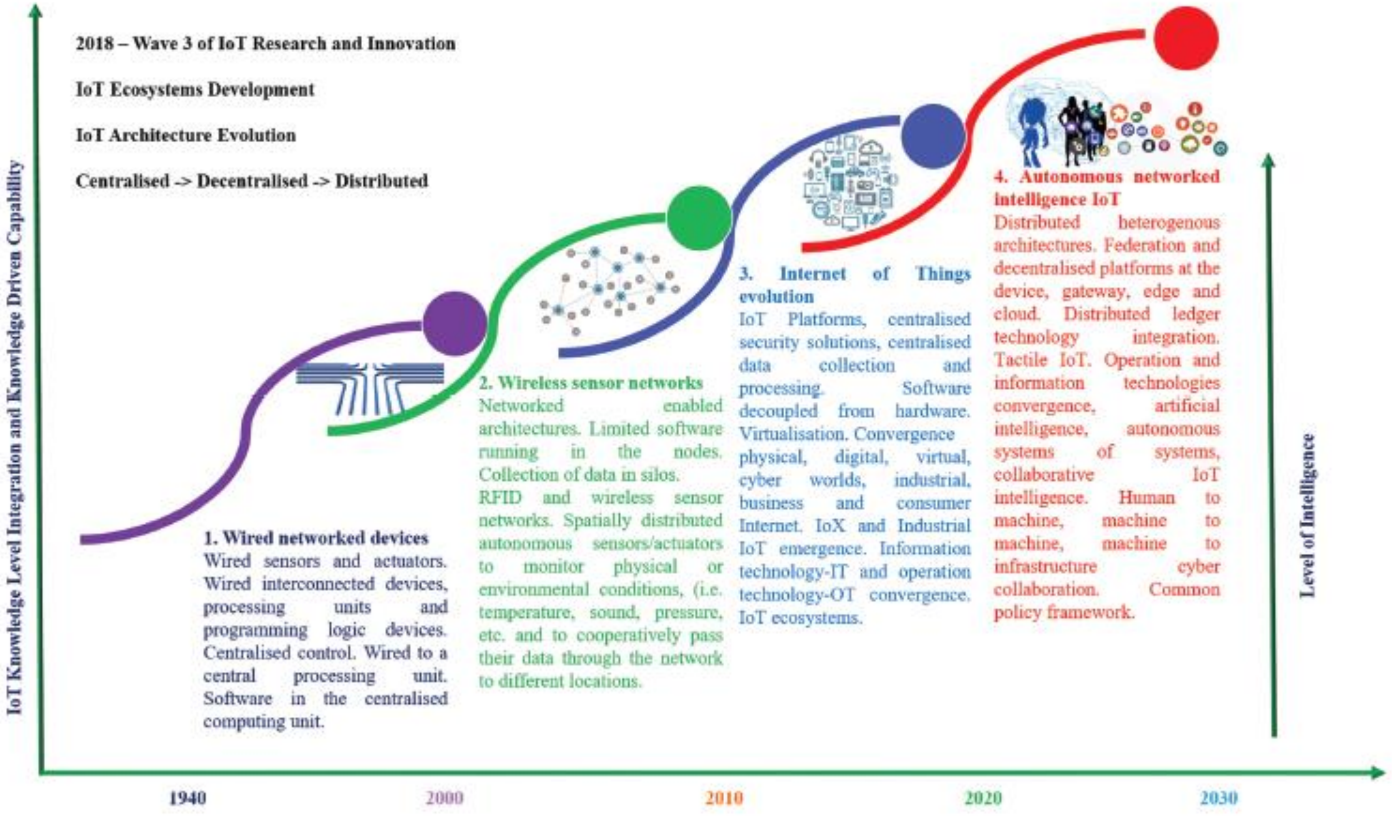
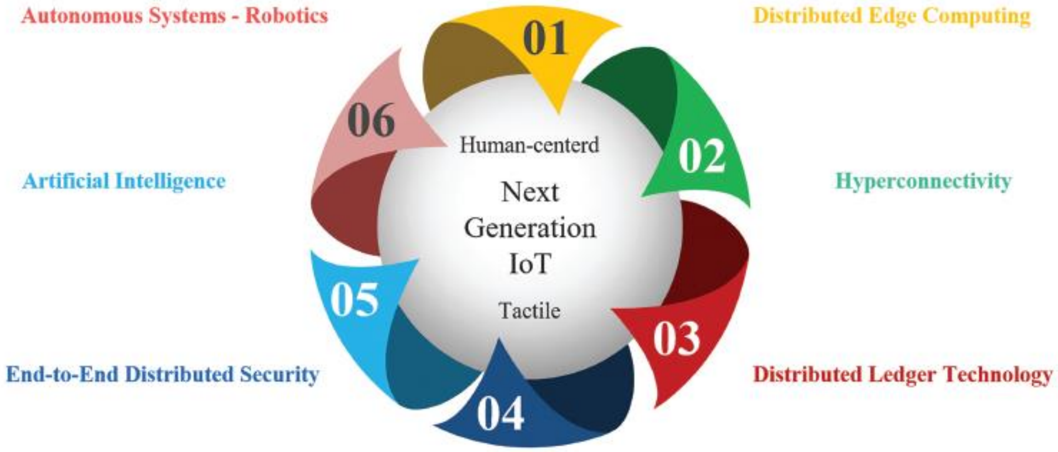




Impact of IIoT on Industry

Design & Engineering

- Built in support for Mobility and Connectivity
- Learning and adapting design that feeds back learned knowledge
- Physics based simulation driven design

