# ENPM 692
# MANUFACTURING AND AUTOMATION

## Smart Manufacturing-
## Network-centric manufacturing

Time: Wednesdays 7:00pm - 9:40pm
JMP 2222

Dr. Mahesh Mani, PhD
Email: mmani@umd.edu

# Lectures

| | | |
|---|---|---|
| Lecture 1 | 1/29/2025 | Introduction Lecture |
| Lecture 2 | 2/5/2025 | Additive Manufacturing- technologies |
| Lecture 3 | 2/12/2025 | Additive Manufacturing- capabilities and applications |
| Lecture 4 | 2/19/2025 | Sustainable Manufacturing –Overview |
| Lecture 5 | 2/26/2025 | Sustainable Manufacturing Practicality |
| Lecture 6 | 3/5/2025 | Industrial Robotics |
| Lecture 7 | 3/12/2025 | Guest Lecture |
| Spring Break | 3/19/2025 | No Lecture-Spring Break |
| Lecture 8 | 3/26/2025 | Manufacturing Simulation |
| Lecture 9 | 4/2/2025 | Digital Manufacturing |
| Lecture 10 | 4/9/2025 | Network Centric Manufacturing |
| Lecture 11 | 4/16/2025 | Smart Manufacturing Platforms |
| Lecture 12 | 4/23/2025 | Smart Manufacturing Platforms |
| Lecture 13 | 4/30/2025 | Final - Project Presentations |
| Lecture 14 | 5/7/2025 | Final - Project Presentations |
| **Final Report** | **5/15/2025** | **Submit Final Reports** |

# Final Project Requirements

## Technical report presenting proposals for making production more efficient.

- Choose any relevant manufacturing scenario
- Technical report summarizes
  - problem definition, goal and scope of the production scenario,
  - research and analysis,
  - smart manufacturing recommendations.
- Oral presentation with clear illustrations, within allotted time
- Reflect on classmates' presentations and provide feedback.

**Final Report on 15th May?**

# Smart Manufacturing

# What is Smart Manufacturing?

> Smart manufacturing marries information, technology and human ingenuity to bring about a rapid revolution in the development and application of manufacturing intelligence to every aspect of business. It will fundamentally change how products are invented, manufactured, shipped and sold. It will improve worker safety and protect the environment by making zero-emissions, zero-incident manufacturing possible. It will help keep jobs in this country by keeping manufacturers competitive in the global marketplace despite the substantially higher cost of doing business in the United States.

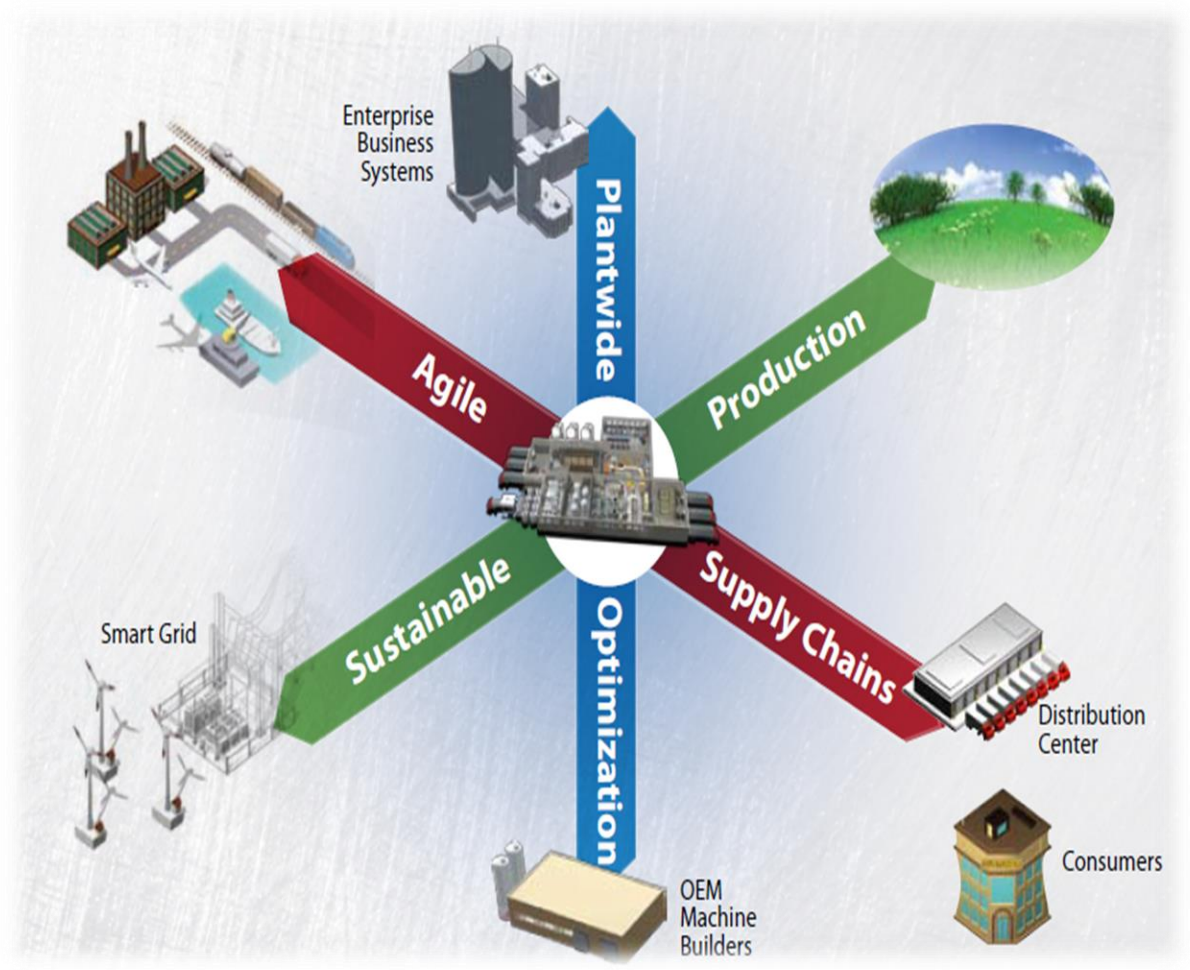
Ref: Time MagazineSMcoverstory

# Smart Manufacturing

Smart Manufacturing is the information-driven, event-driven, efficient and collaborative orchestration of business, physical and digital processes within plants, factories and across the entire value chain.

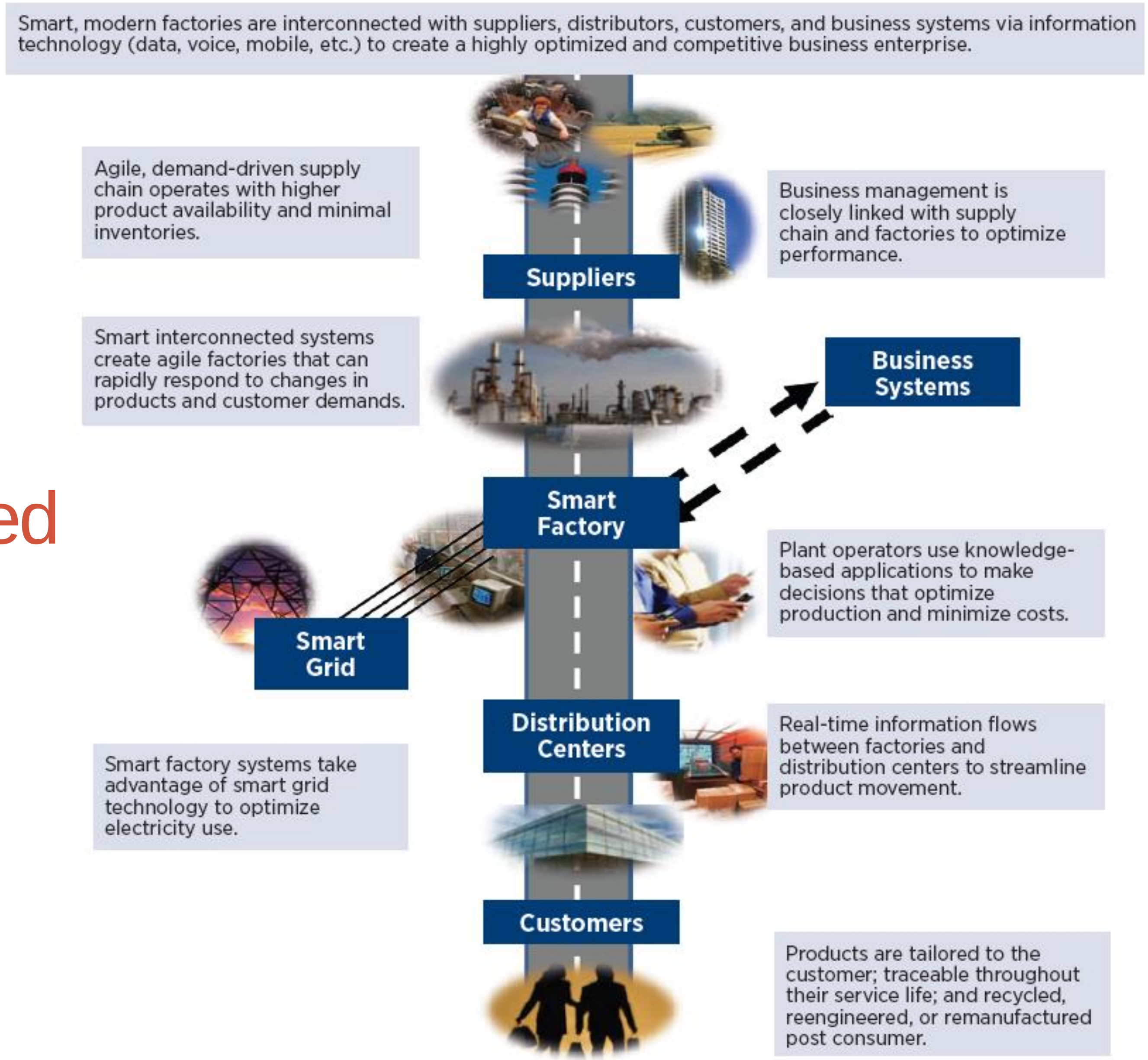
*Source: https://www.cesmii.org/about/what-is-smart-manufacturing/*

# Strategy




*Source:smartmanufacturingcoalition*

# Interconnected




*Source:smartmanufacturingcoalition*

# Ten Priority Actions for SM

**Figure ES-2. Ten Priority Actions for Smart Manufacturing**

## Industrial Community Modeling and Simulation Platforms for Smart Manufacturing

1. Create community platforms (networks, software) for the virtual plant enterprise
2. Develop next generation toolbox of software and computing architectures for manufacturing decision-making
3. Integrate human factors and decisions into plant optimization software and user interfaces
4. Expand availability of energy decision tools (energy dashboards, automated data feedback systems, energy 'apps' for mobile devices) for multiple industries and diverse skill levels

## Affordable Industrial Data Collection and Management Systems

5. Establish consistent, efficient data methods for all industries (data protocols and interfaces, communication standards)
6. Develop robust data collection frameworks (sensors/ data fusion, machine and user interfaces, data recording and retrieval tools)

## Enterprise-wide Integration: Business Systems, Manufacturing Plants, and Suppliers

7. Optimize supply chain performance through common reporting and rating methods (dashboard reports, metrics, common data architecture and language)
8. Develop open platform software and hardware to integrate and transfer data between small and medium enterprises (SMEs) and original equipment manufacturers (OEMs) (data sharing systems and standards, common reference architectures)
9. Integrate product and manufacturing process models (software, networks, virtual and real-time simulations, data transfer systems)

## Education and Training in Smart Manufacturing

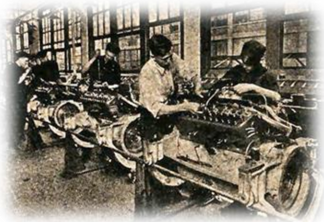
10. Enhance education and training to build workforce for smart manufacturing (training modules, curricula, design standards, learner interfaces)

