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Research Advances in Manufacturing with Service-Oriented e-Work and Production

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PRISM Lab/Purdue

PRISM Center
Production, Robotics, and Integration
Software for Manufacturing and Management

"Knowledge through information; Wisdom through collaboration"

PURDUE UNIVERSITY

Service as product; Service-added value

I slept and dreamt that life was joy.

I awoke and saw that life was service.

I acted and behold, service was joy.

Rabindranath Tagore

- Software as service
- Upgrades
- Repairs; maintenance
- Design and innovation services
- Reverse logistics (sustainability)
- Service engineering

Can intelligent mfg. exist without them?

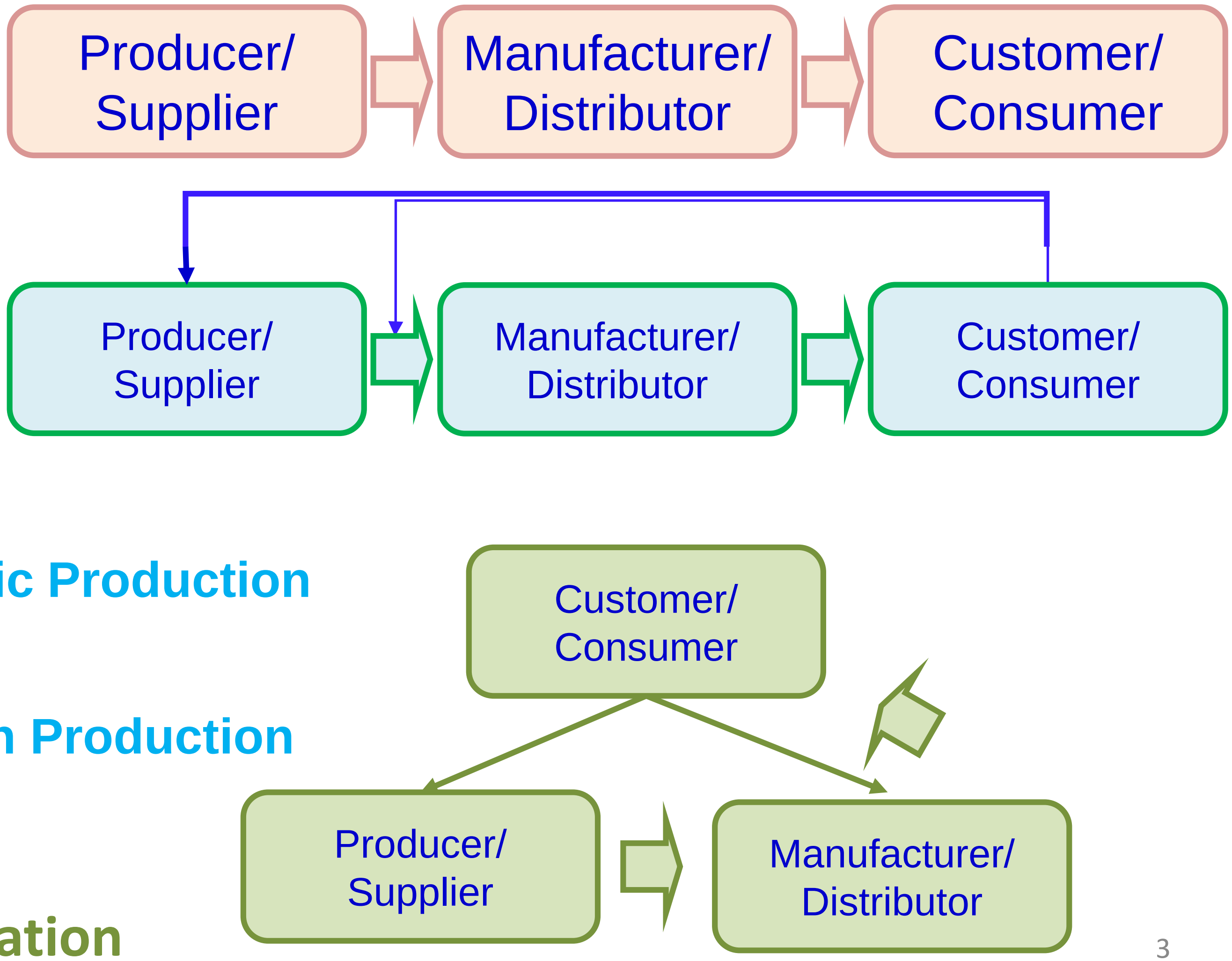
Stages of advancing supply & mfg. services – enabled by better information exchange and knowledge sharing (*internal and external*)