Manufacturing

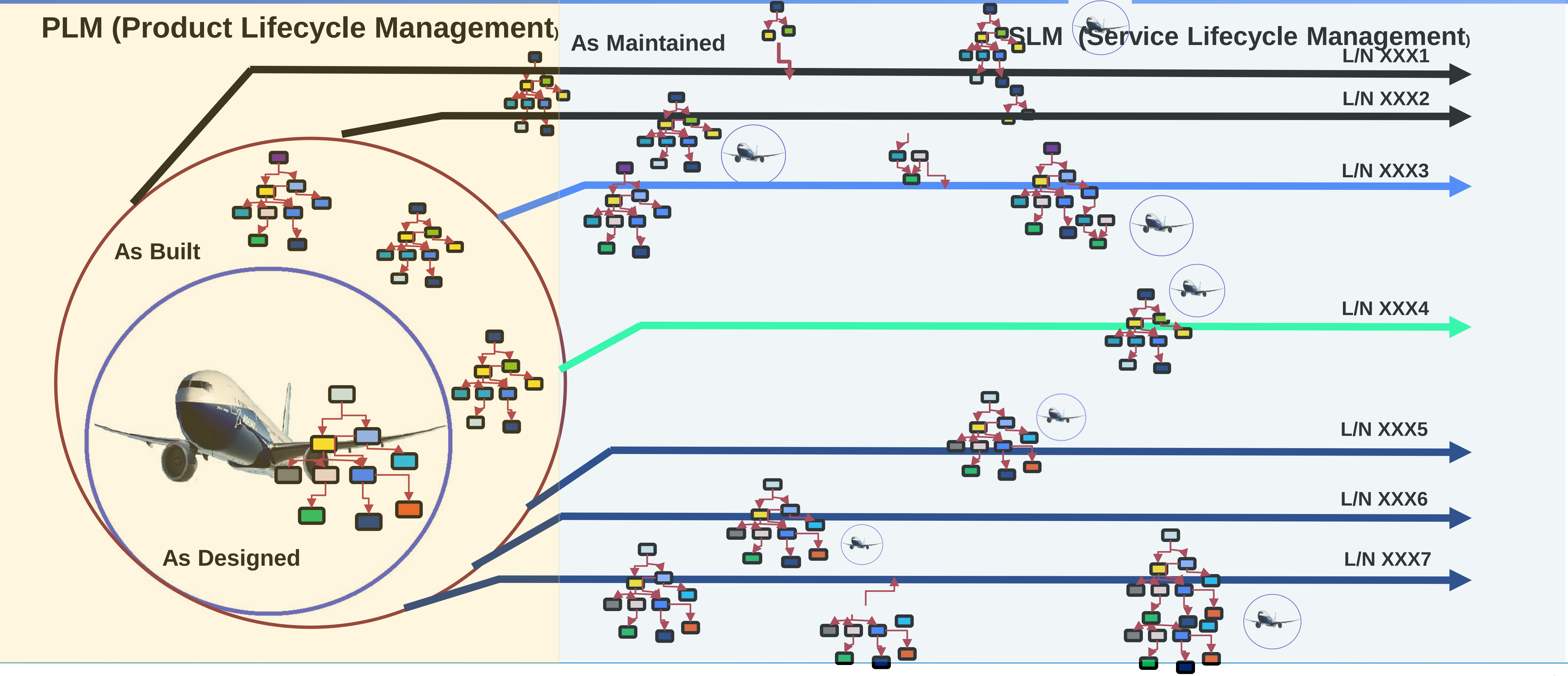
Allow Predictive Maintenance of Manufacturing Machines
"It's like going to the doctor. The doctor doesn't just look at the stethoscope, the doctor looks at the patient history to understand what happened, how you were prescribed, what the results were. We do exactly the same with the machine. You can't do it just from the sensors, you have to understand the history."

- Reduced parts inventory, Identifying root causes quicker leading to better designs in future.

Services

- With the ability to monitor machines that are in use at customer sites, makers of industrial equipment can shift from selling capital goods to selling their products as services
- Sensor data will tell the manufacturer how much the machinery is used, enabling the manufacturer to charge by usage. Service and maintenance could be bundled into the hourly rate, or all services could be provided under an annual contract.
- This "as-a-service" approach can give the supplier a more intimate tie with customers that competitors would find difficult to disrupt.
- Vehicles. In the vehicles setting, we assess the potential for IoT to monitor and improve the performance of planes, trains, and other vehicles while in use, which could generate $210 billion to $740 billion per year in IoT impact for this setting in 2025.

PLM and SLM



"USAF data indicates that the total operating cost of major weapons systems averages over twenty times the capital value"

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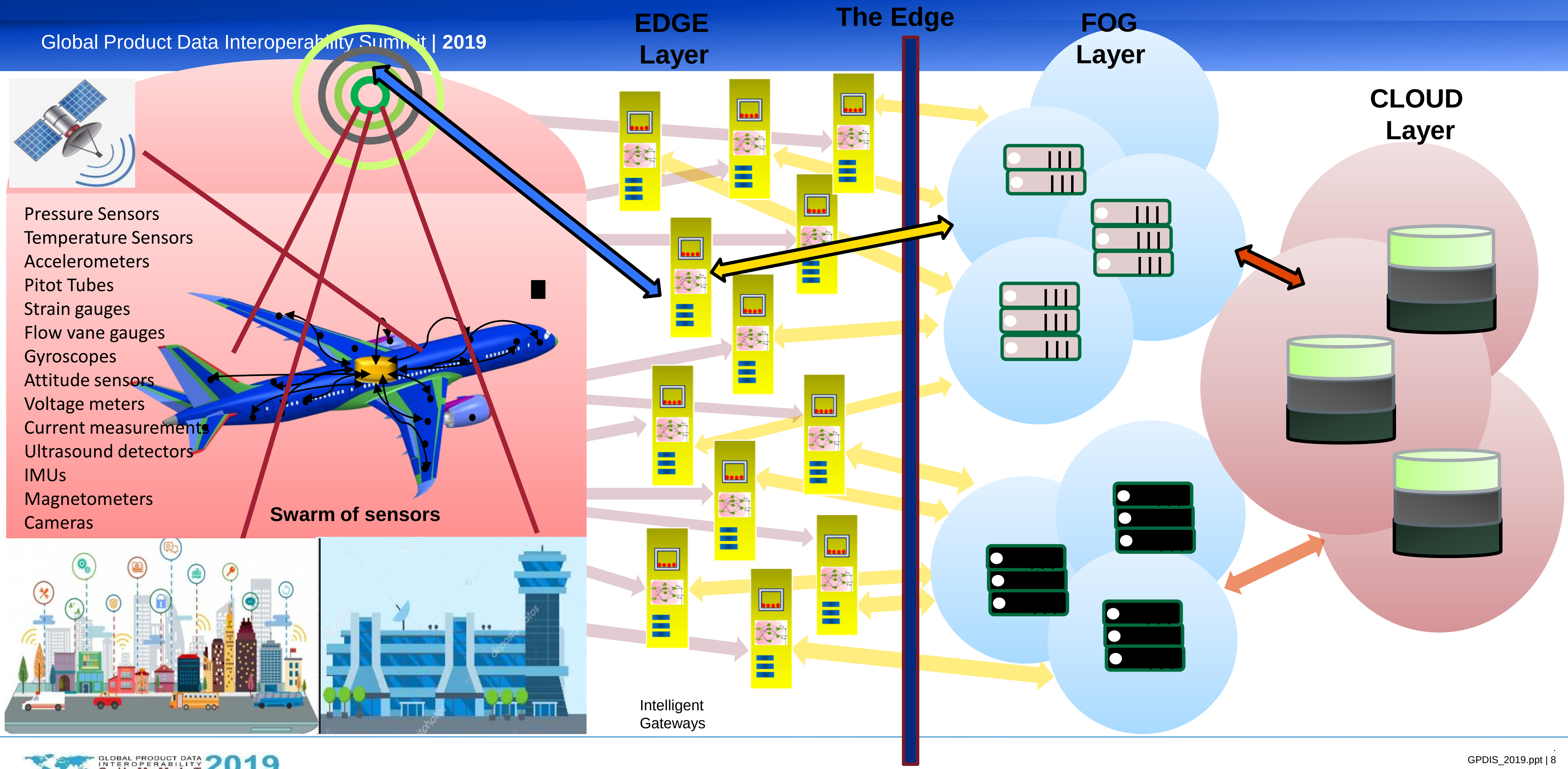
PLM and SLM at the Edges