*Source:smartmanufacturingcoalition*

# Network-centric Manufacturing

Technologies: Making it happen

# Manufacturing Trends

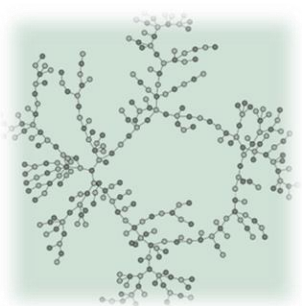


Mass production or production-driven manufacturing

Flow production, series production, standardized products

Customer-driven manufacturing

Built-to-order, configurable products

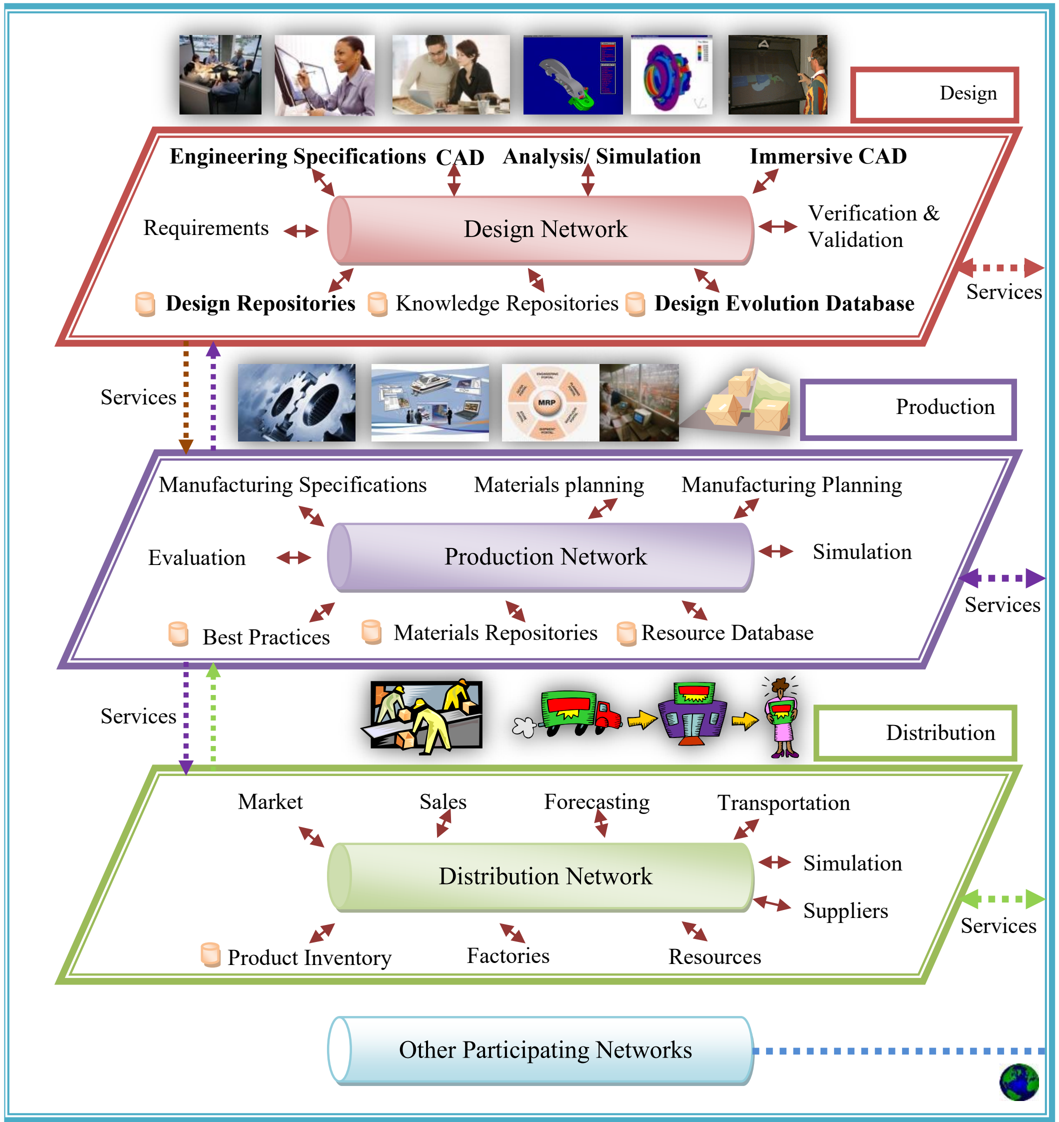


Network-centric manufacturing

Variety, collaborative composable on demand  networks

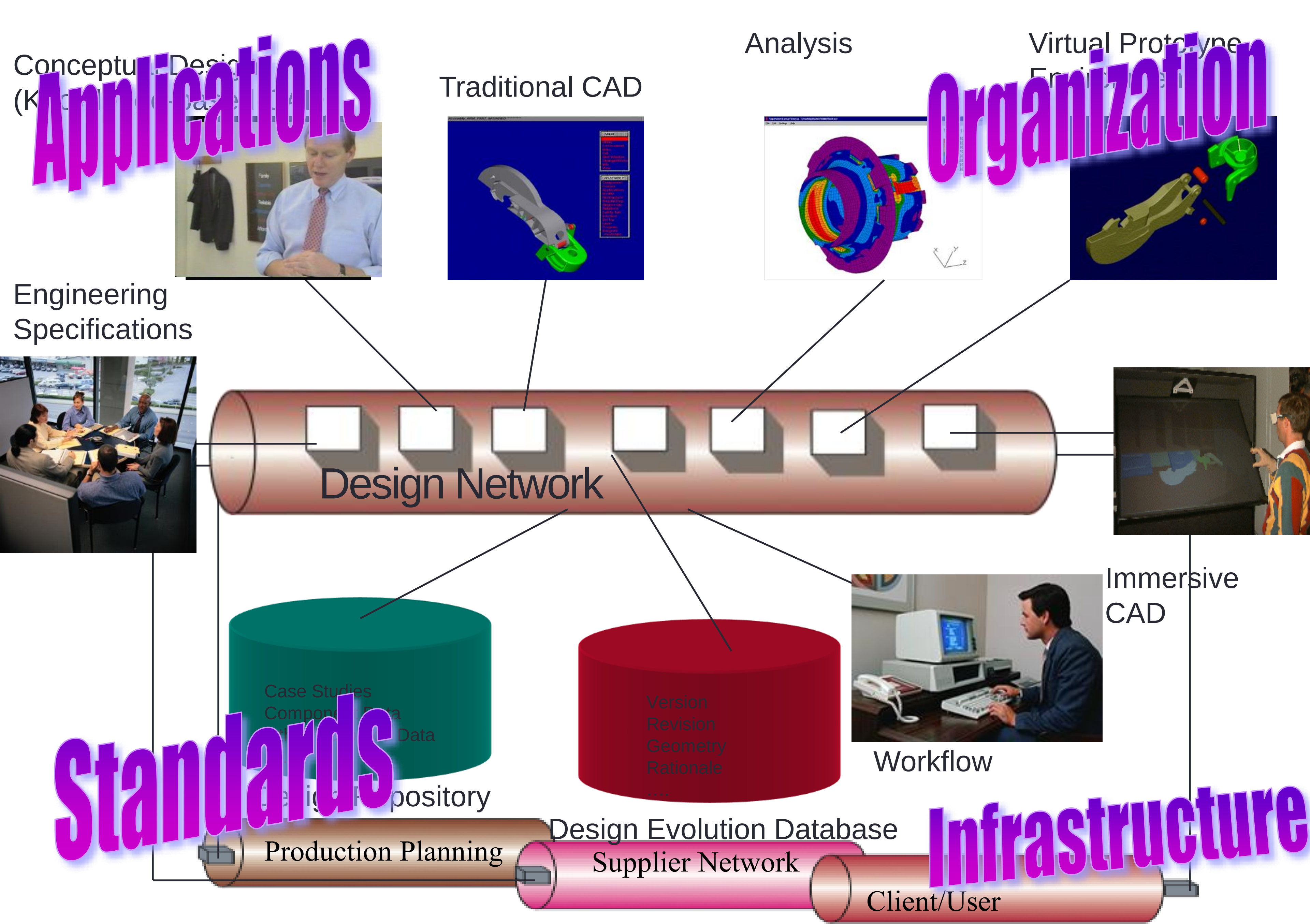
# Networked Enterprises

N E T W O R K - C E N T R I C



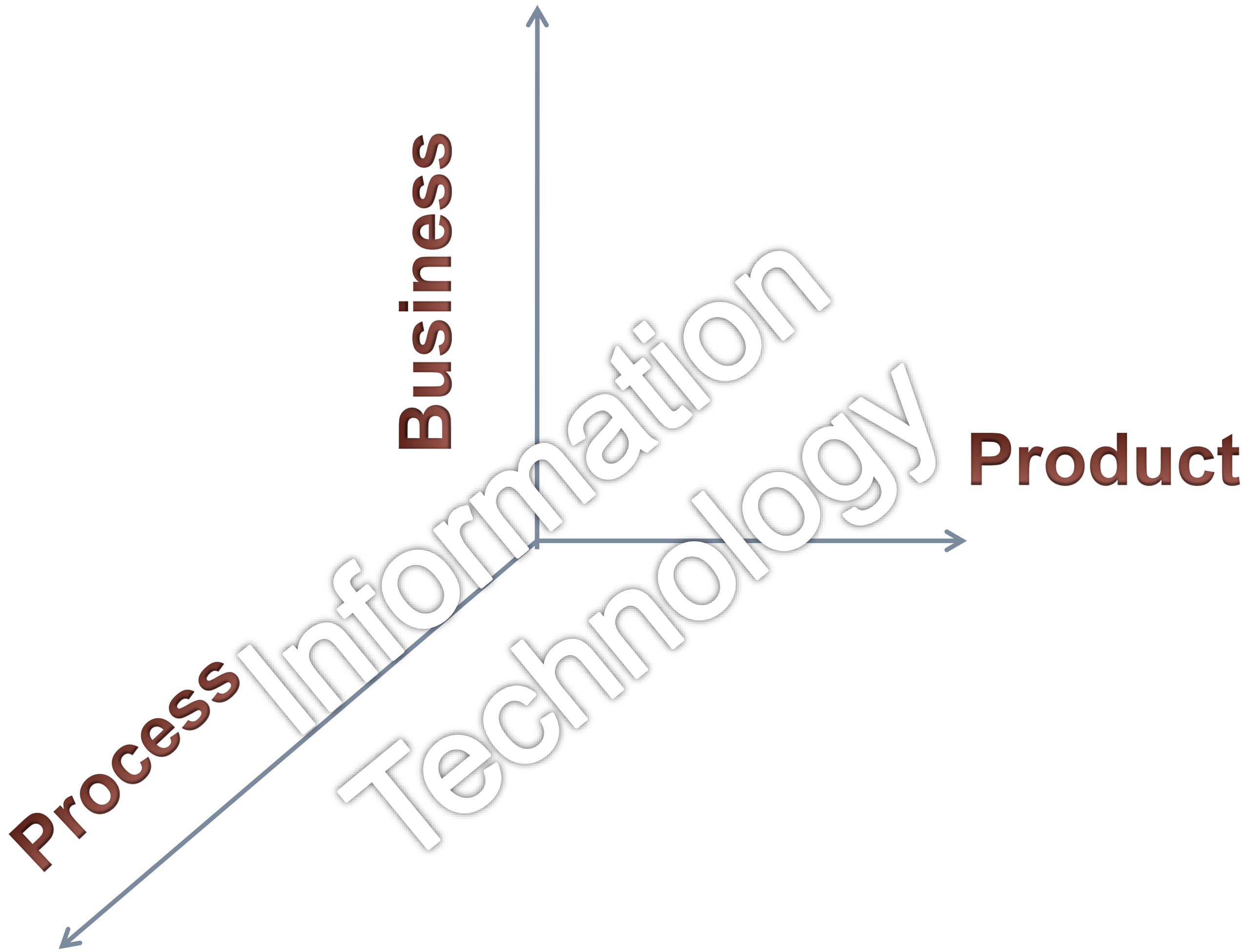

- Collection of business processes
- Consists of many networks:
  - design,
  - production,
  - distribution,
  - Others

**Network-centric computer aided product realization (CAPR)**

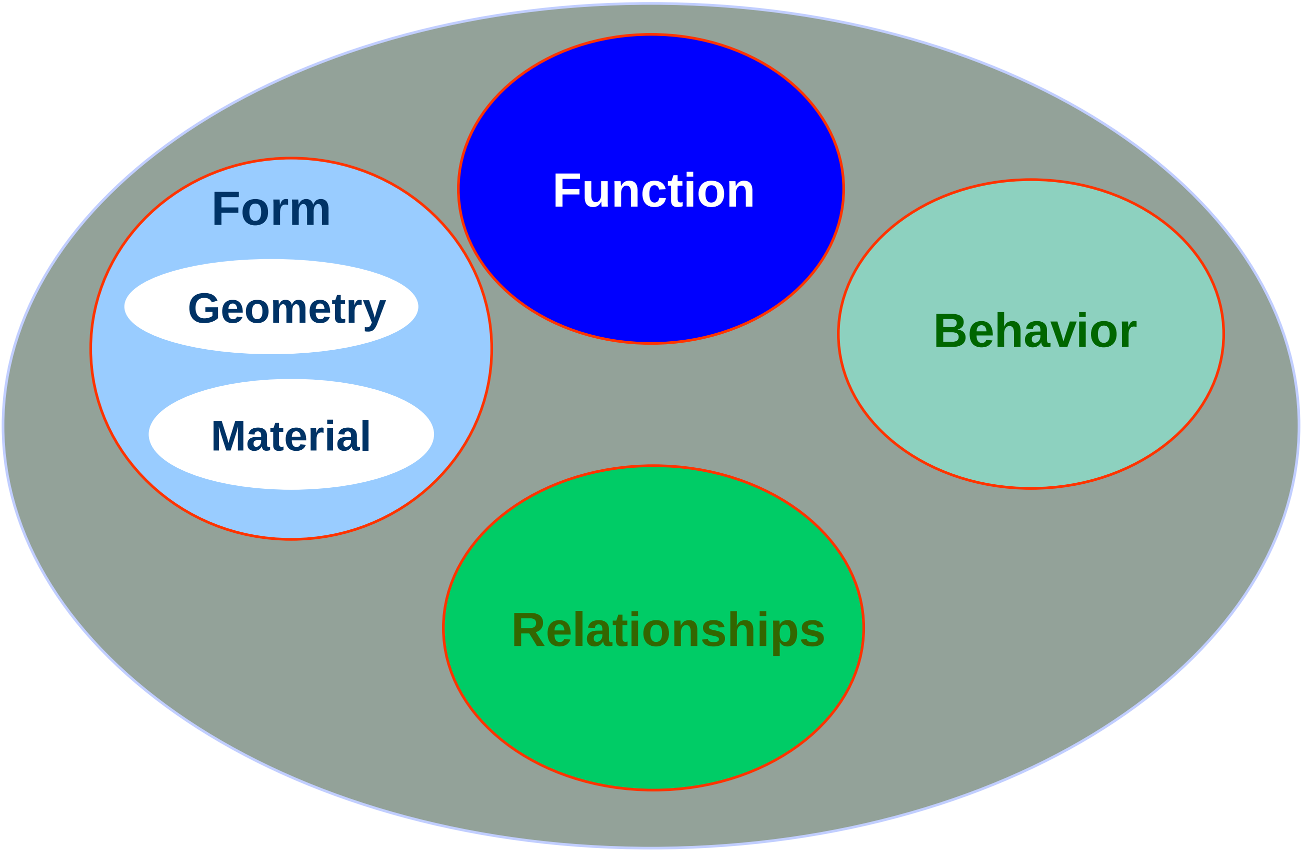

Applications
Organization
Analysis
Traditional CAD
Engineering Specifications
Design Network
Immersive CAD
Workflow
Case Studies
Version
Revision
Geometry
Rationale
Standards
Design Evolution Database
Infrastructure
Production Planning
Supplier Network
Client/User

# Enabling Technologies ?

# Dimensions of Product Life Cycle



# Knowledge Representation

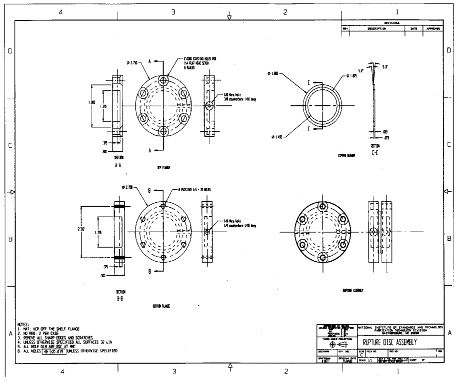



**A product is represented by a hierarchy of entities of the class Artifact, which is an aggregation of Function, Form and Behavior.**