a. Push Production

b. Pull Production

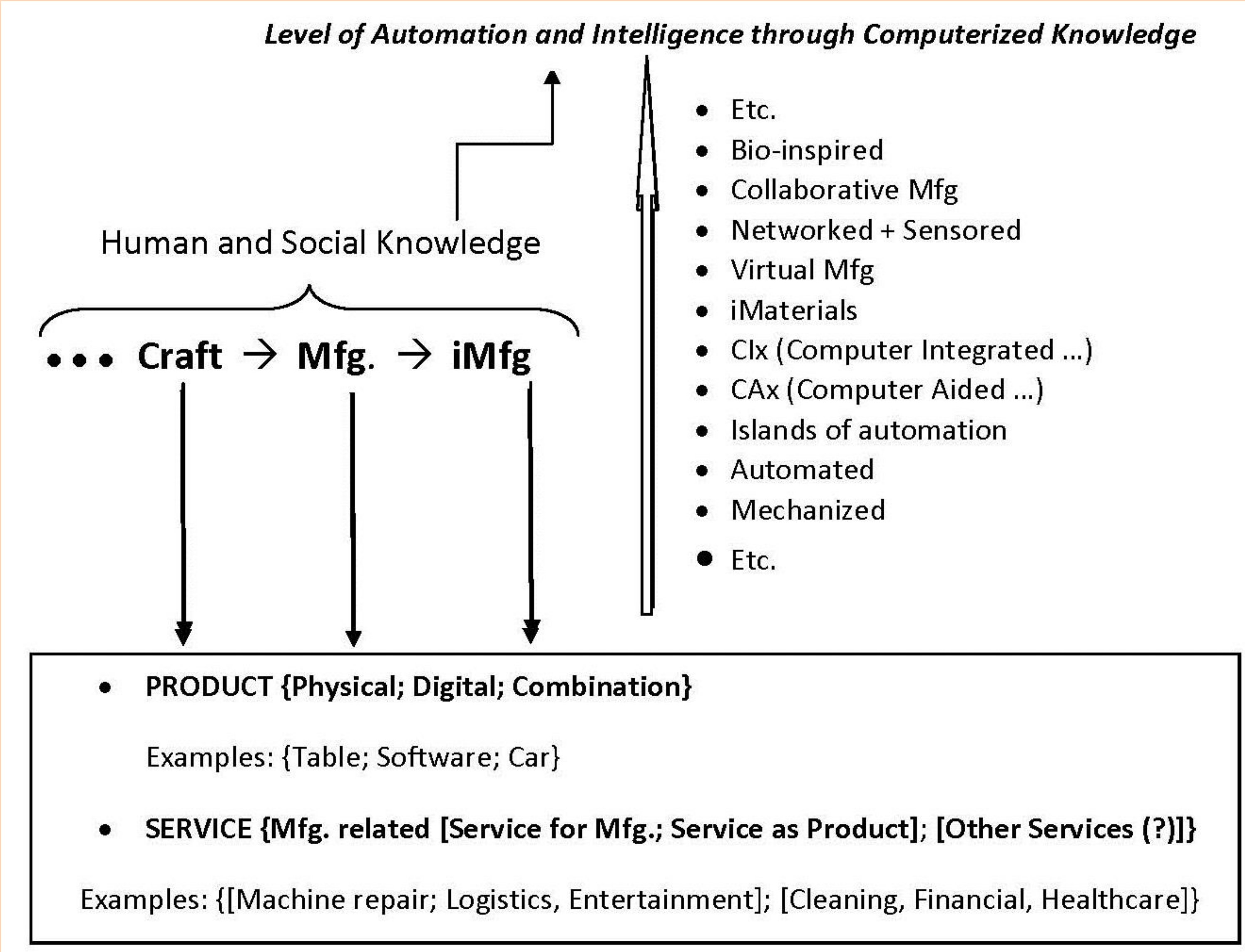
c. Customer - Centric Production

d. Customer - Driven Production



1/2. Service Orientation

Intelligent mfg. → Services-oriented mfg.