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Media Technologies (VIS)

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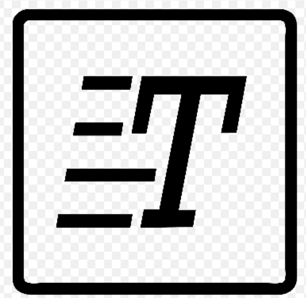
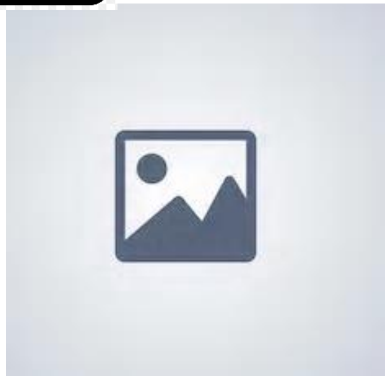


Text

Increasing Immersion in Design and Manufacturing, Richer media and Realism

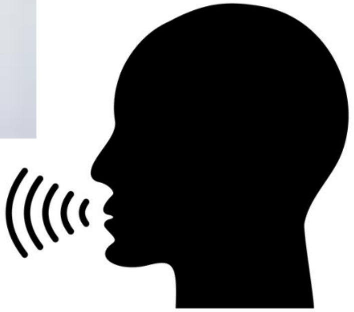
VR/AR



Image

Holograms

Voice



Video

Impact of Visualization Technologies on Industry

Design & Engineering

- Collaboration
- Design and Engineering Reviews

Manufacturing

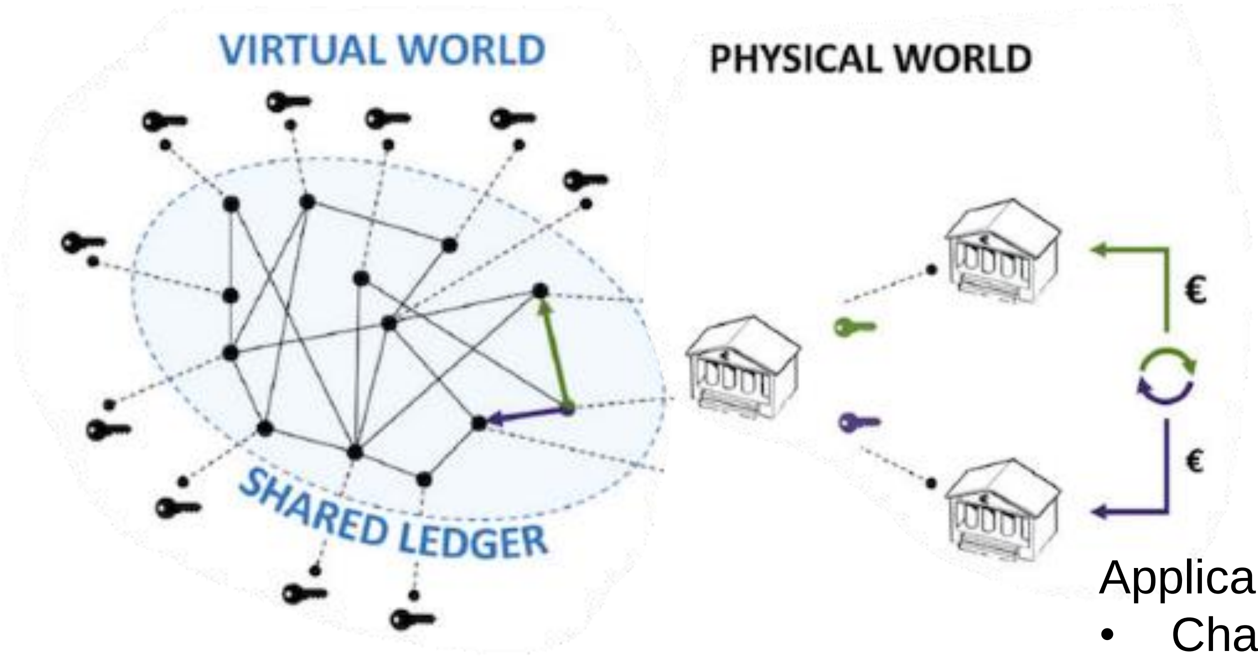
- Facility Inspections
- Shop Floor Employee Training
- Electronic Work Instructions
- Quality Inspections
- Comparing Planned vs Built

Services

- Maintenance Training
- Service Instructions
- Monitoring and Maintenance
- Remote Visualization

Ref: Eran Nadel, Siemens Realize Innovation, 2018

Distributed Ledger Technologies (DLT)



A distributed ledger is decentralized to eliminate the need for a central authority or intermediary to process, validate or authenticate transactions