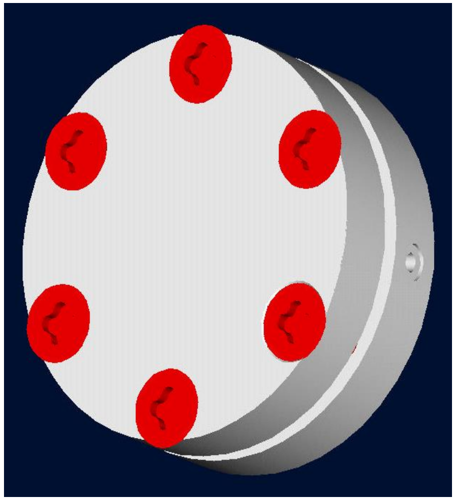
# Form

## Rupture Disc

Digital Picture

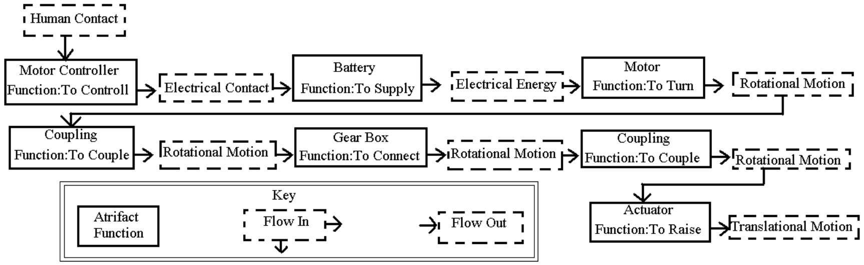


Detailed Design

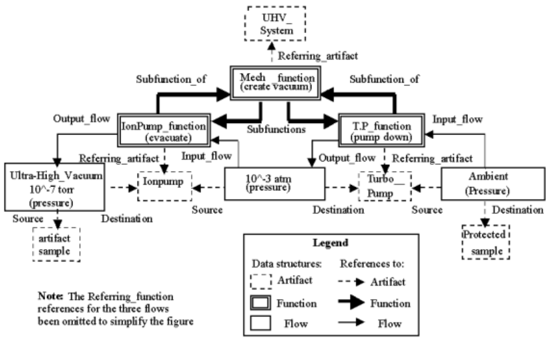


3D Model

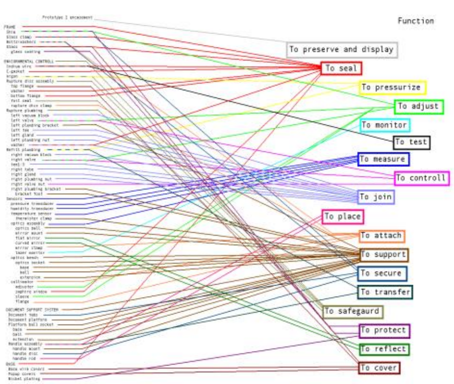
# Function




Simplified Function Flow

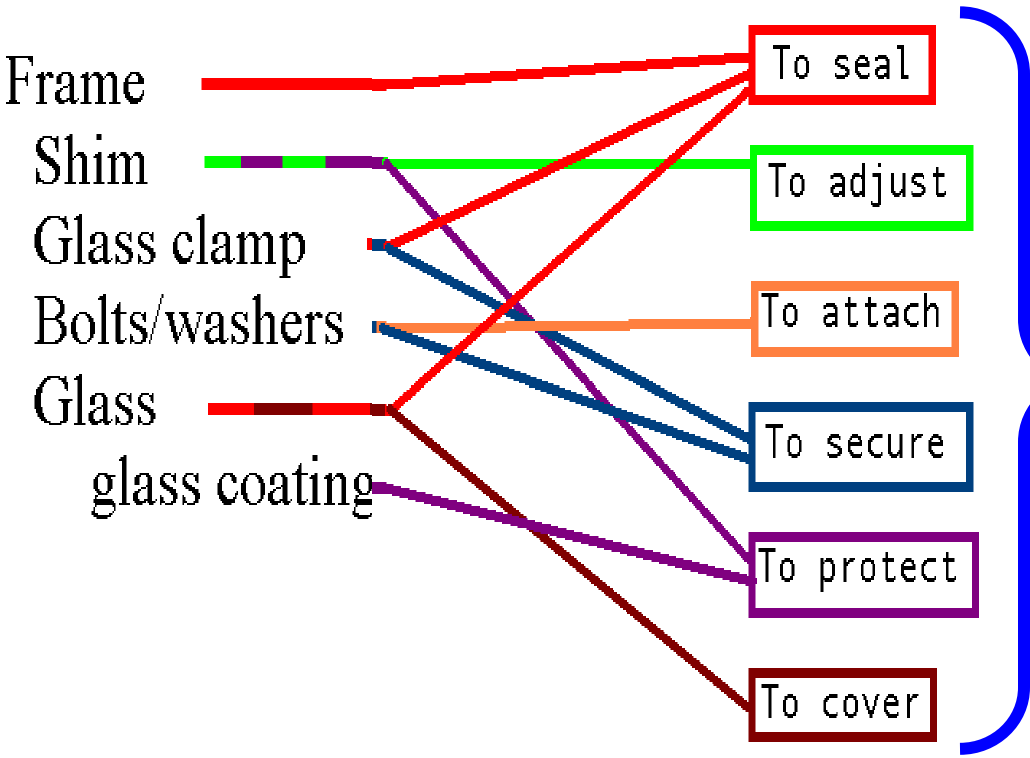



Detailed Function Flow




Function Links

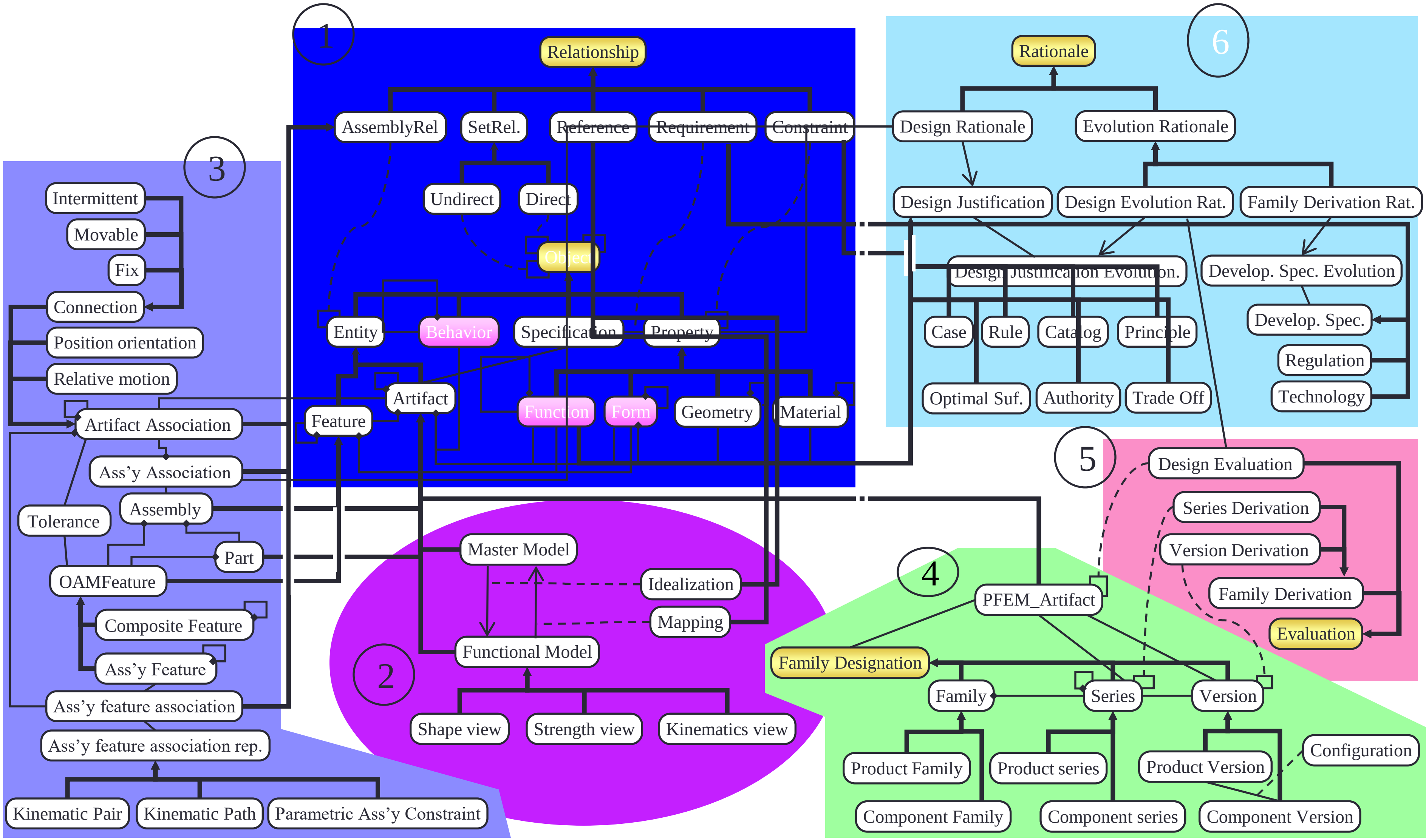
# Links between Function and Artifact



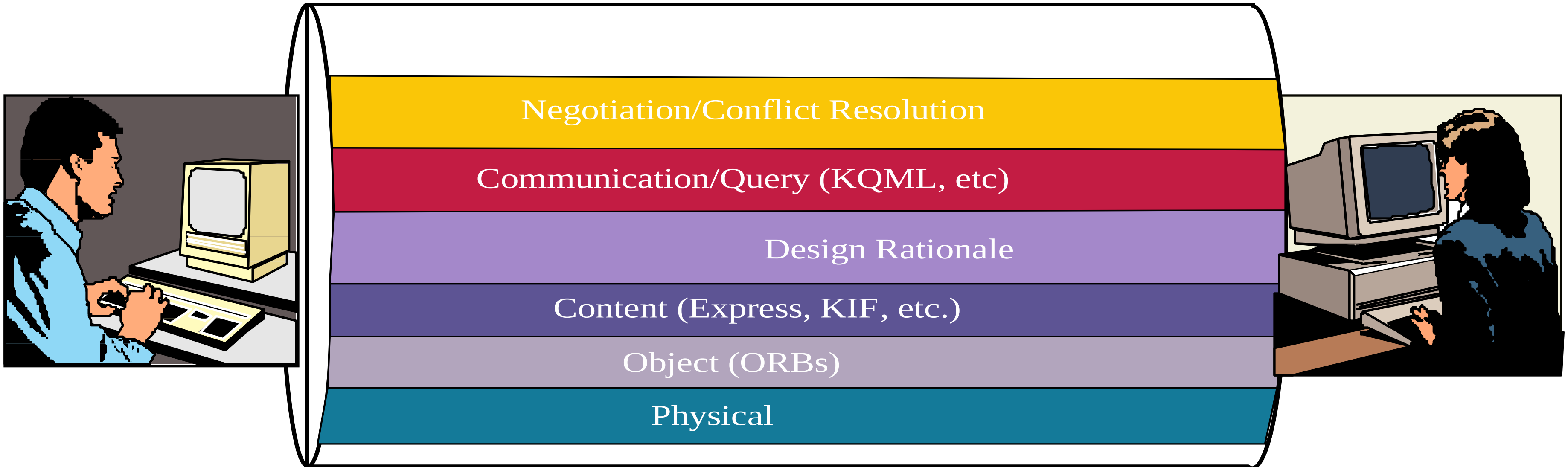

Function
- Usage-function
  - Sink
    - Absorb
    - Consume
    - Destroy
    - Dissipate
    - Eliminate
    - Empty
    - Export
    - Remove
  - Source
    - Add
    - Create
    - Emit
    - Extract
    - Generate
    - Import
    - Supply
  - Storage
    - Accumulate
    - Collect
    - Store
- Combination/ distribution-function
  - Branch
  - Combine
  - Connect
  - Couple
  - Distribute
  - Divide-flow
  - . . .
- Conveyance-function
  - Advance
  - Channel
  - Conduct
  - Convey
  - Direct
  - Divert
  - Guide
  - Generic-move
  - Rotate
  - Transfer
  - Translate
  - Transmit
  - Transport
- Signal/Control-function
  - Actuate
  - Adjust
  - Close
  - Decrease
  - Delay
  - Detect
  - Display
  - Equalize
  - Enhance
  - Generic-control
  - Identify
  - Increase
  - Indicate
  - Inhibit
  - Limit
  - . . .