2/2. Internal and external embedded software services

Increasing role of knowledge services embedded in intelligent manufacturing

Manufacture = (1) Create + (2) Innovate + (3) Design + (4) Market + (5) Supply (including also procure, plan, handle materials, etc.) + (6) Fabricate + (7) Build + (8) Assemble + (9) Test + (10) Inspect + (11) Repair + (12) Package + (13) Ship and Distribute + (14) Install + (15) Maintain, Clean + (16) Recycle

+

Manage: (a) Human Resources + (b) Finance + (c) Transport + (d) Facilities and Projects + (e) Accounting + (f) Utilities + (g) Information + (h) Legal and Community Relations + (i) Inspiration, Innovation, Beauty and Spirit of Manufacturing.

Work → e-Work → c-Work as services become inherent to manufacturing <u>within an enterprise</u>

Knowledge Services:
Information,
Control,
Interactions,
Decisions

Major service tools of c-Work

Error elimination; Faster; Higher integration complexity

Services become inherent to mfg. throughout the supply network's interactions

Challenges in Collaborative e-Work and e-Service

Proctor et al. (2011); Singh & Khamba (2011); PPC (2012); Nof et al. (2013)

- The principles of the work system have changed.
- Advancing technology increases productivity yet challenges and complexities also increase:

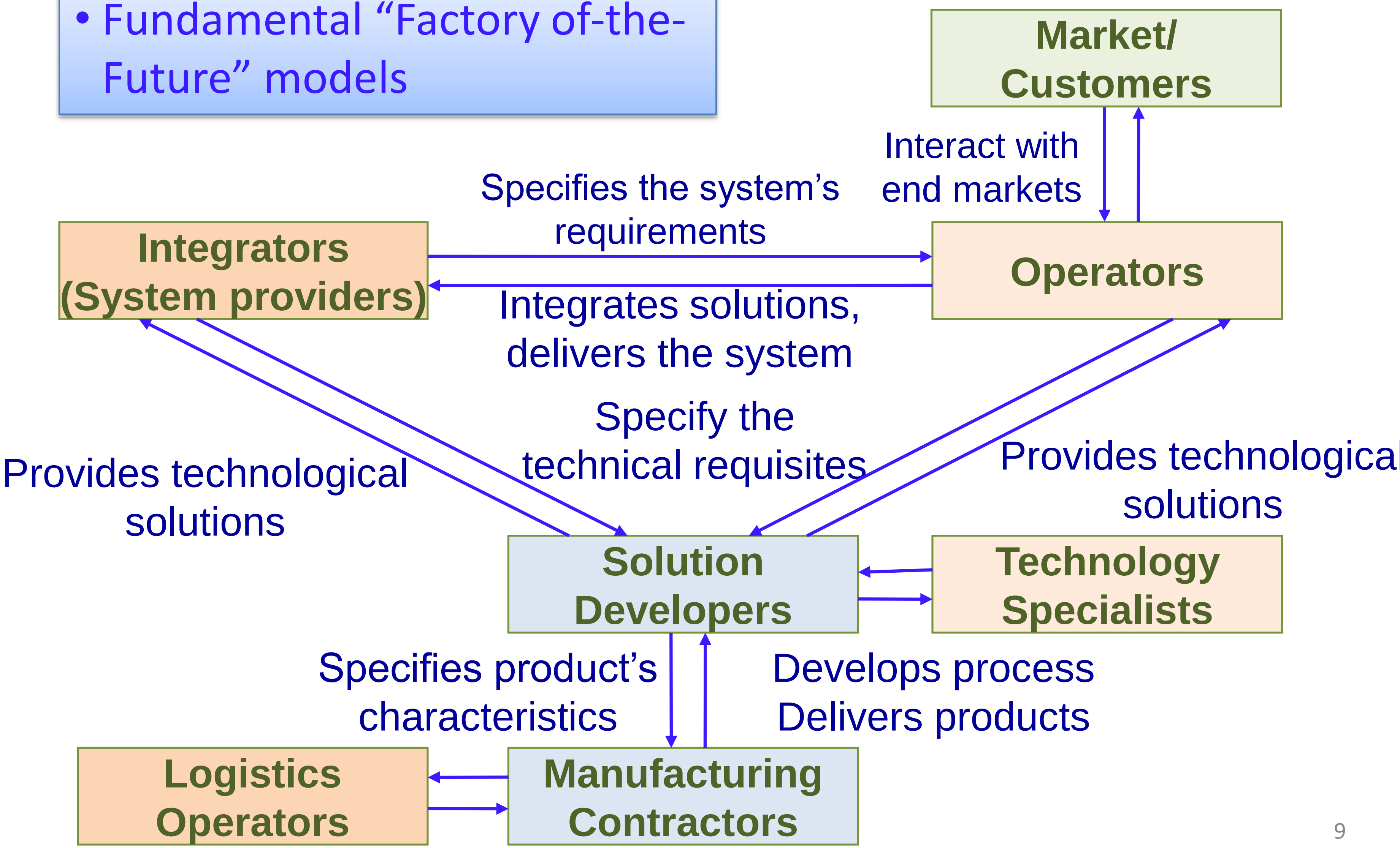
1. Optimize operations despite information and task **overloads**;
2. **work complexity**;
3. Higher inter-**dependence**;
4. **Integrity** and **trust**;
5. Need for **coordination, cooperation**, and **synchronization**;
6. **Communication** challenges and failures;
7. **Mismatch** obstacles -- inconsistent versions, cultural differences;
8. Repeated **training** requirements and associated **costs**.