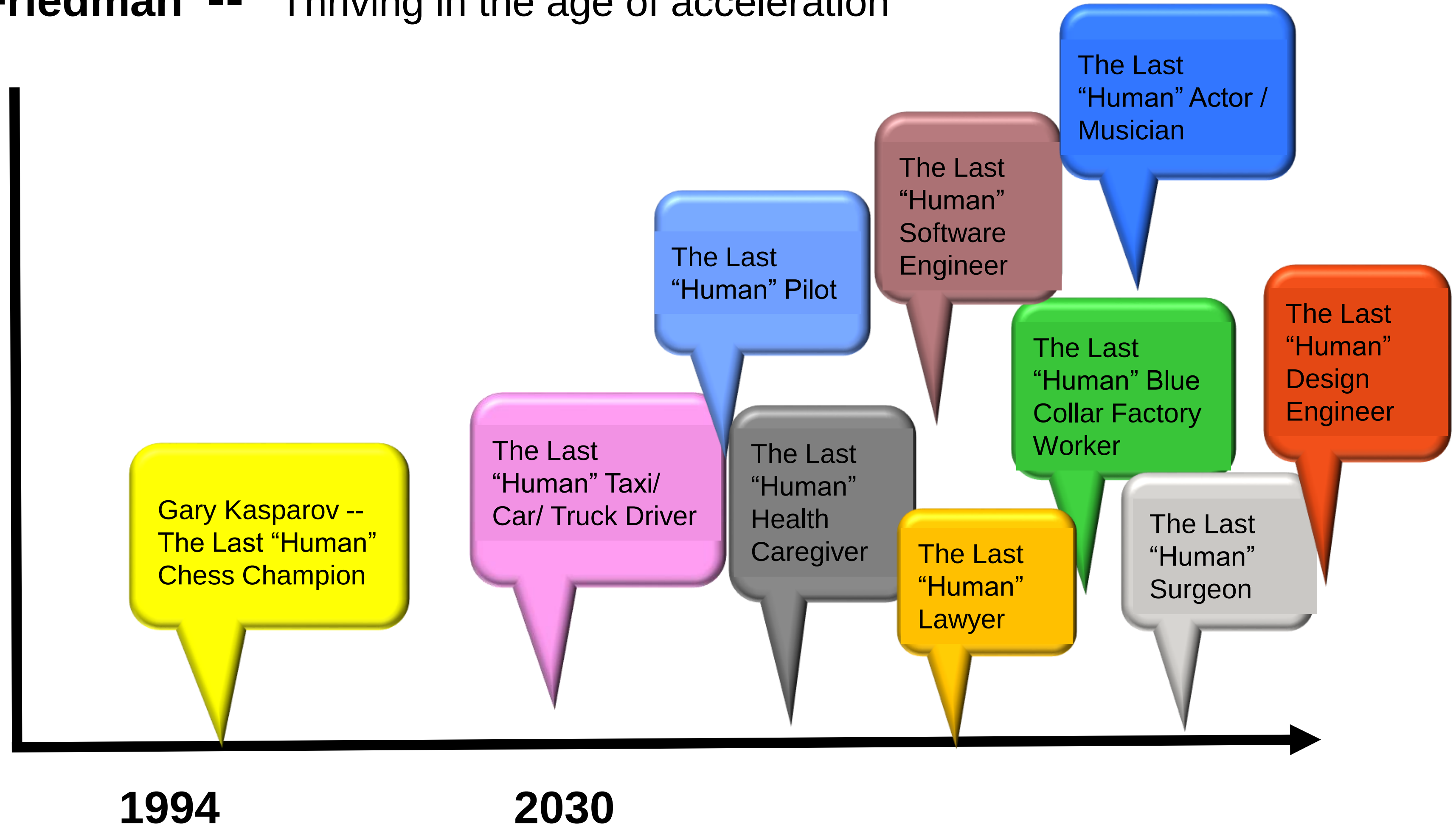
- A verifiable and auditable history of all information stored on that particular dataset.
- Provides data transparency and consensus

Applicability in PLM:

- Change Management
- Workflow processes
- Extended Enterprise Collaboration
- Real Time Work management and Contracts
- Design Collaboration – Follow the Sun Engineering
- Real time Process planning

AI and Machine Learning

Tom Friedman -- "Thriving in the age of acceleration"



AI and Machine Learning

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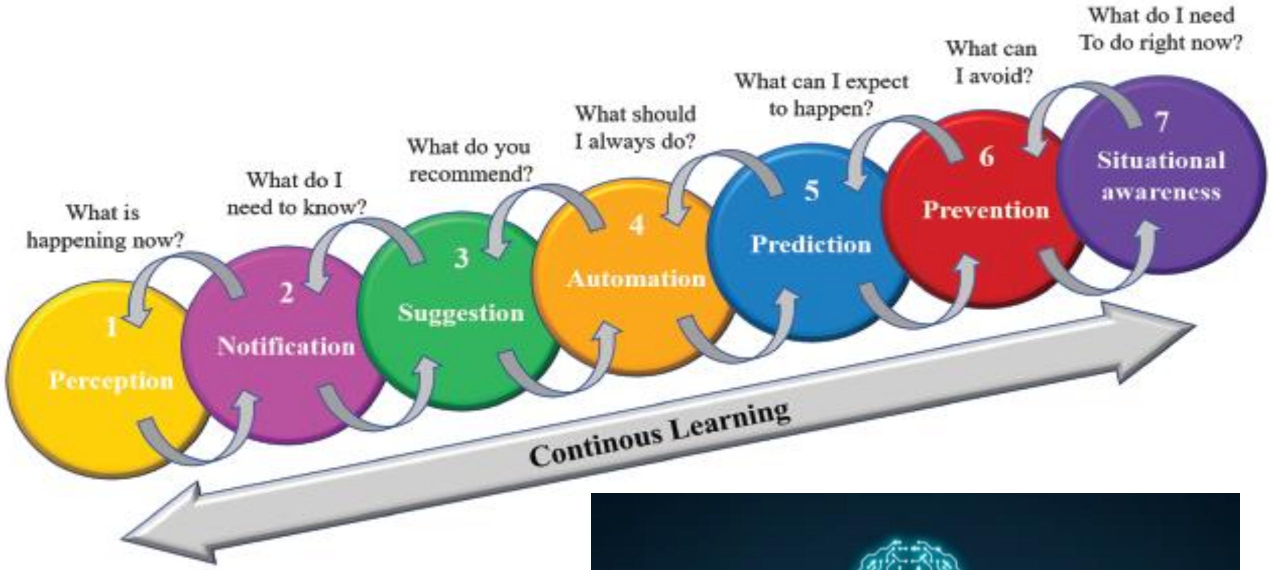


Requirements:

Explainability: Rationale
Availability: Provide data and resources in timely fashion
Trustworthiness: Authenticated devices
Security: End to end security
Safety: Protect people & objects
Privacy: Data privacy
Transparency: Insight
Fairness: Compliance standards
Inclusiveness: Allow human intervention
Collaboration: Self-organize around common goal
Integration: Open and flexible perspectives
Reliability: Without outages
Resiliency: Stable mode operation
Accountability: To customers, partners, stakeholders
Verifiability: Correctness of output