Design Objects Function types Function Taxonomy

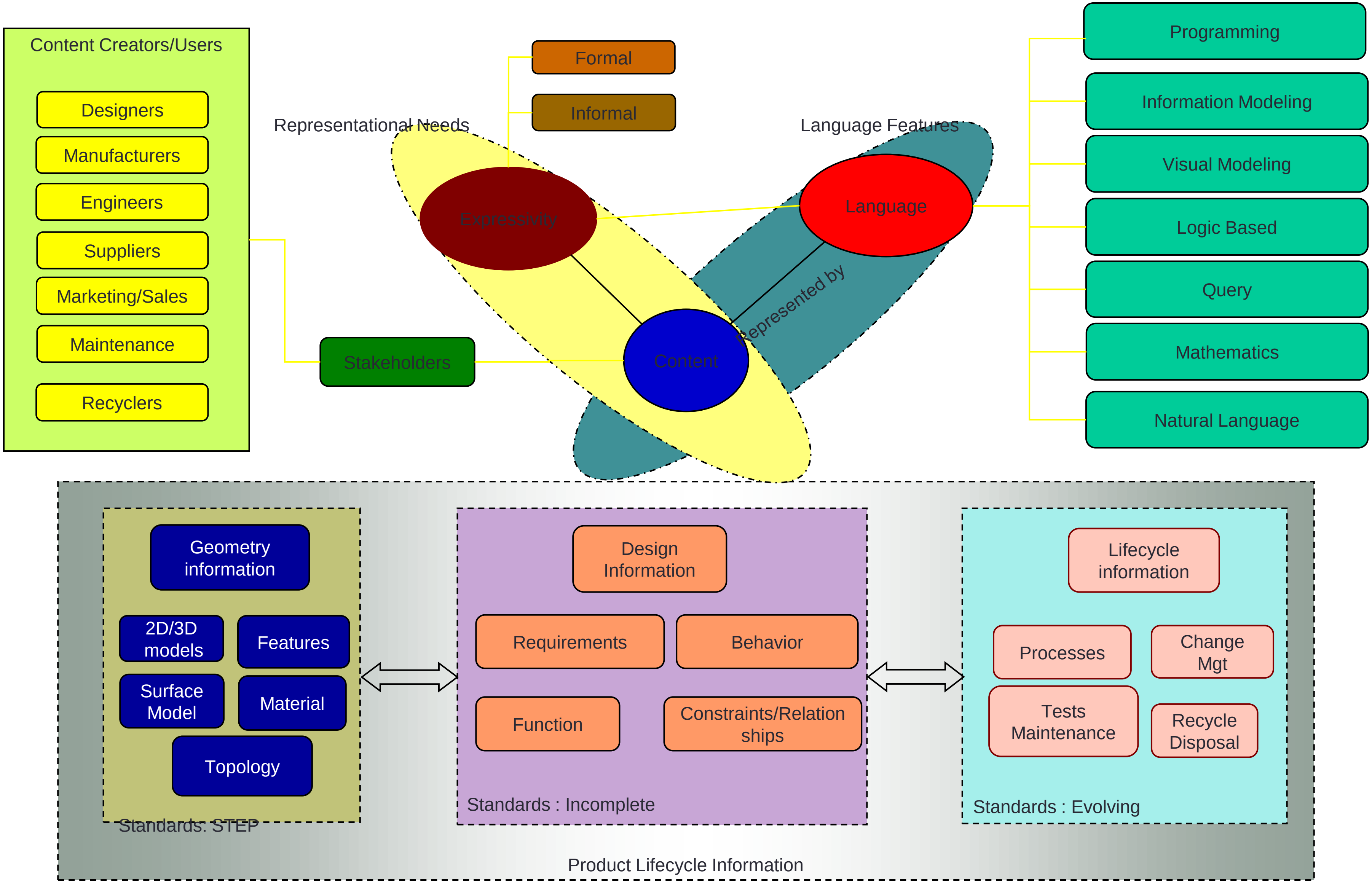
# Product Representation: Summary



# Communication Levels

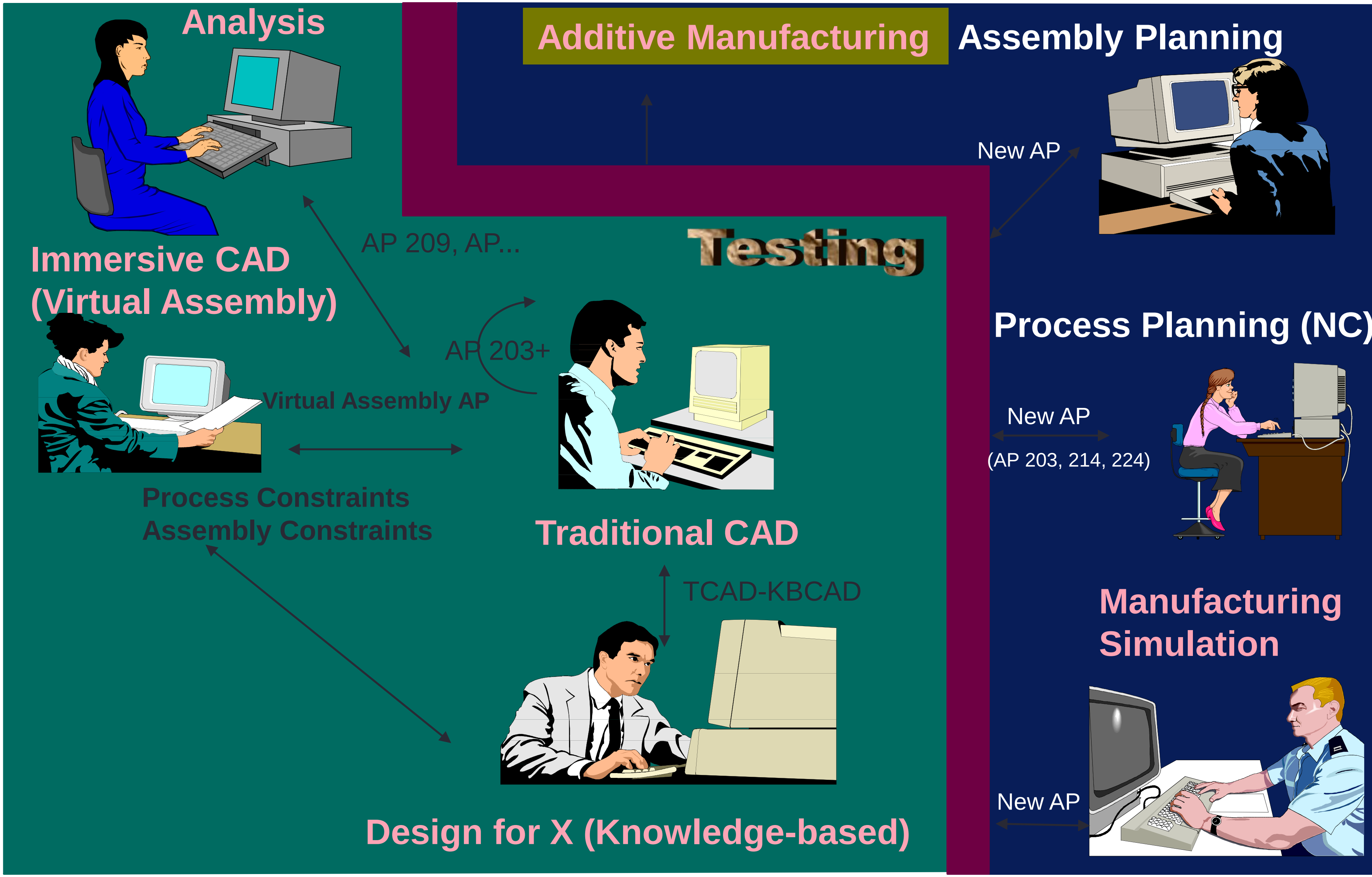


# Content, Language, and Expressivity

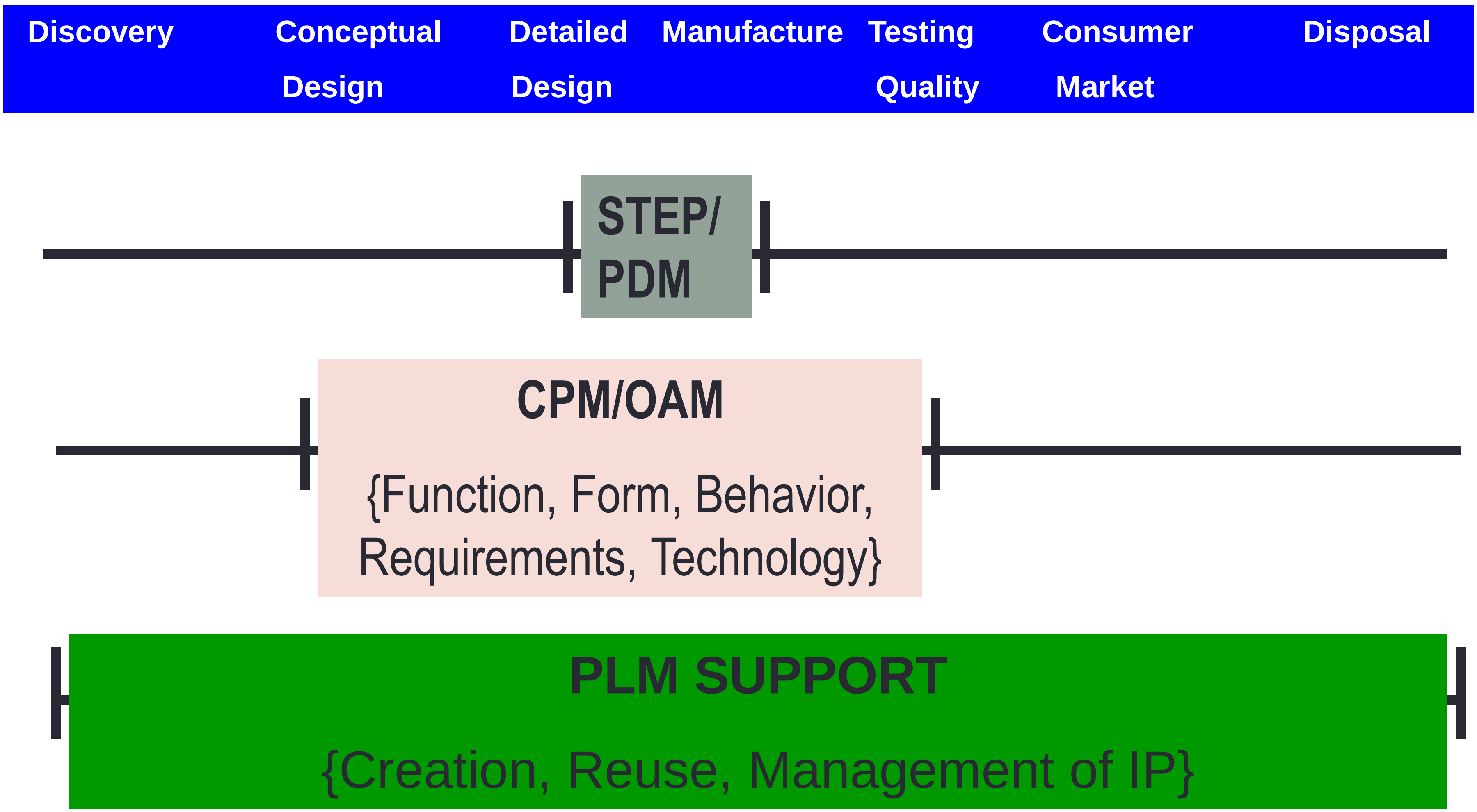



*Courtesy: Subrahmanian*

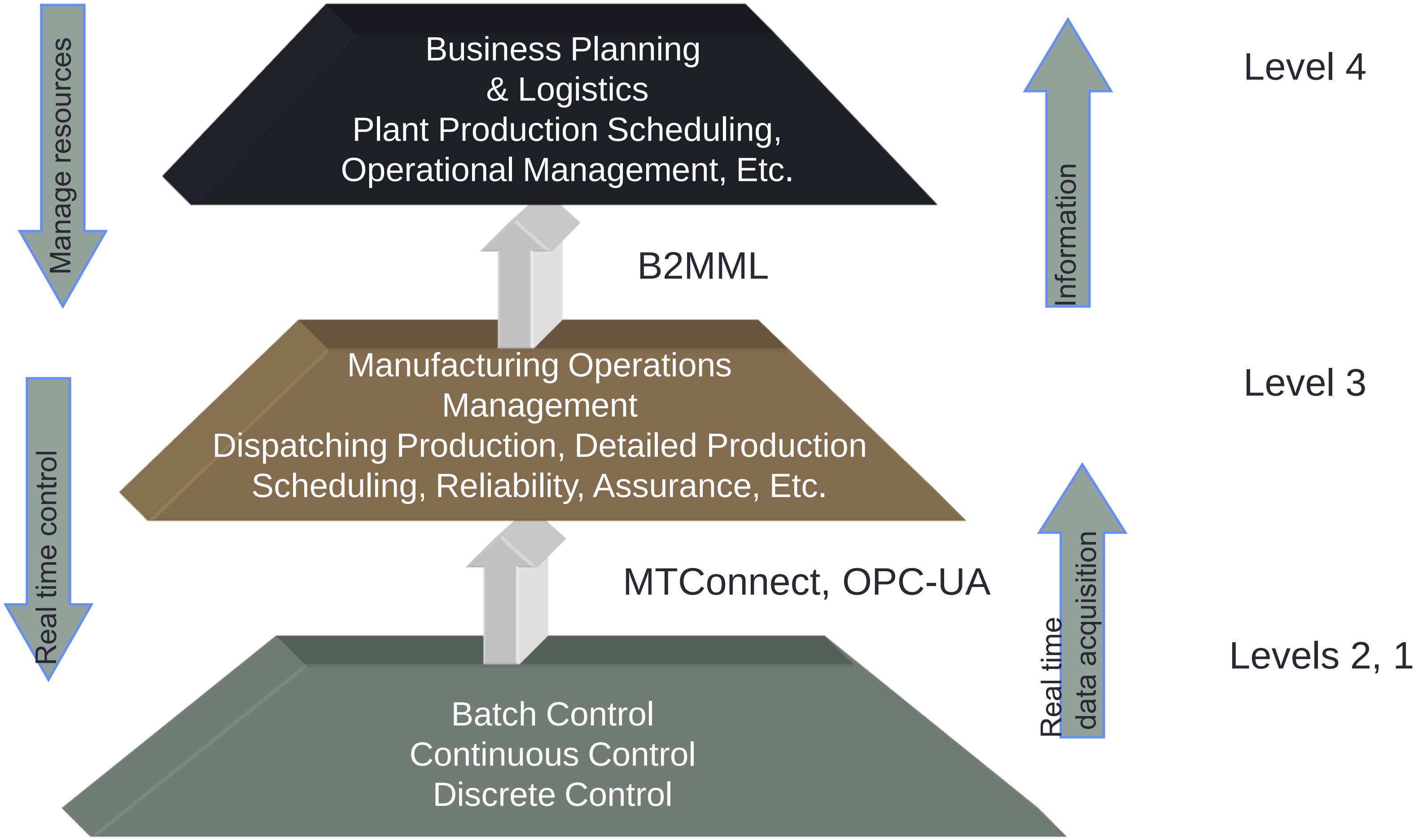
# Design-Manufacturing Integration



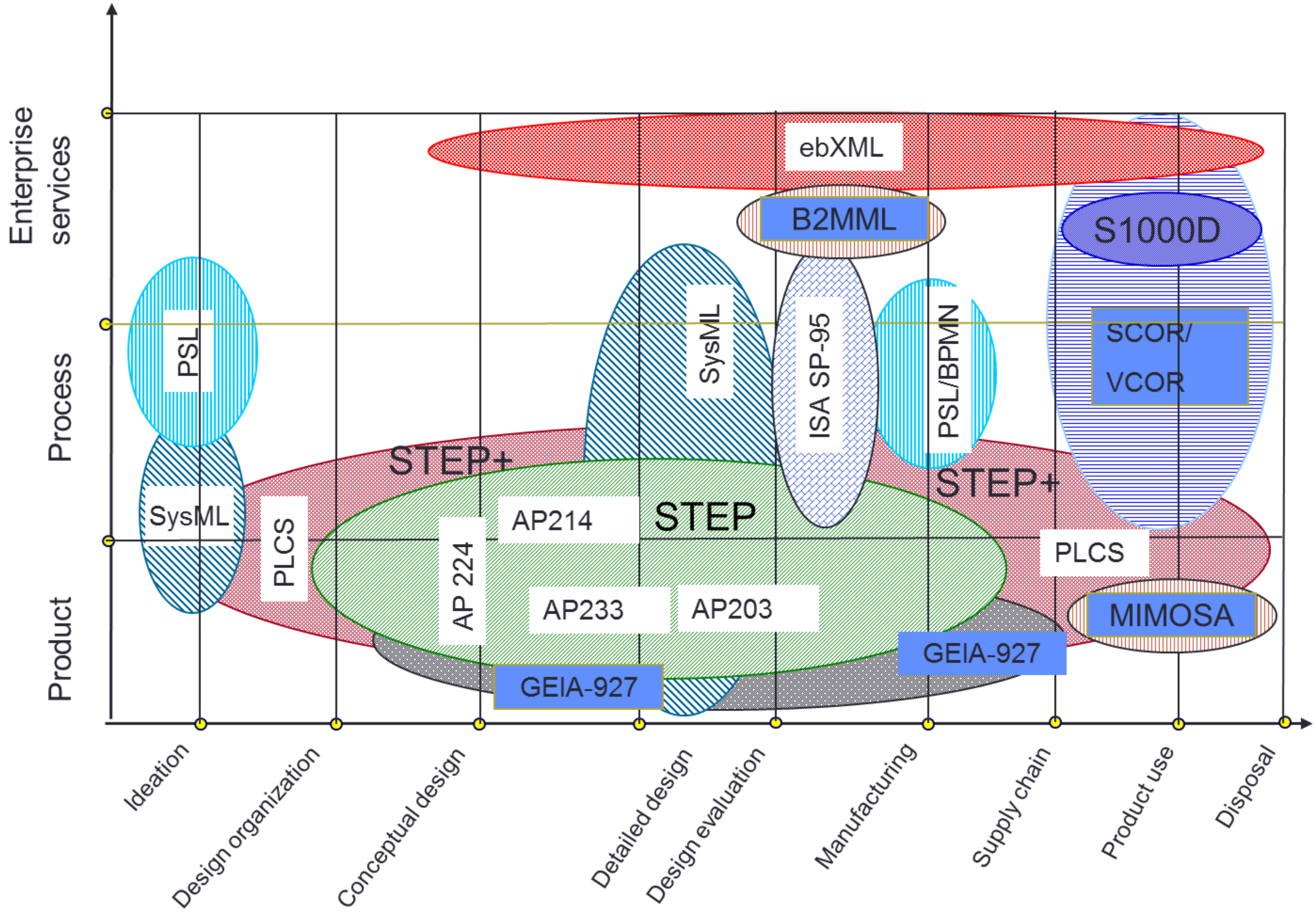
# A Broad Overview of Standards



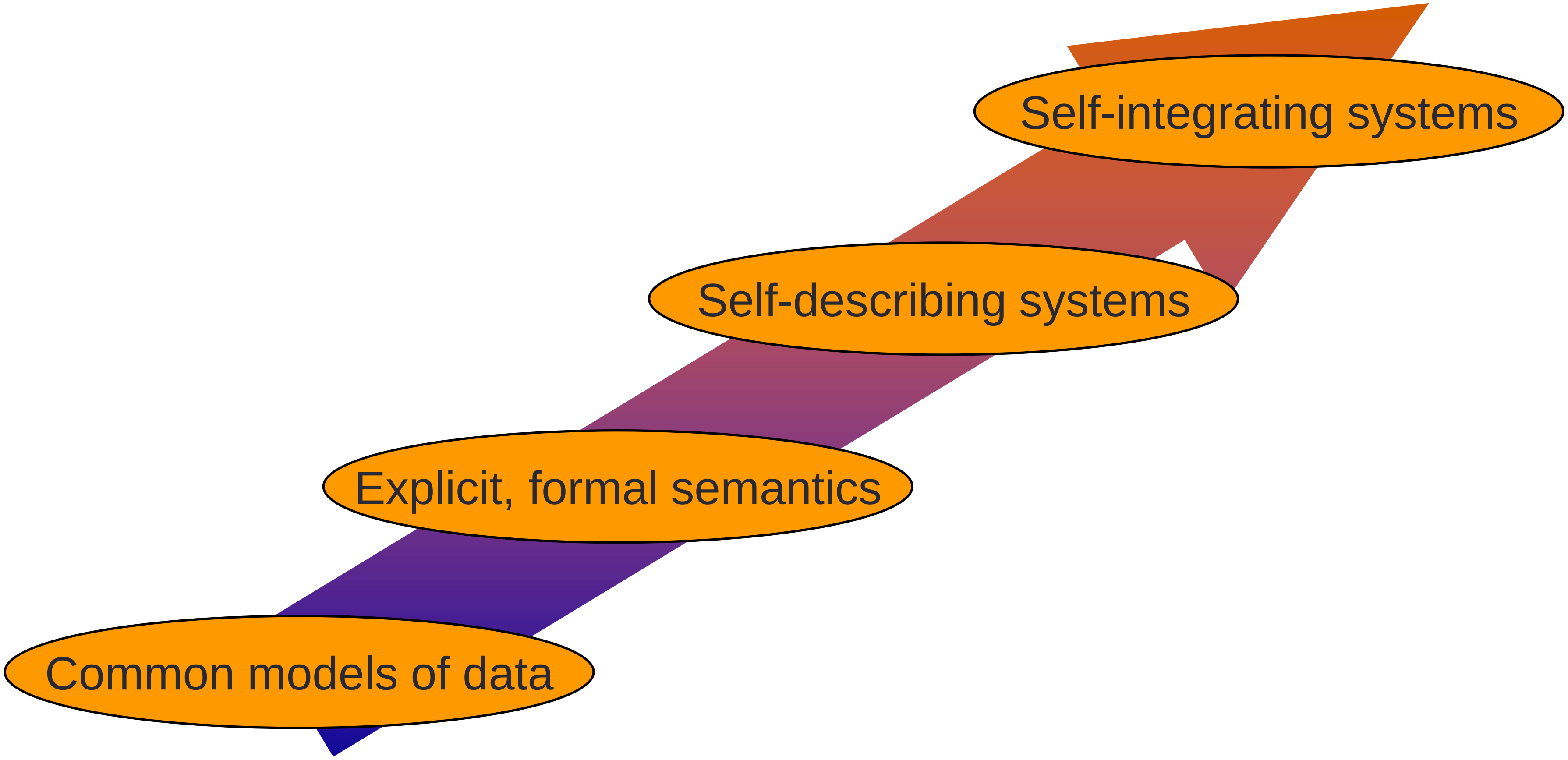
# ISA 95 Model for Enterprise-Control System Integration



# Representative Standards



# Roadmap for Systems Integration



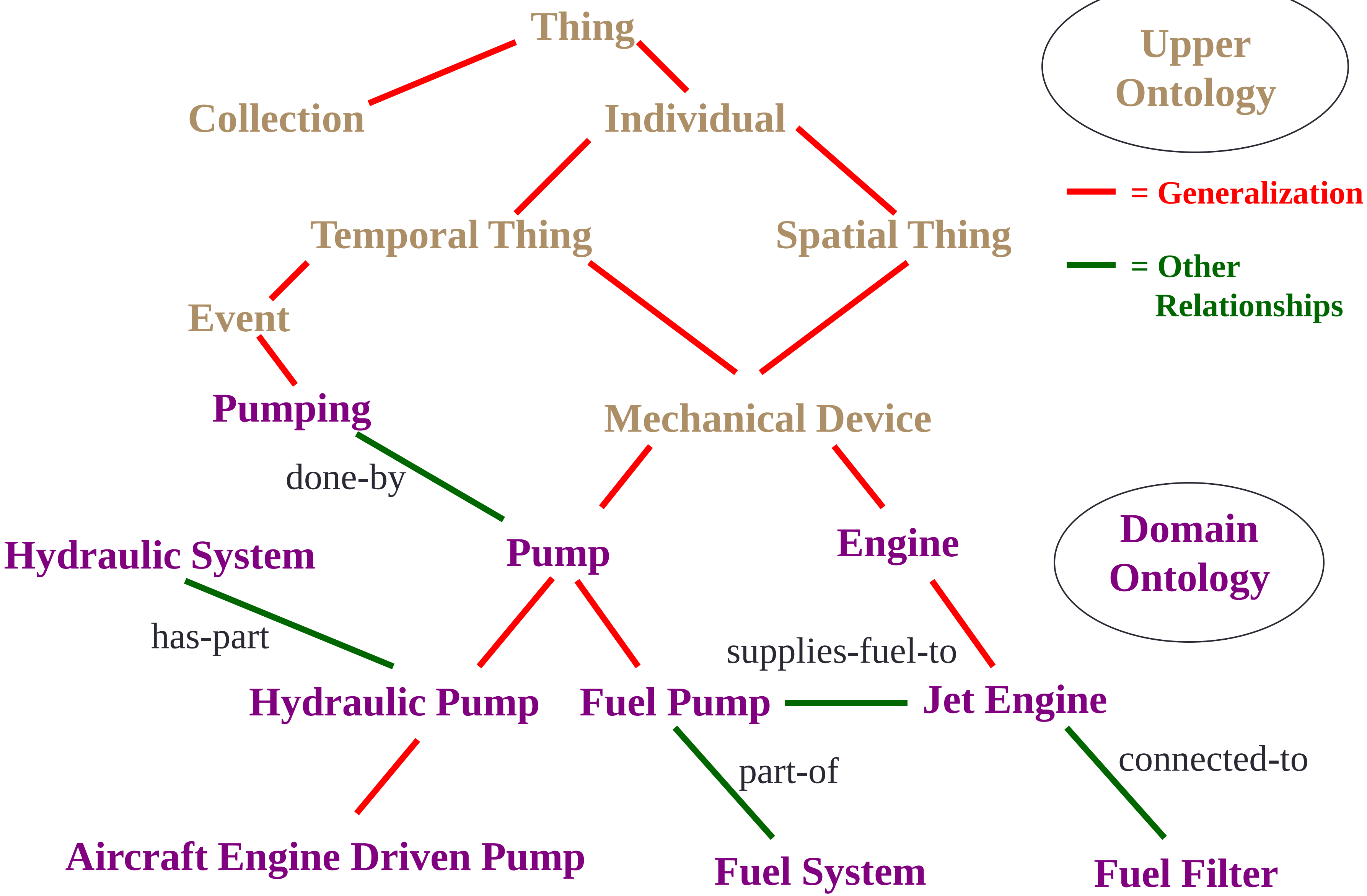