Knowledge-based e-Services are viewed as major contributors for addressing these challenges.

The Telecommunication-Based Factory (TBF)

Fleury & Fleury (2007); Fleury, Gregory, Bennett (2007)

- Fundamental "Factory of-the-Future" models

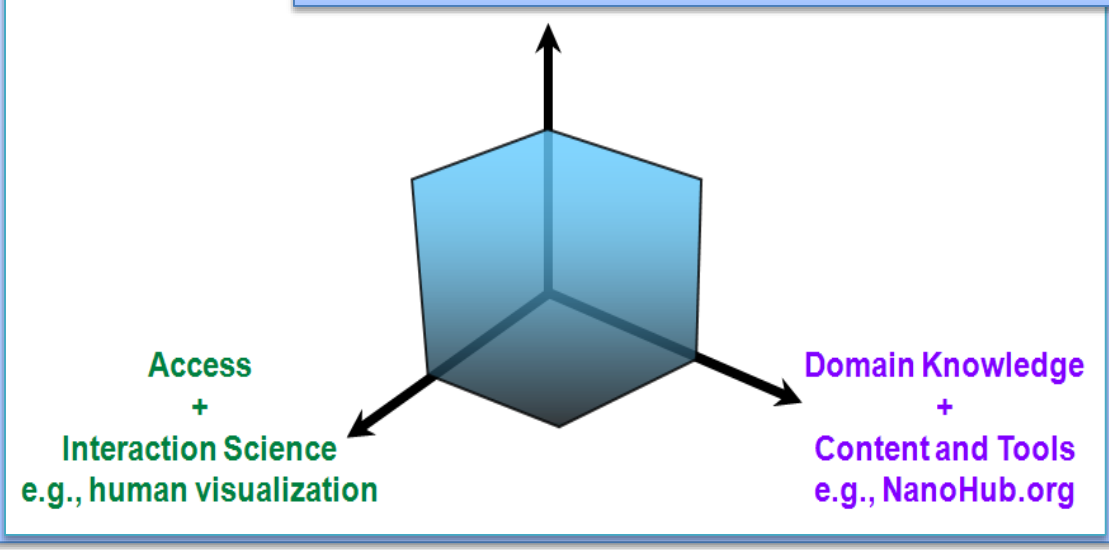


Collaborative Control Theory (CCT) principles, and CSS, Collaboration Support Systems

1. *CRP* : Collaboration Requirement Planning
2. *PARK*: Parallelism + KISS: “Keep It Simple, cyber System!”
3. *CEDP* : Conflict & Error Detection and Prognostics / Prevention
4. *CFT* : Collaborative Fault-tolerance by Teaming
5. *JLR* : Join/ Leave/ Remain in a collaborative network
6. *LOCC*: Lines Of emergent Command and Collaboration

- HUBs (“Internet on steroids”) enable CI, Collaborative Intelligence focused on improving human ability to collaborate effectively

CCT + CSS = Collaboratorium Initiative for CI [Purdue ,2008]