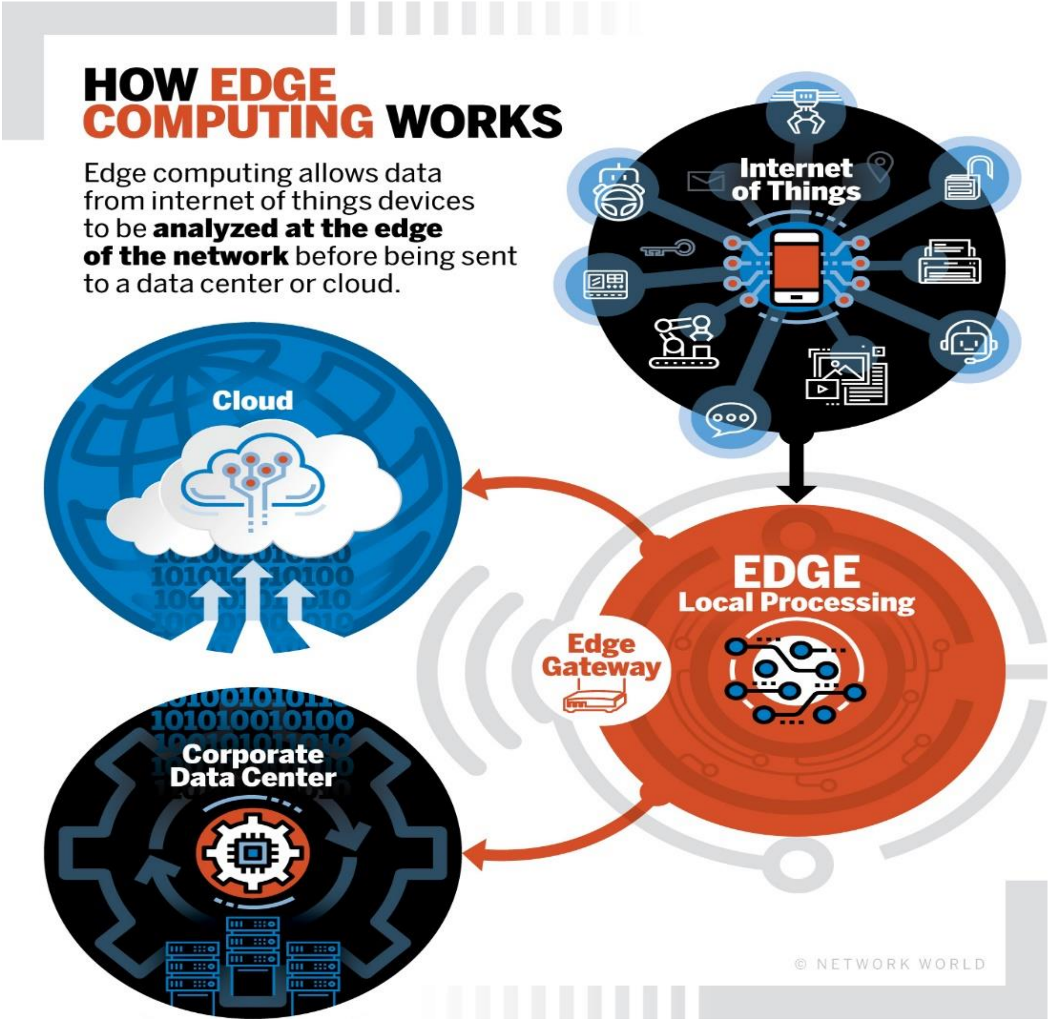
Design & Engineering

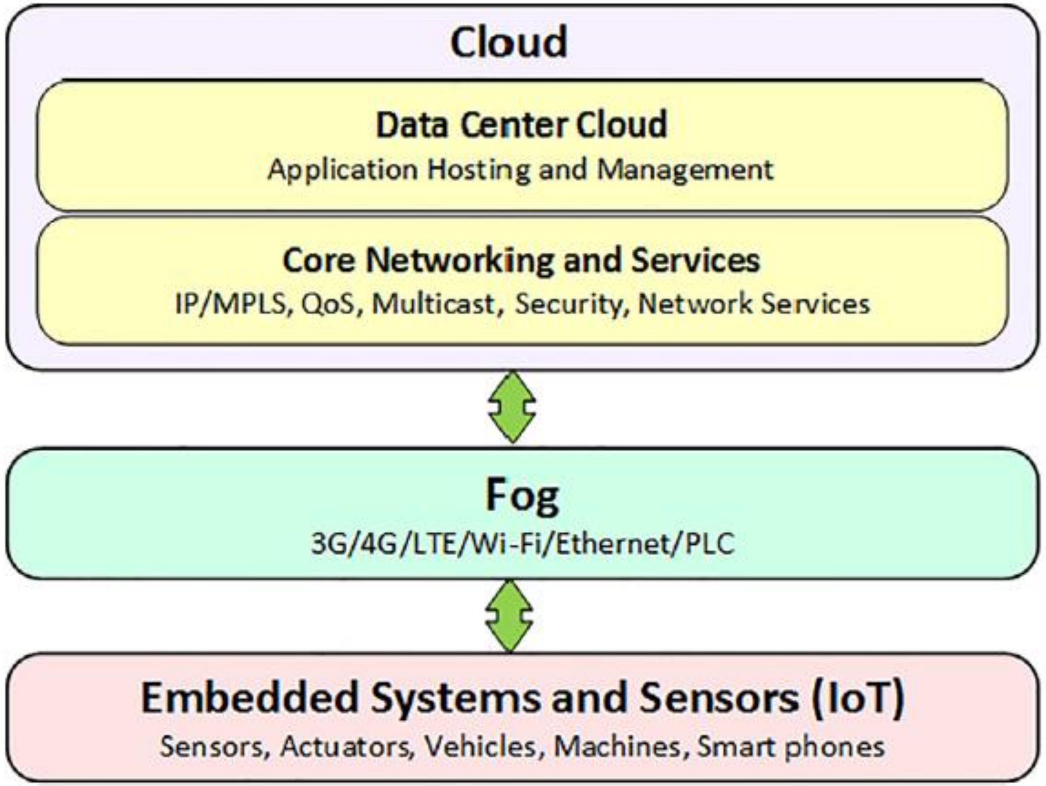
- **Increasing Design Productivity.** Machine learning can be harnessed in PLM to create adaptive interfaces that increase user design productivity.

- **Reducing Supply Chain Delays.** Faster time-to-market is always important, and a PLM solution that uses machine learning can quickly recommend alternative suppliers at competing costs, in a geographical location that won't increase costs or cause further delays.

- **Better Decision Management.** Machine learning is increasingly being leveraged in the product design process to provide a competitive advantage. ML can be used to deliver valuable business insights more quickly and efficiently, and it has the power to process, analyze, and learn from large volumes of data. When provided access to historic sales data and unfiltered customer feedback, machine learning insight can enable product designers to utilize insights to improve future product lines.