# Self Integrating Systems: Achieving Semantic Interoperability

To achieve semantic interoperability we will need to encode semantics of the domain. Ontologies provide one such path.

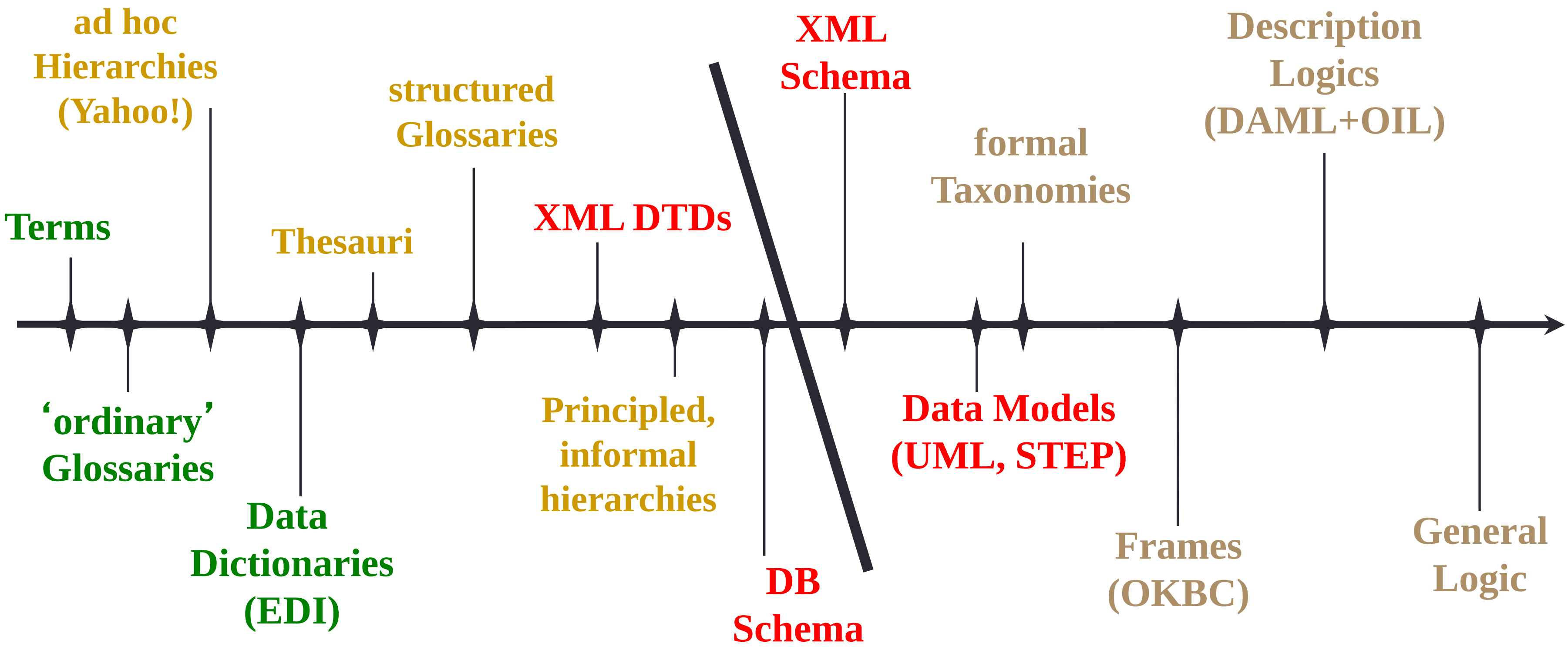
# What Is An Ontology

- An ontology is an explicit description of a domain:
  - concepts
  - properties and attributes of concepts
  - constraints on properties and attributes
  - Individuals *(often, but not always)*
- An ontology defines
  - a common vocabulary
  - a shared understanding