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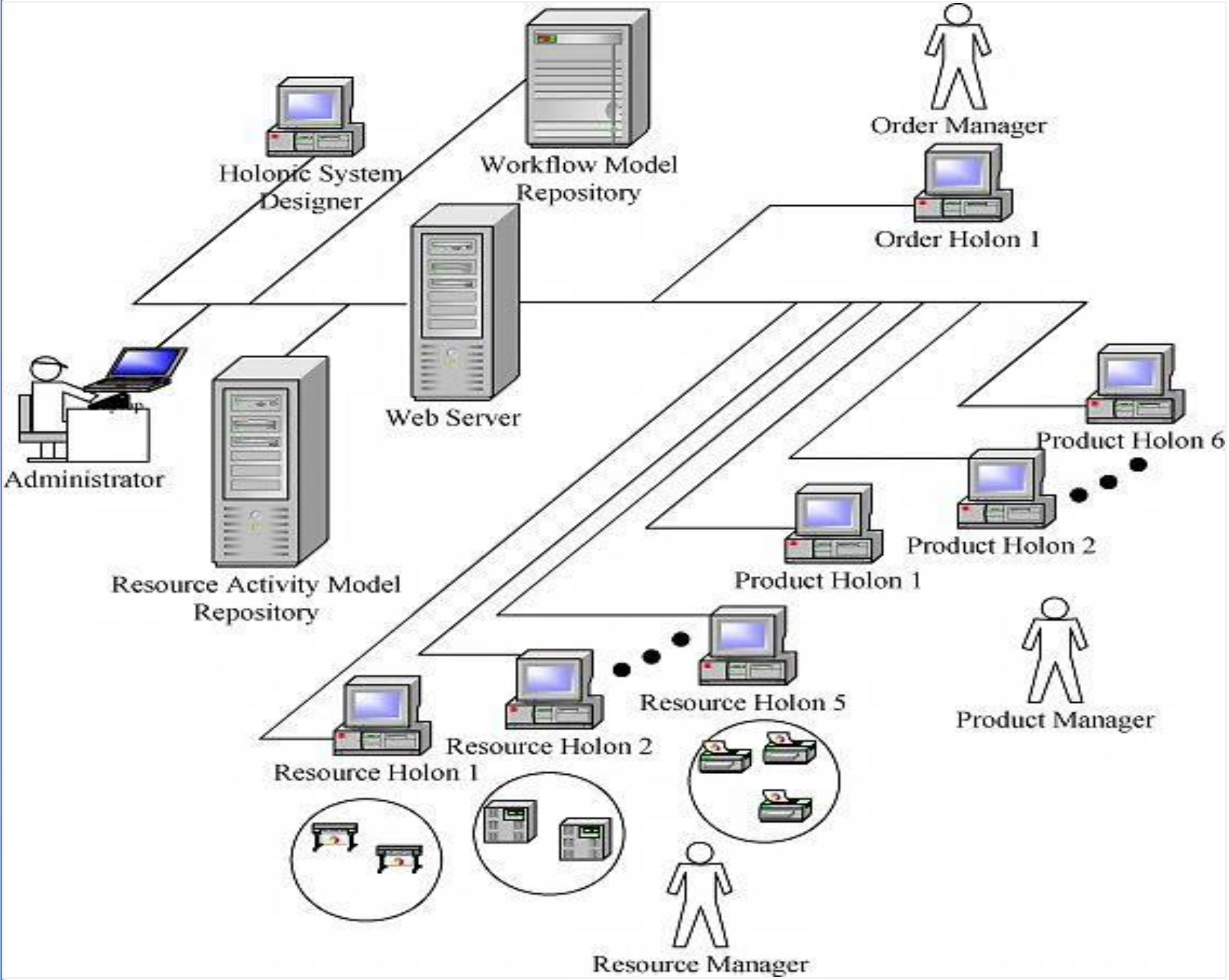
e-Work agents models: Holonic Mfg. System (HMS) bio-inspired architecture *Hsieh & Chiang ; Brennan, Gruver, Hall (2011), Valquenaers (2013)*

- *Workflow model repository*
- *Resource activity model repository*
- *HMS Designer*
- *Administrator*
- *Order manager*
- *Product manager*
- *Resource manager*
- **Features:**
  1. Autonomy
  2. Responsiveness
  3. Redundancy
  4. Distributedness
  5. Learning
  6. Efficiency
  7. Less conflicts / errors