Edge Computing, Fog Computing, and Cloud Computing (EC)





Domain Specific Languages (DSL)

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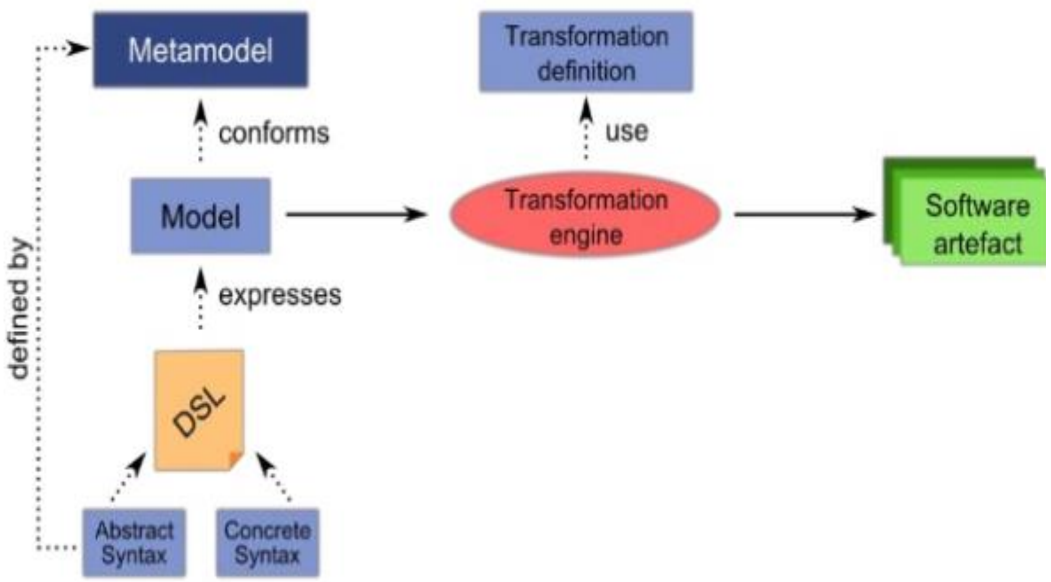

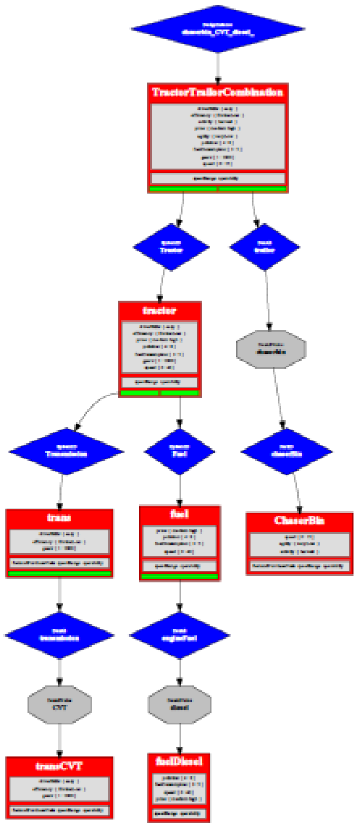

System

```
Section system
 Top-level System TractorTrailorCombination
  OperationSpace () {
   AbstractSystem Tractor tractor
   DesAlt(trailor) {
      chiselPlow
         AbstractPart trailorChiselPlow TrailorChiselPlow
  trailortiller AbstractPart trailorTiller TrailorTiller
      chaserbin AbstractPart chaserBin ChaserBin
      notrailor Part NoTrailor
         OperationSpace ( load [0 0] activity { none })}

 System tractor OperationSpace () {
   AbstractSystem Transmission trans
   AbstractSystem Fuel fuel }

System trans OperationSpace() { DesAlt (transmission){
  unsynchronized Part transUnsynchronized
      OperationSpace ( driverSkills {advanced moderate
      easy} continousOperation { no } gears [ 1 24 ] )
  doubleClutch Part transDoubleClutch
      OperationSpace ( driverSkills { moderate easy }
      gears[ 1 2 4])
  CVT Part transCVT
      OperationSpace ( driverSkills {easy}
      efficiency { frictionLoss } gears [ 1 1000 ] )}}

System fuel OperationSpace () { DesAlt (engineFuel){
  steam Part fuelSteam
   OperationSpace (pollution [5 10] speed [0 30] )
  diesel Part fuelDiesel
   OperationSpace (pollution [4 8] fuelConsumption [3 5]
    speed [0 40] price { medium high } )
  gasoline Part fuelGasoline
   OperationSpace(pollution [2 5] fuelConsumption [4 10]
    speed [0 50] price { medium high })
  electric Part fuelElectric
   OperationSpace(pollution [0 4] fuelConsumption [8 12]
    speed [0 55] price { high })}}}
```

Part

```
Section part
 Part TrailorChiselPlow
   OperationSpace ( speed [0 25] agility { low veryLow }
   activity { plow } )
 Part TrailorTiller
   OperationSpace ( speed [0 25] agility { low veryLow }
   activity { till } )
 Part ChaserBin
   OperationSpace ( speed [0 15] agility { veryLow }
   activity { harvest } )
```

Requirement

```
Section requirements
 Legal Requirement speedRange
   minimum OperationSpace ( speed [5 15] )
   maximum OperationSpace ( speed [0 45] )
 Business Requirement fuelAndPurchaseCosts
   maximum OperationSpace
      ( fuelConsumption [0 20] price {medium})
 Design Requirement operability
   maximum OperationSpace ( driverSkills easy )
```

Design Space

```
Section design space
 DesignSpace (
  trailor {chiselPlow trailortiller chaserbin notrailor}
  transmission { unsynchronized doubleClutch CVT }
  engineFuel { steam diesel gasoline electric } )
```


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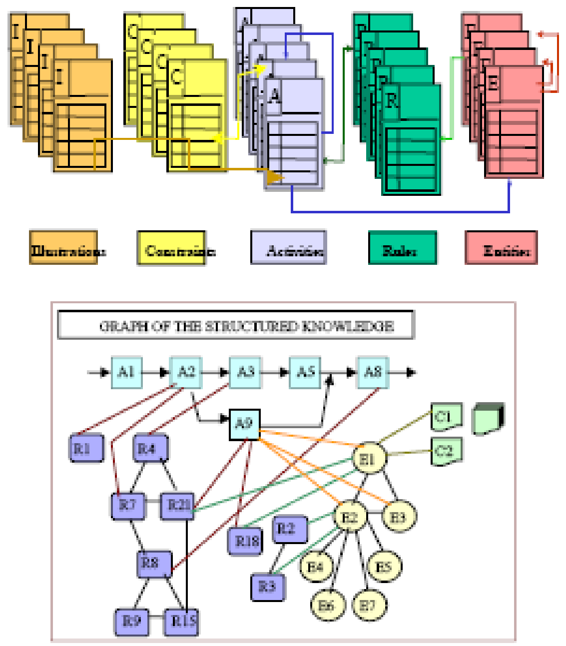
Knowledge Based Engineering (DSL)