# Engineering Ontology



# Kinds of Ontologies



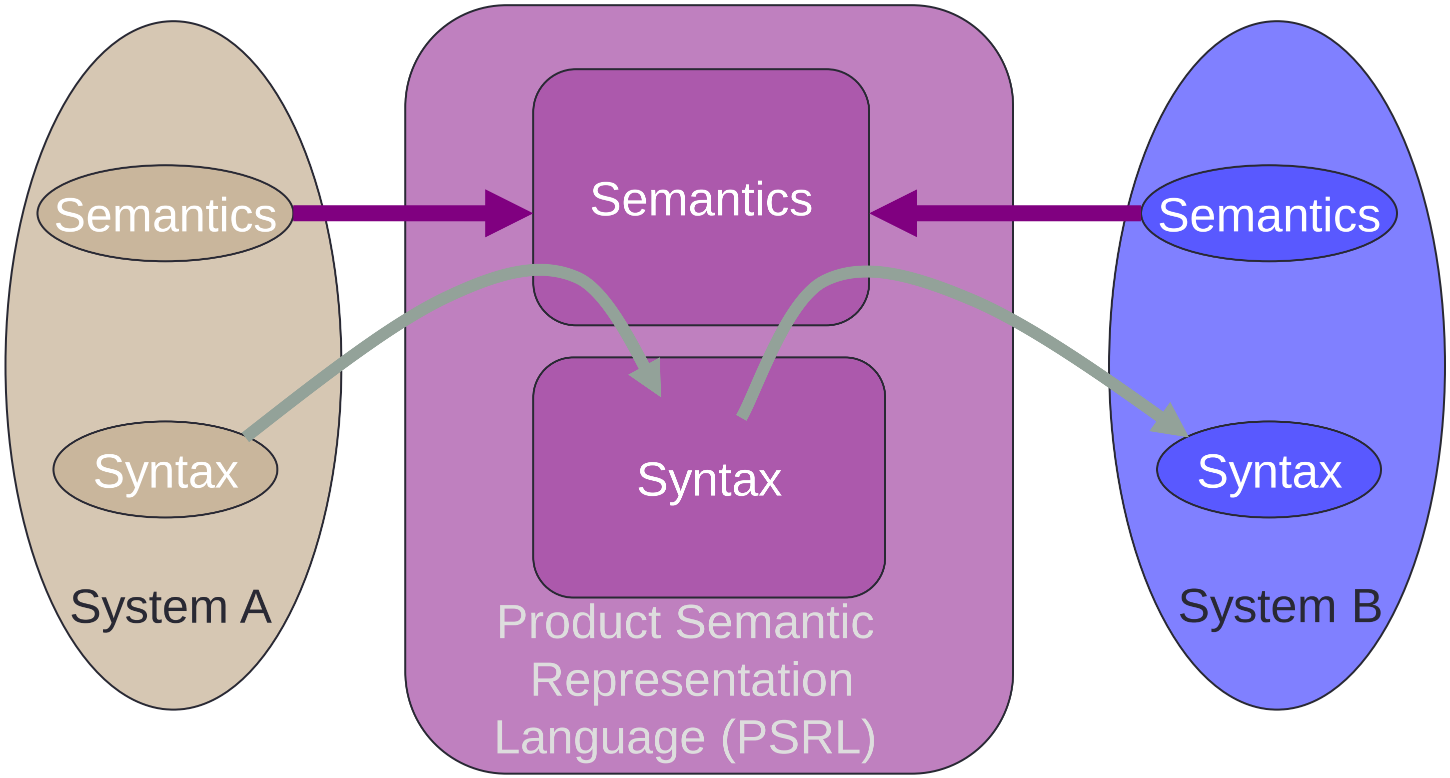

***Glossaries & Data Dictionaries***

***Thesauri, Taxonomies***

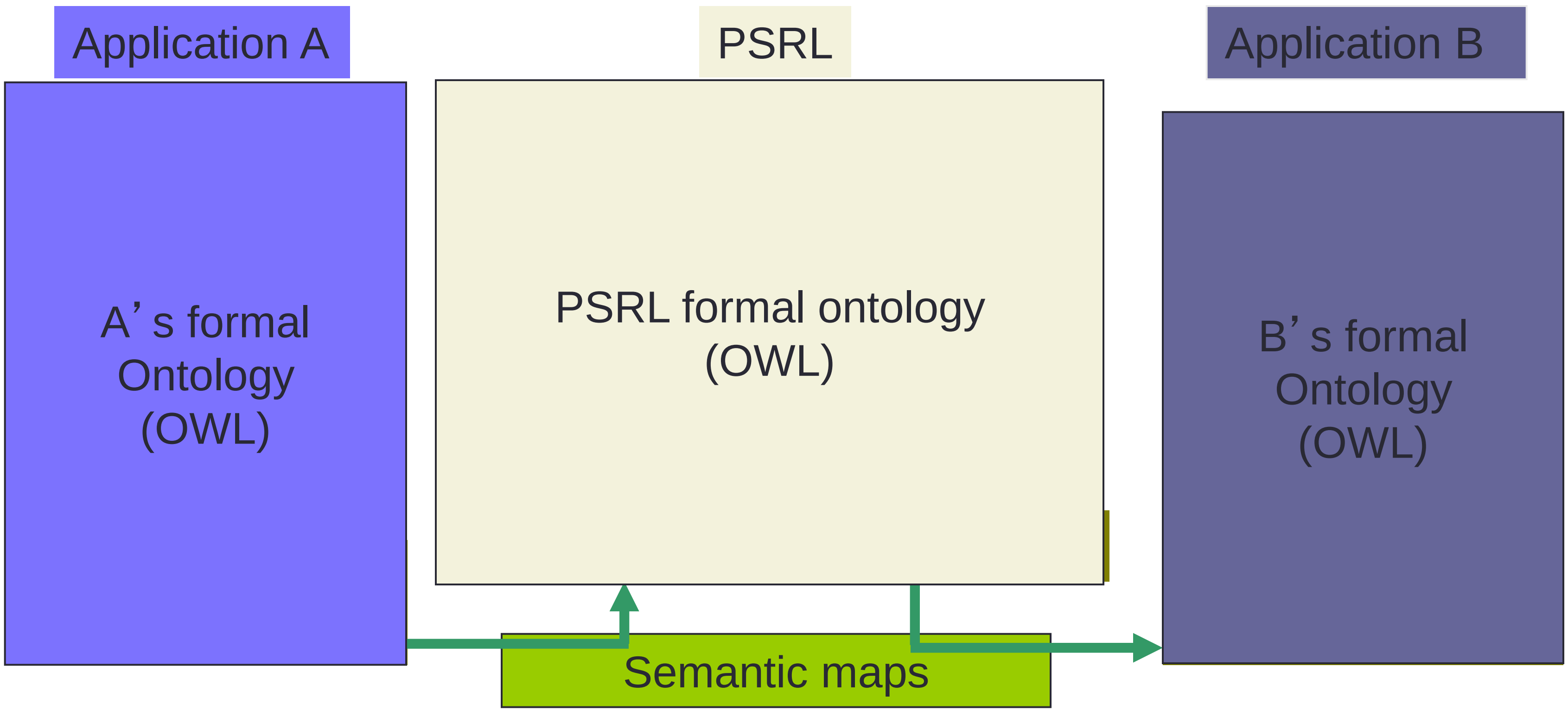
***MetaData, XML Schemas, & Data Models***

***Formal Ontologies & Inference***

# Semantic interoperability of product information

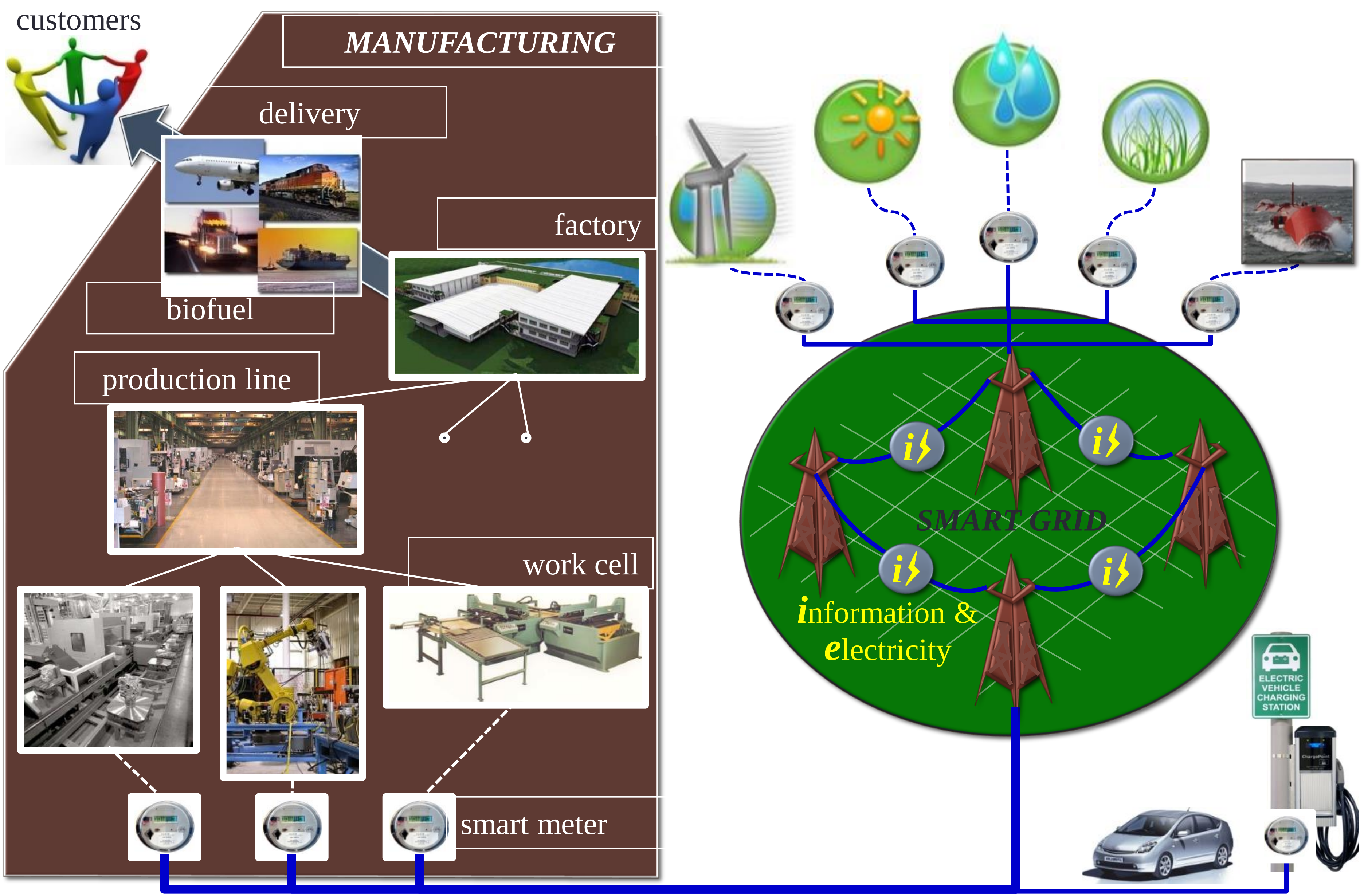


# Semantic interoperability: Technical approach



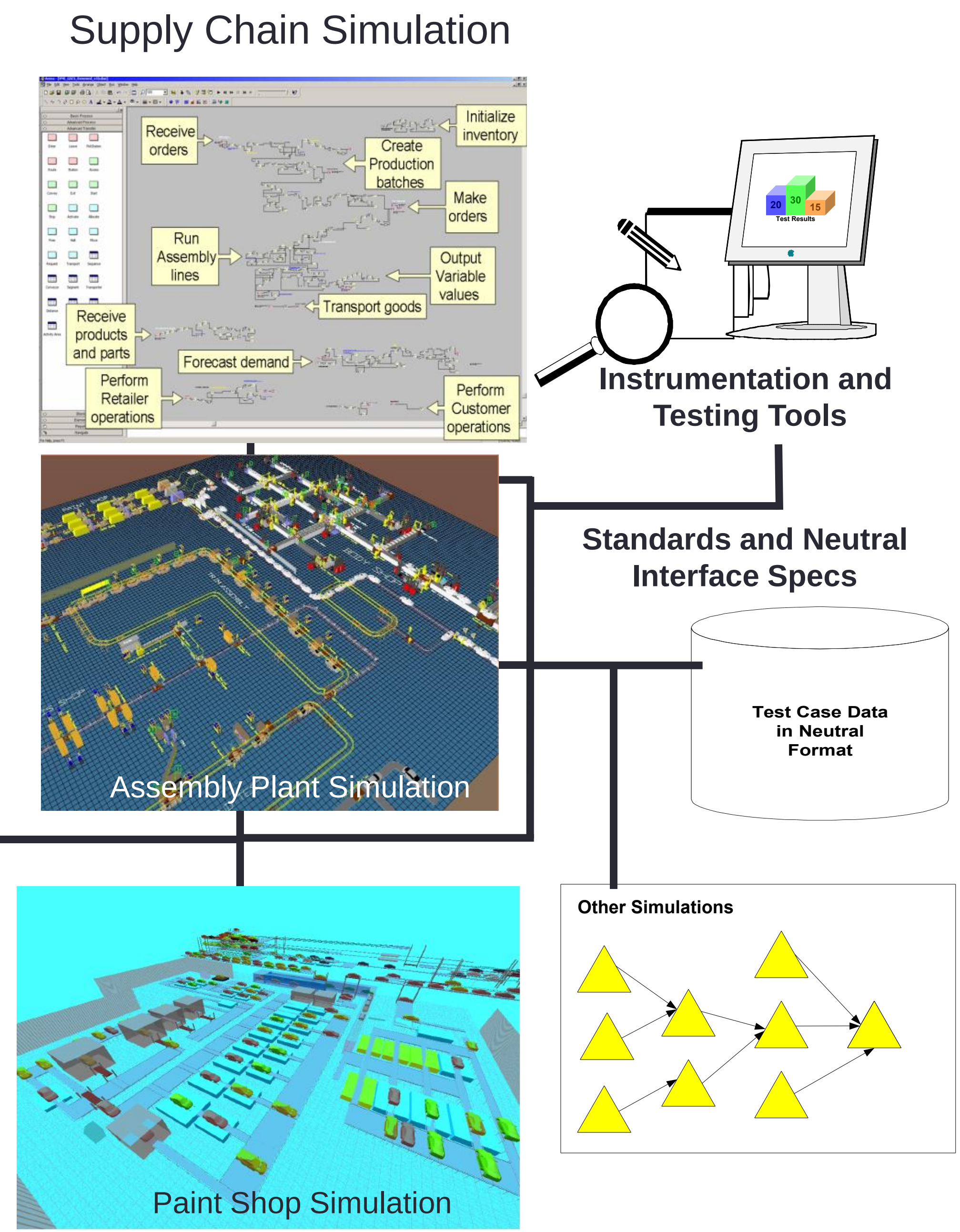
# Why is all this important?