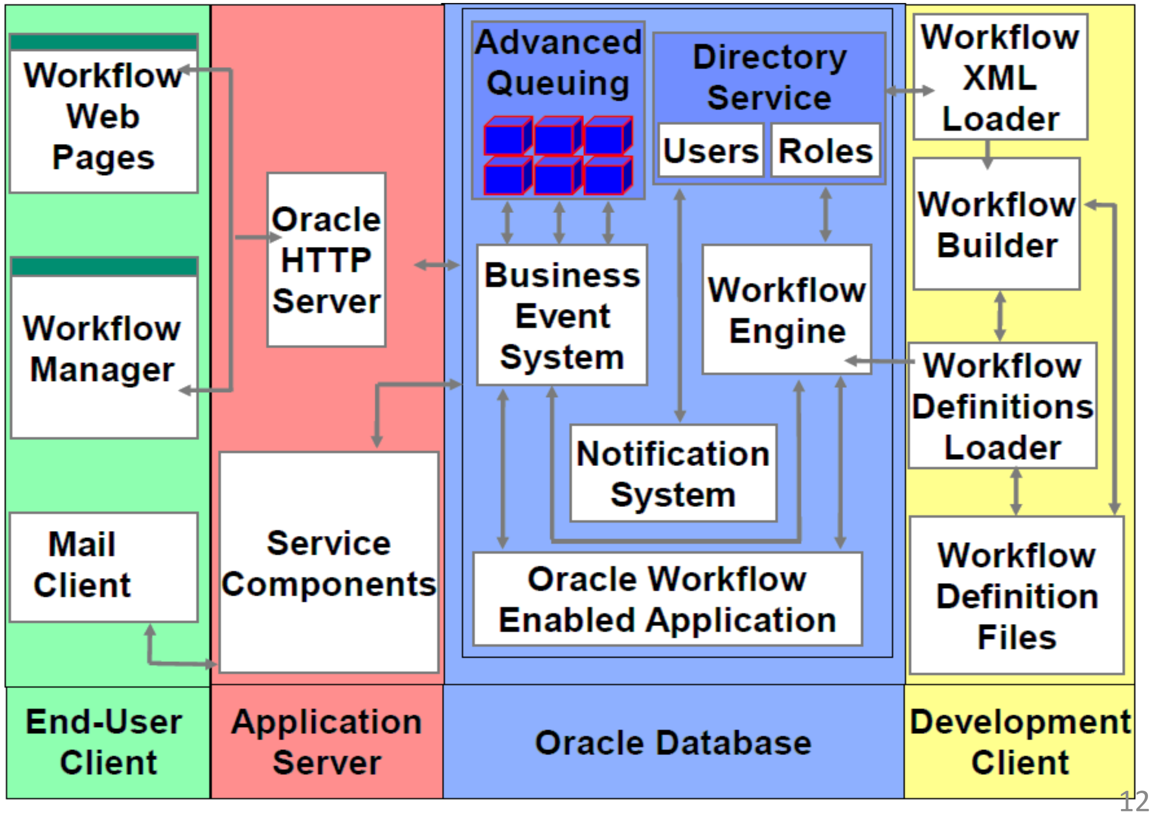
e-Work middleware: The Service Oriented Architecture (SOA)

SOA activities:

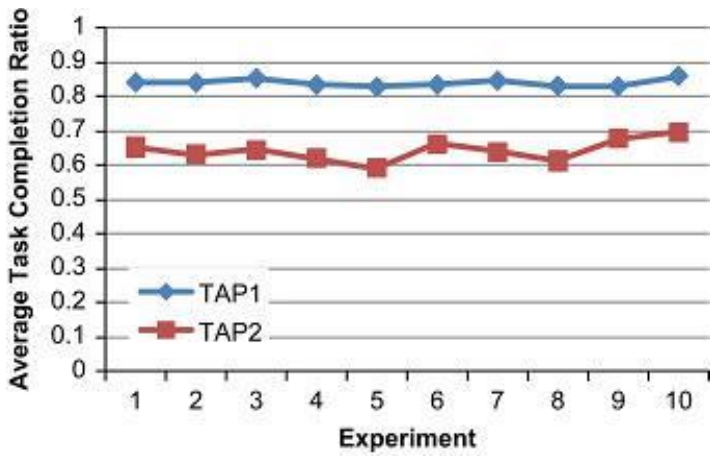
1. Collaborative automation units
2. System of systems by networking
3. Operating to achieve goals