Customer Requirement Ontology

The Informal model

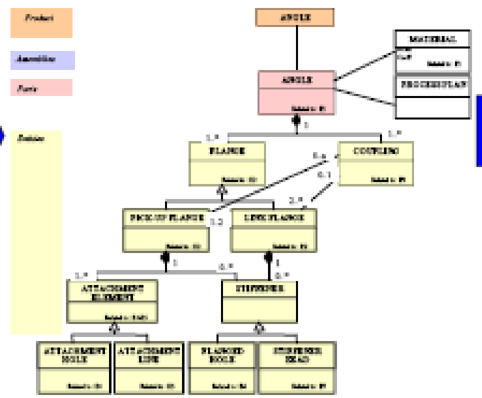
Elaborating ICARE forms



Engineering Ontology

The formal model

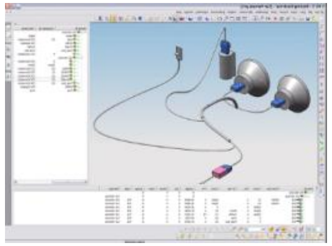
Elaborating Product model and Design Process model



KBE application

Use of a neutral format for Code generation

CAD/PDM Artifacts



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Data Driven Design & Fabrication (DD)

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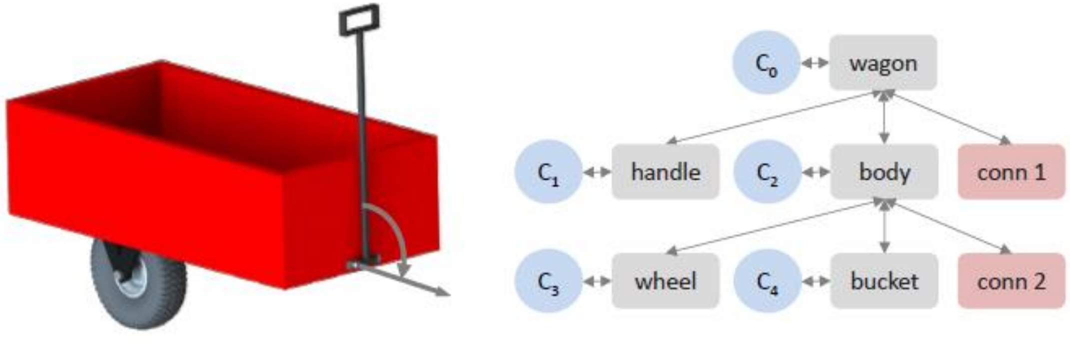
Items Catalog