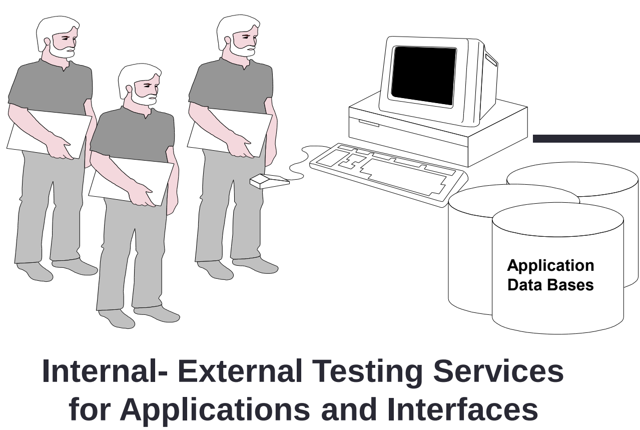
# Example 1: Manufacturing on Smart Grid using Renewable Energy



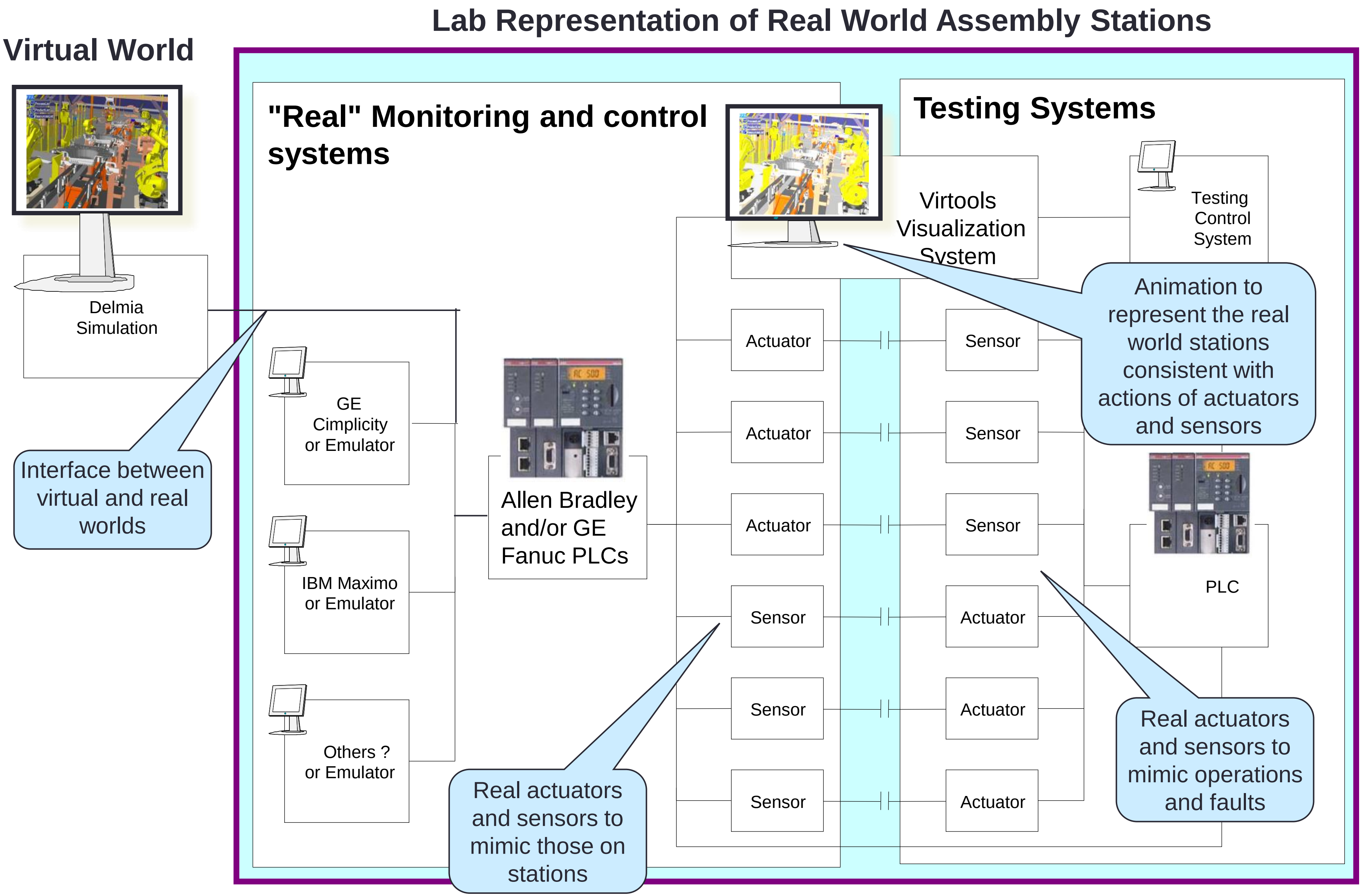
# Example 2: Virtual Manufacturing

Establish the VME test bed to include simulations of manufacturing supply chains, facilities, systems, operations, and processes as well as interface specifications, testing tools, and data sets



# Example 3: Testing Interoperable Virtual to Real-World Environment



# Discussions

# A Vision for Manufacturing Information Network

A widely available, easy to use service to:

- discover and connect design and manufacturing services
- securely exchange information
- develop a plug and play model evolving networks

# Features of MIN

- Heterogeneous networks of design and manufacturing services
- No single, top-down-designed architecture
- Decentralized bottom-up deployment of services responding to specific opportunities/needs
- Need for interoperability among services of vastly different granularities

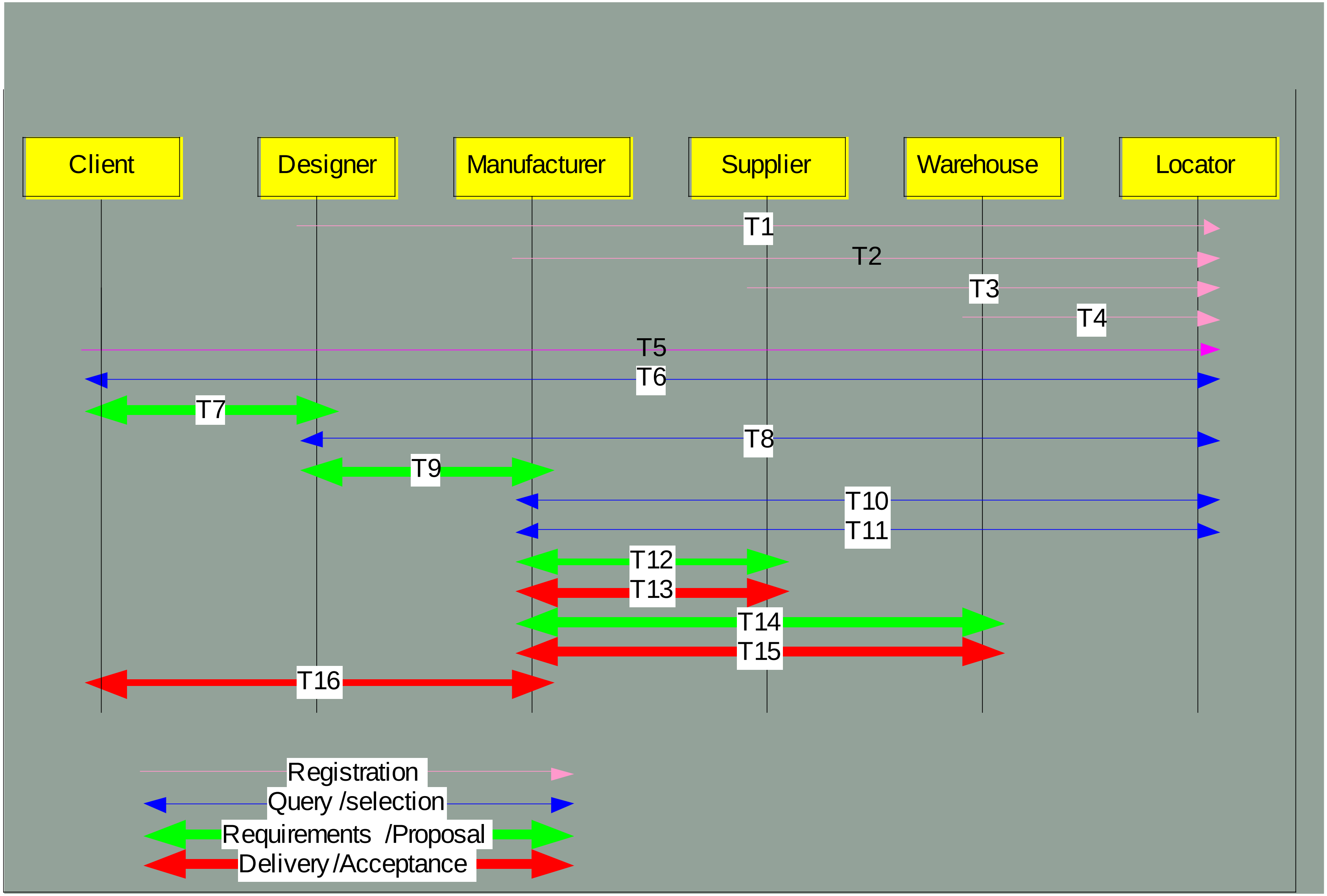
# Services in Strawman Manufacturing Information Network (MIN)

| Code | Description |
|---|---|
| S1 | Client |
| S2 | Designer |
| S3 | Manufacturer |
| S4 | Supplier |
| S5 | Warehouse |
| S6 | Locator |

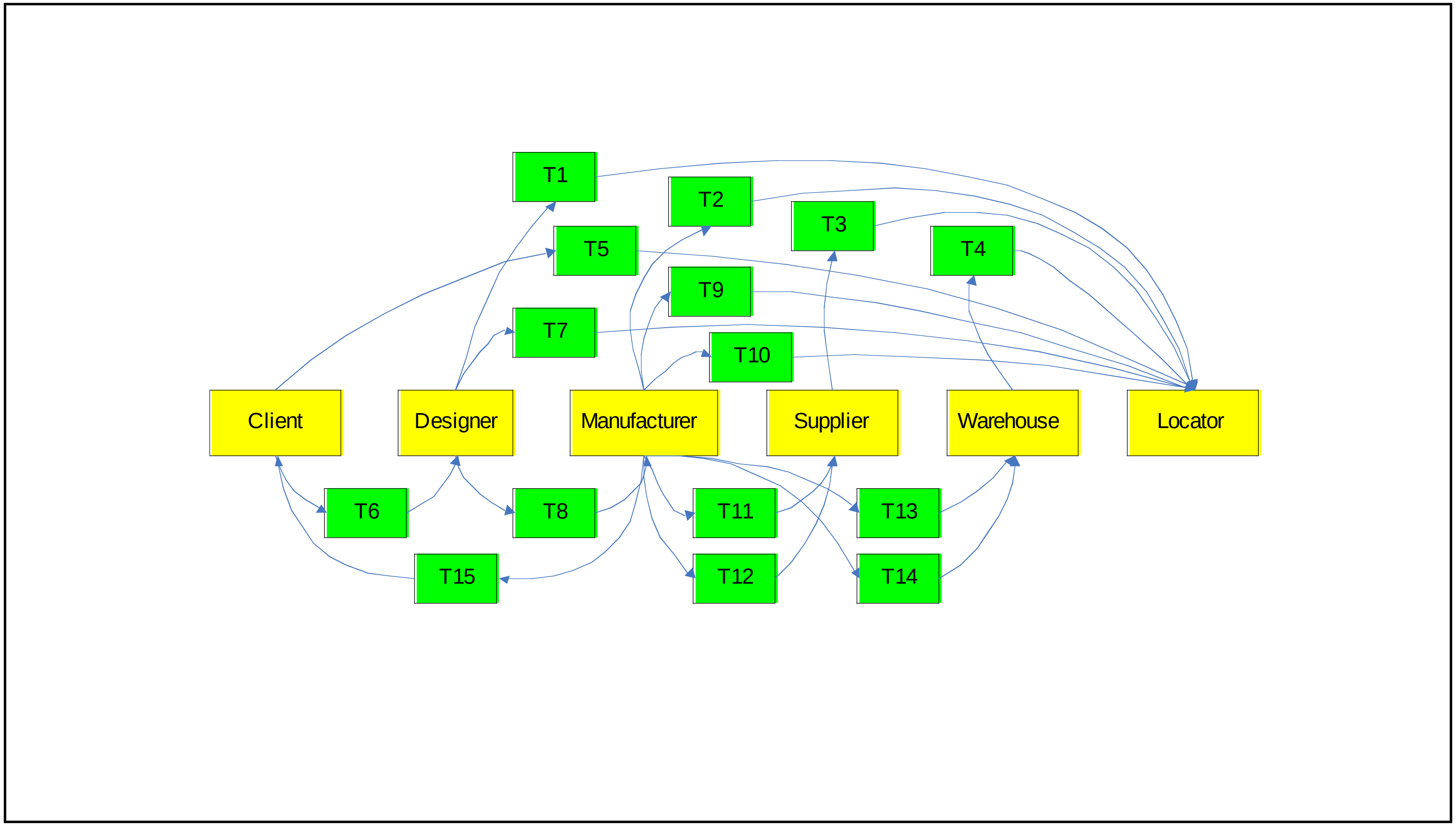
# Sample Set of Transactions for MIN

| Code | Description | From service | To service |
|---|---|---|---|
| T1 | Designer identification | Designer | Locator |
| T2 | Manufacturer identification | Manufacturer | Locator |
| T3 | Supplier identification | Supplier | Locator |
| T4 | Warehouse identification | Warehouse | Locator |
| T5 | Designer selection | Client | Locator |
| | Designer alternates | Locator | Client |
| | Designer approval* | Client | Locator |
| T6 | Initial client specs | Client | Designer |
| | Design proposal | Designer | Client |
| | Design approval* | Client | Designer |
| T7 | Manufacturer selection | Designer (or client) | Locator |
| | Manufacturer alternates | Locator | Designer (or client) |
| | Manufacturer approval* | Designer (or client) | Locator |
| T8 | Manufacturing specifications | Designer | Manufacturer |
| | Manufacturer feedback | Manufacturer | Designer |
| | Manufacturing approval* | Designer | Manufacturer |
| T9 | Supplier selection | Manufacturer | Locator |
| | Supplier alternatives | Locator | Manufacturer |
| | Supplier approval* | Manufacturer | Locator |