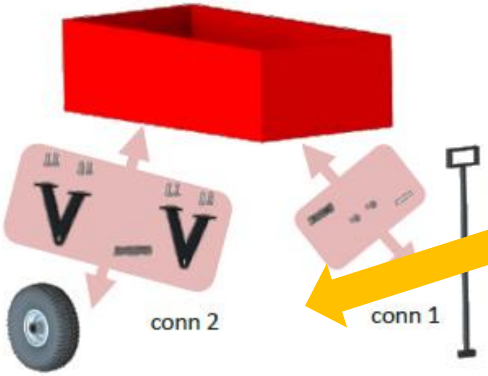
Parameterized Template Based Design

Optimization

Simulation

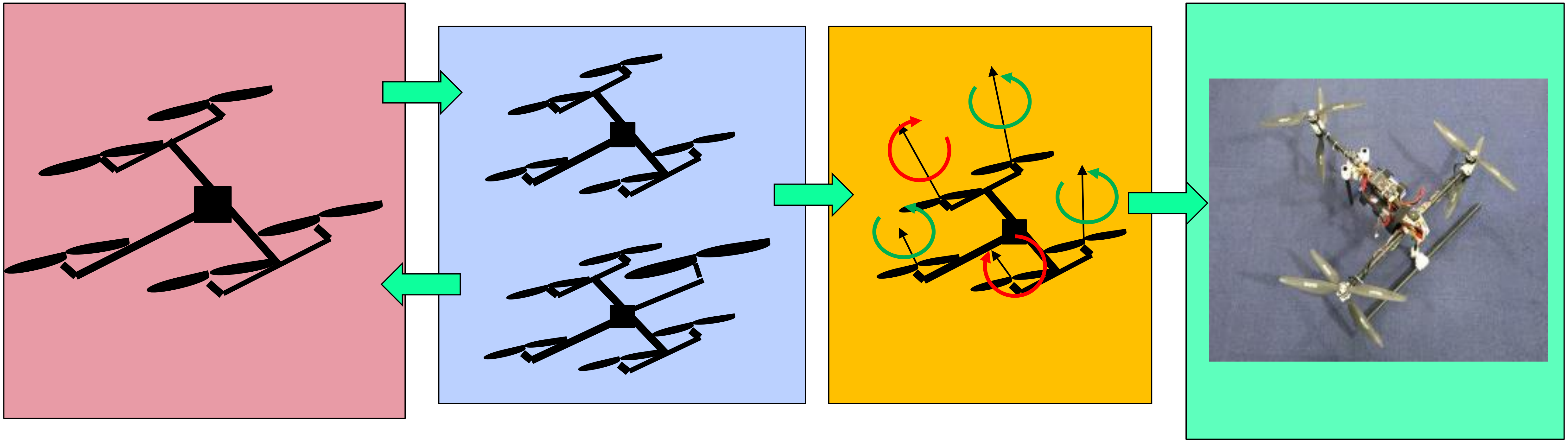
Fabrication





Hierarchical Template Tree

Computational Design Optimization – Multi-Copter Design



Geometry **Optimization** **Simulation** **Fabrication**

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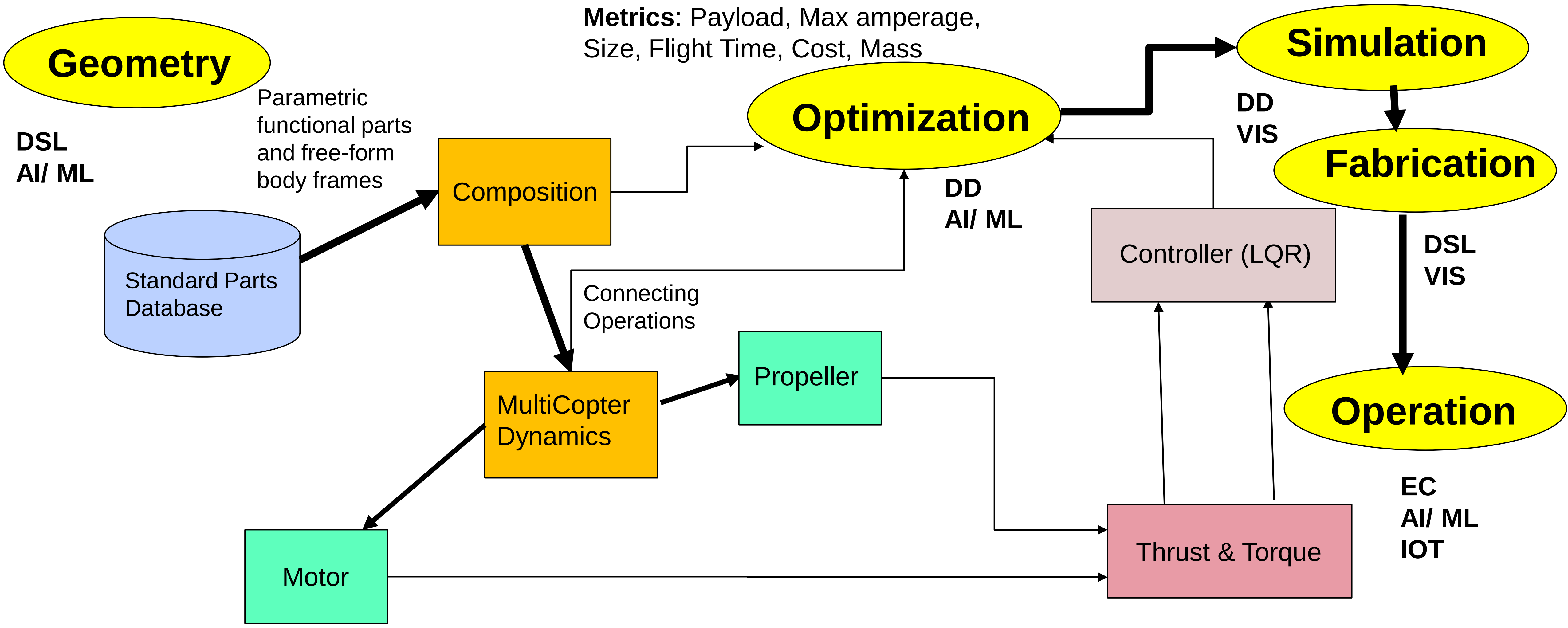
Computational Design Optimization – Multi-Copter Design



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What will these enable?

Product Lines

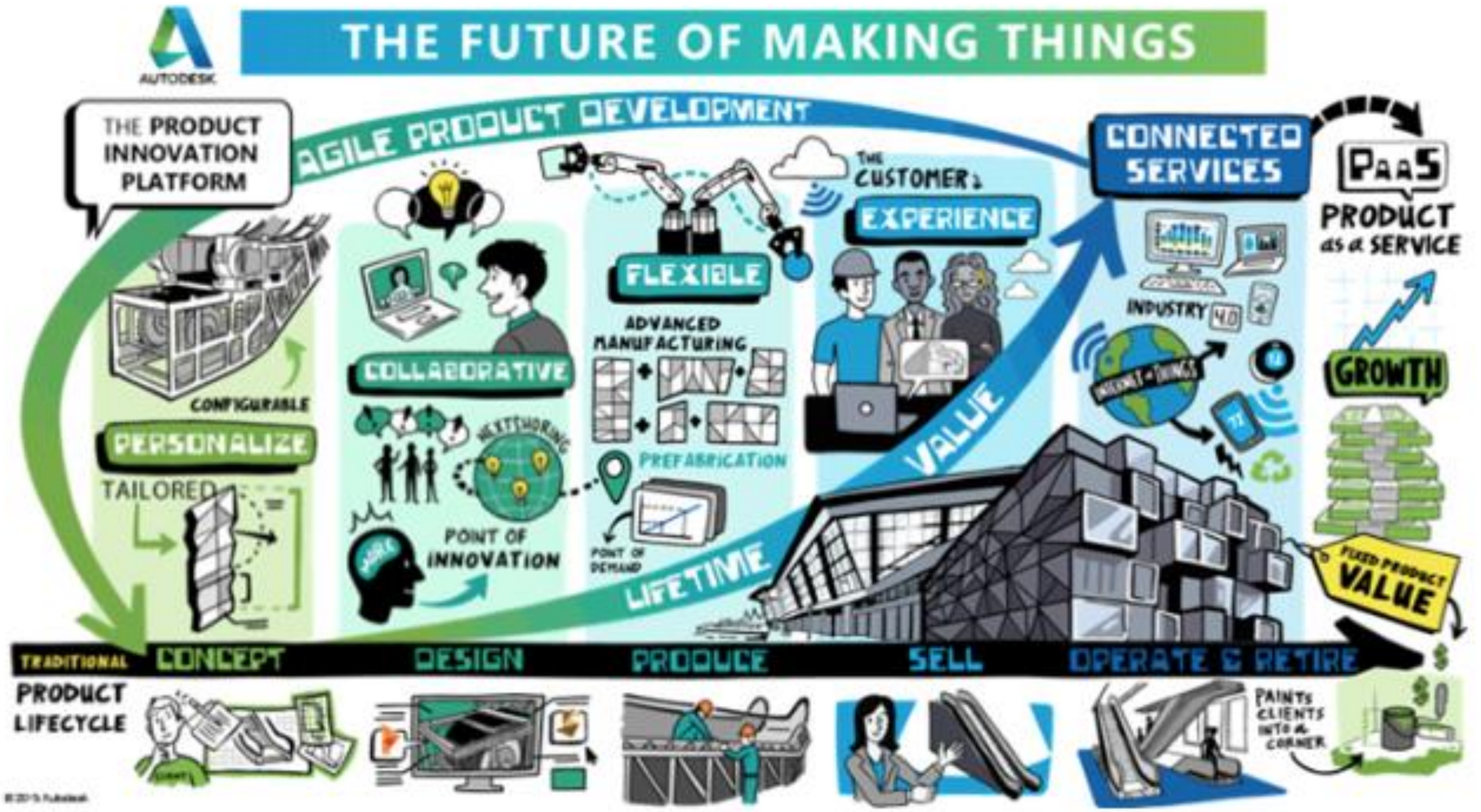
- Autonomous products
- Highly Connected
- Highly Customizable

Manufacturing Lines

- Lights out Manufacturing
- Build close to Customer

Business Models

- Product as a Service



Source: Autodesk

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Conclusions

- **Reviewed the impacts of Disruptive Technologies on future state PLM**
- **Future Cyber Physical System Design and Manufacturing will involve increased levels of disruptive technologies**
- **Digitization will impact entire eco-systems, business models, and underlying functions in company's value chain**
- **IOT , AI, and DLT will enable new business models in all industries**
- **PLM scope will grow to include all these disruptive technologies in future**
- **The impacts will be seen in Product Lines, Production Systems, and Business Models**

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