## Interaction Diagram: Manufacturing Straw Man Use Case



# Manufacturing Strawman Use Case

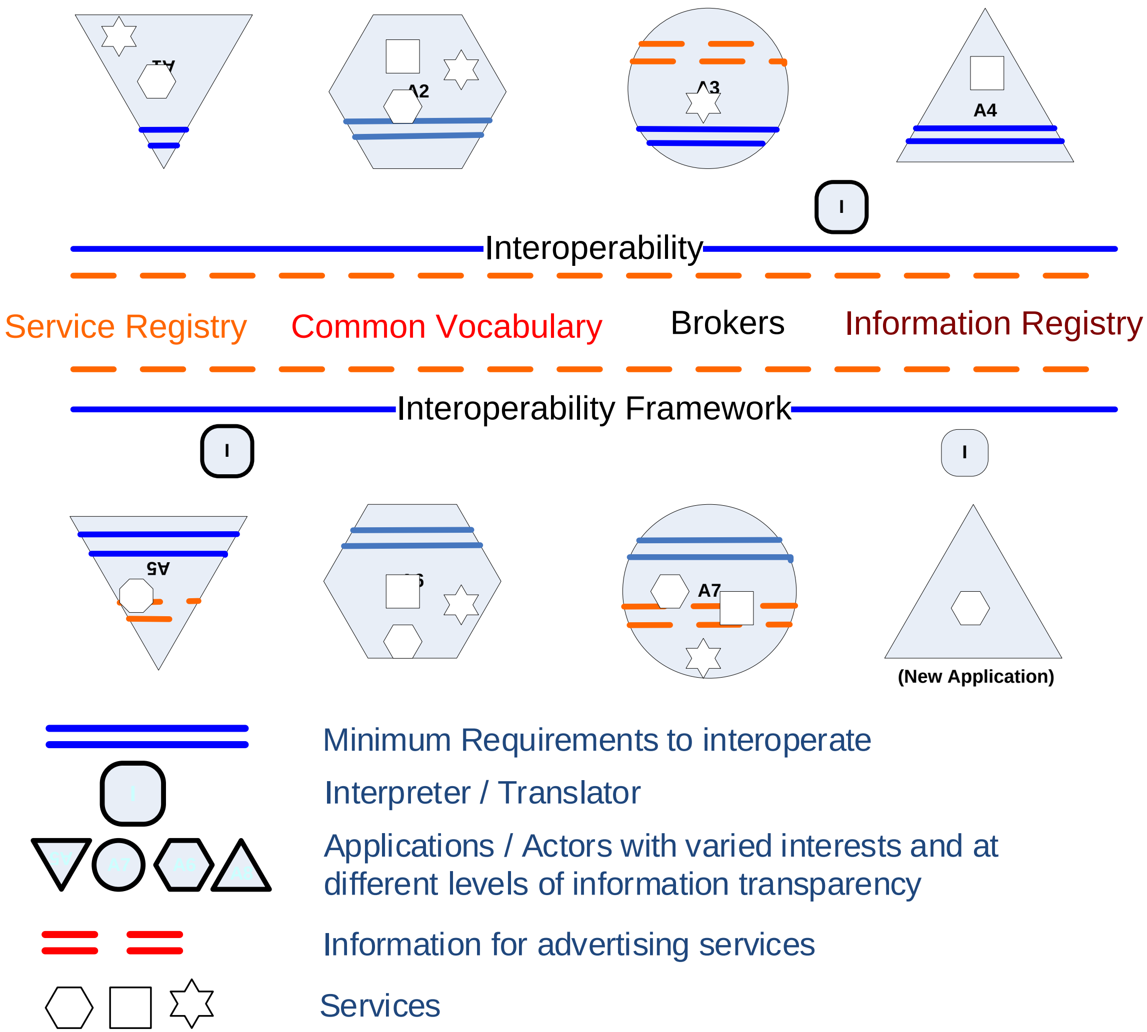


# Challenges for MIN

- Model services in Design and Manufacturing
- Maintain different use case scenarios
- Provide location services based on demand
- Test service to service interaction requirements
- Simulate different MIN architectural models
- Apply Complex Adaptive Systems theory to characterize and model supply chains

# Composable Virtual Manufacturing Networks

NETWORK-CENTRIC




- Dynamically created from global resources
- Service oriented architecture
- Communications infrastructure that automates, as much as possible, the exchange of required manufacturing- and business-related knowledge

# Composable Virtual Manufacturing Networks

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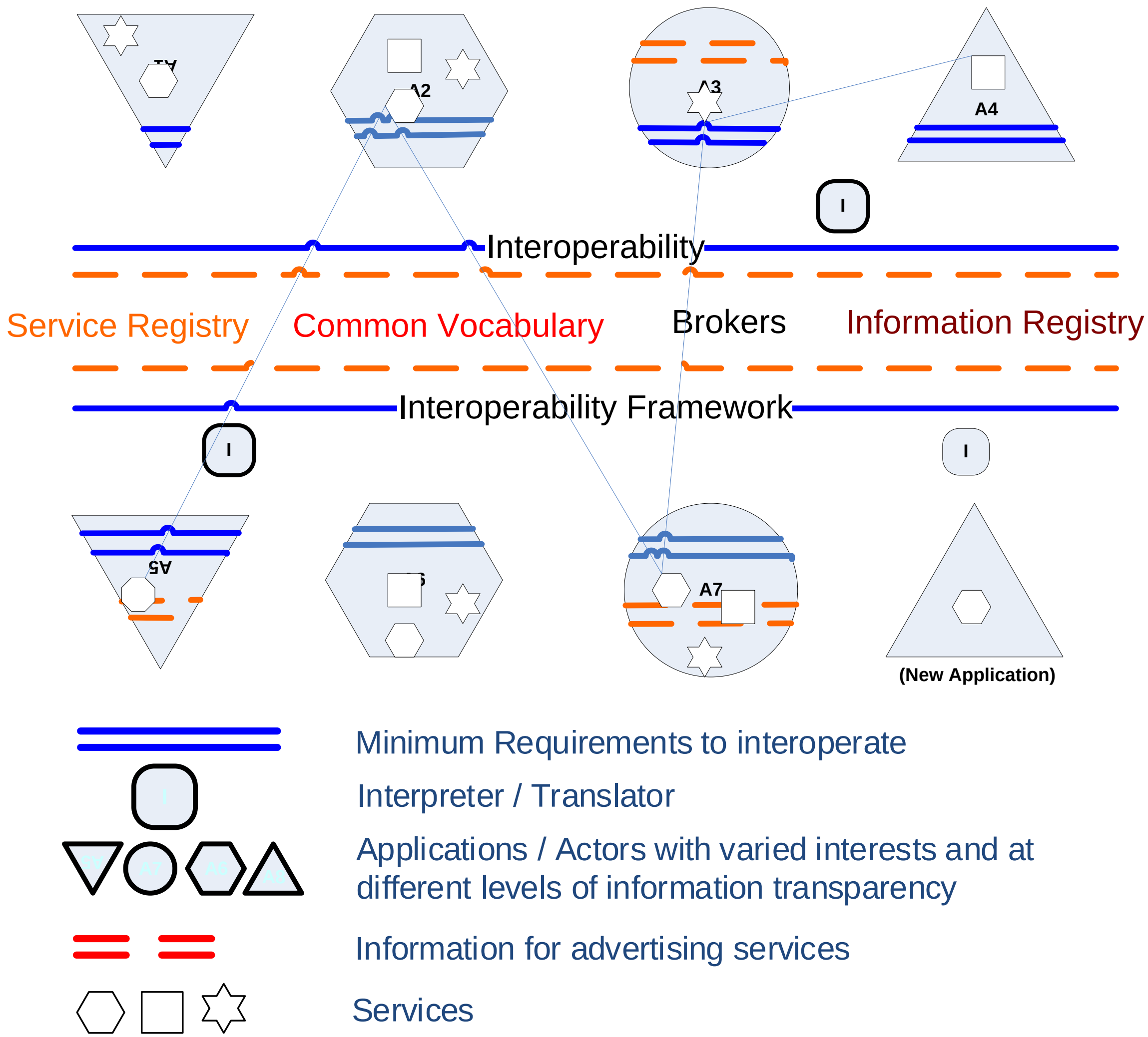
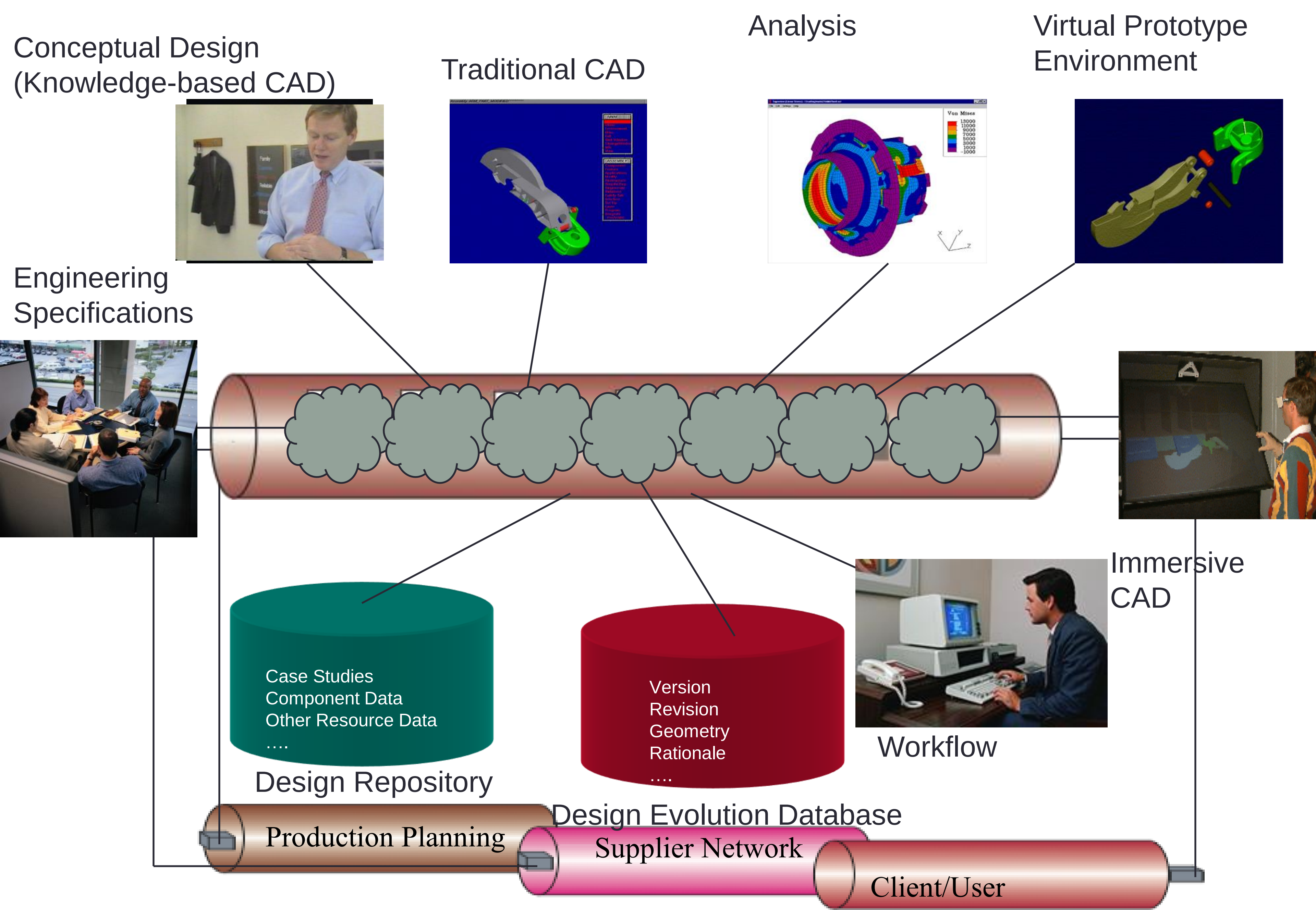
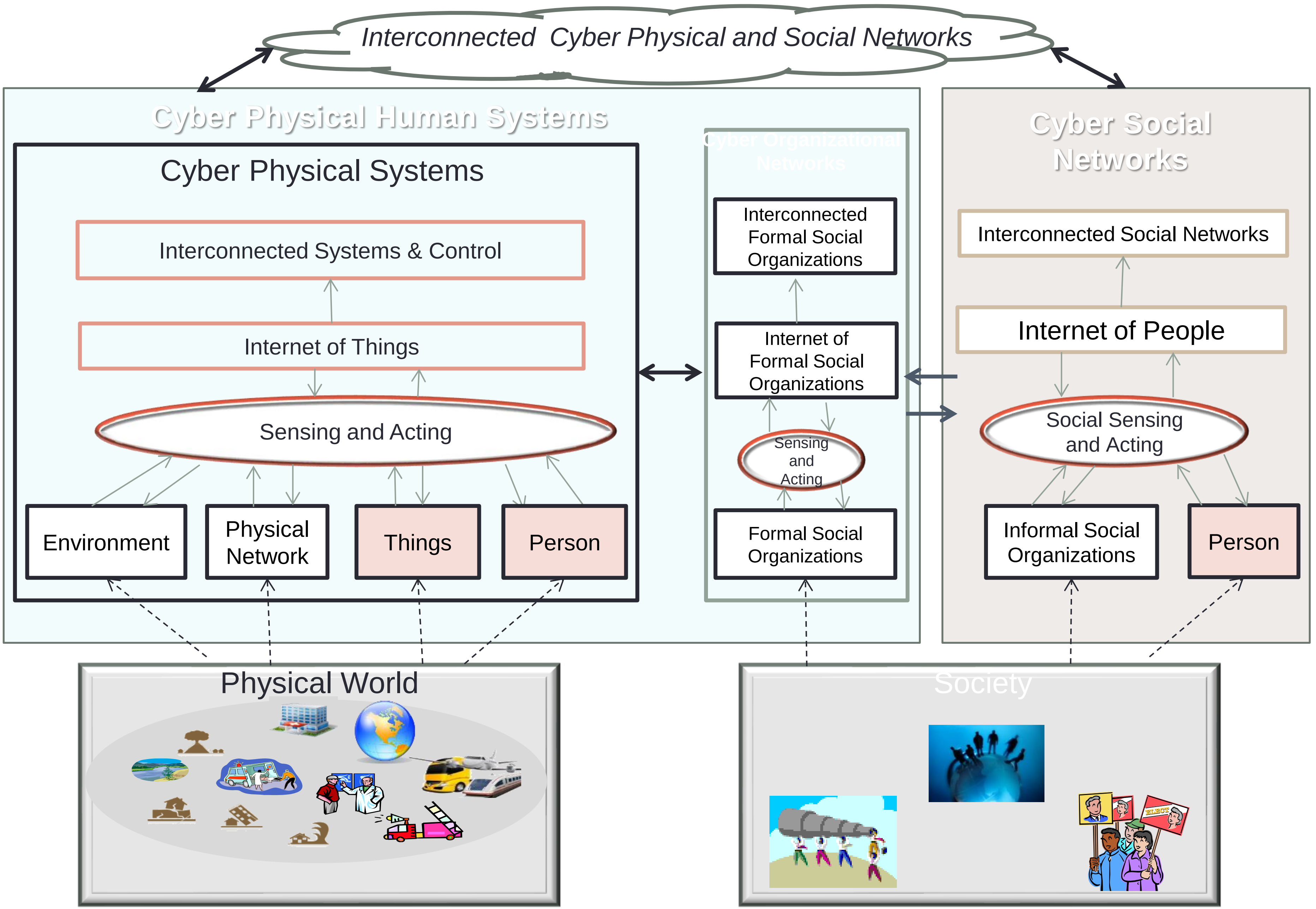



*Services:* engineered for interoperability , supports open environment.

*Knowledge Repositories:* support s structured and unstructured information, semantically rich metadata, advertisement services

*Brokers:* bureau services, dynamically assemble components belonging to different applications into integrated processes


Conceptual Design
(Knowledge-based CAD)
Traditional CAD
Analysis
Virtual Prototype
Environment
Engineering
Specifications
Immersive
CAD
Case Studies
Component Data
Other Resource Data
….
Design Repository
Version
Revision
Geometry
Rationale
….
Design Evolution Database
Workflow
Production Planning
Supplier Network
Client/User




*Courtesy: Subrahmanian*

# Homework Assignment

Explore Smart Manufacturing Platforms

- Industrial Internet Reference Architecture (IIRA)
- Reference Architectural Model for Industrie (RAMI) 4.0

Create 4 slides on what you learnt

- Send the slides to Dhairya Shah by 4/15
- Present and discuss in the next class 4/16