Example: Oracle® Workflow Architecture *(Sayed & Ameen, 2011)*

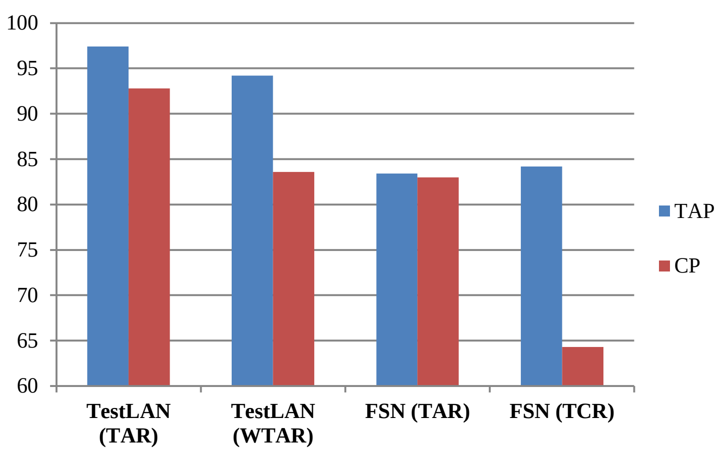
- Role of data mining and discovery to
  - Maintain timely, relevant, proactive knowledge;
  - Online analytics;
  - Predictive decision support



Value of competitive agents and protocol design



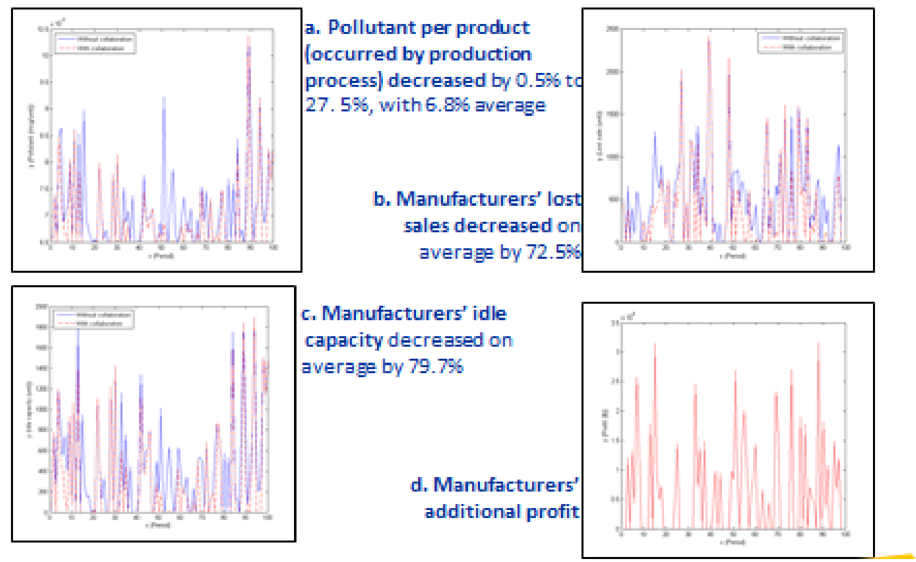
Comparing two logic designs for TAPs



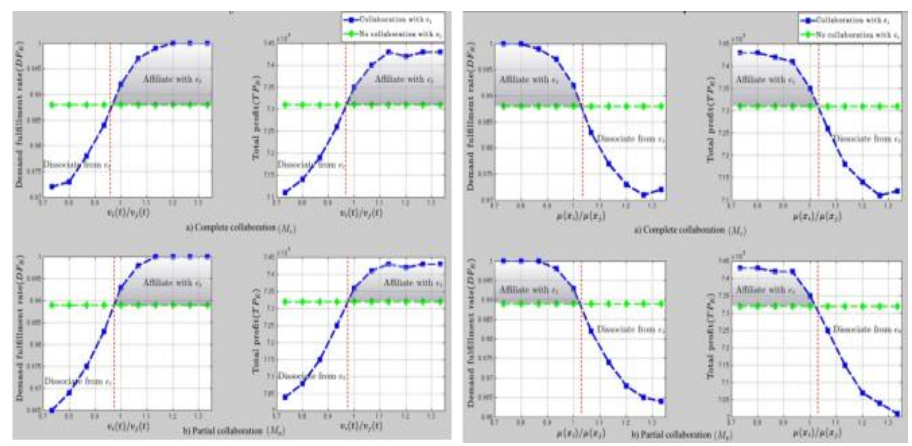
Comparing TAP to Coordination protocol *(Ko & Nof, 2012)*

Case: **Collaborative production scheduling and sustainability**

Significant impacts of employing S-DSP with CCT - - -



(Seok et al. 2012)



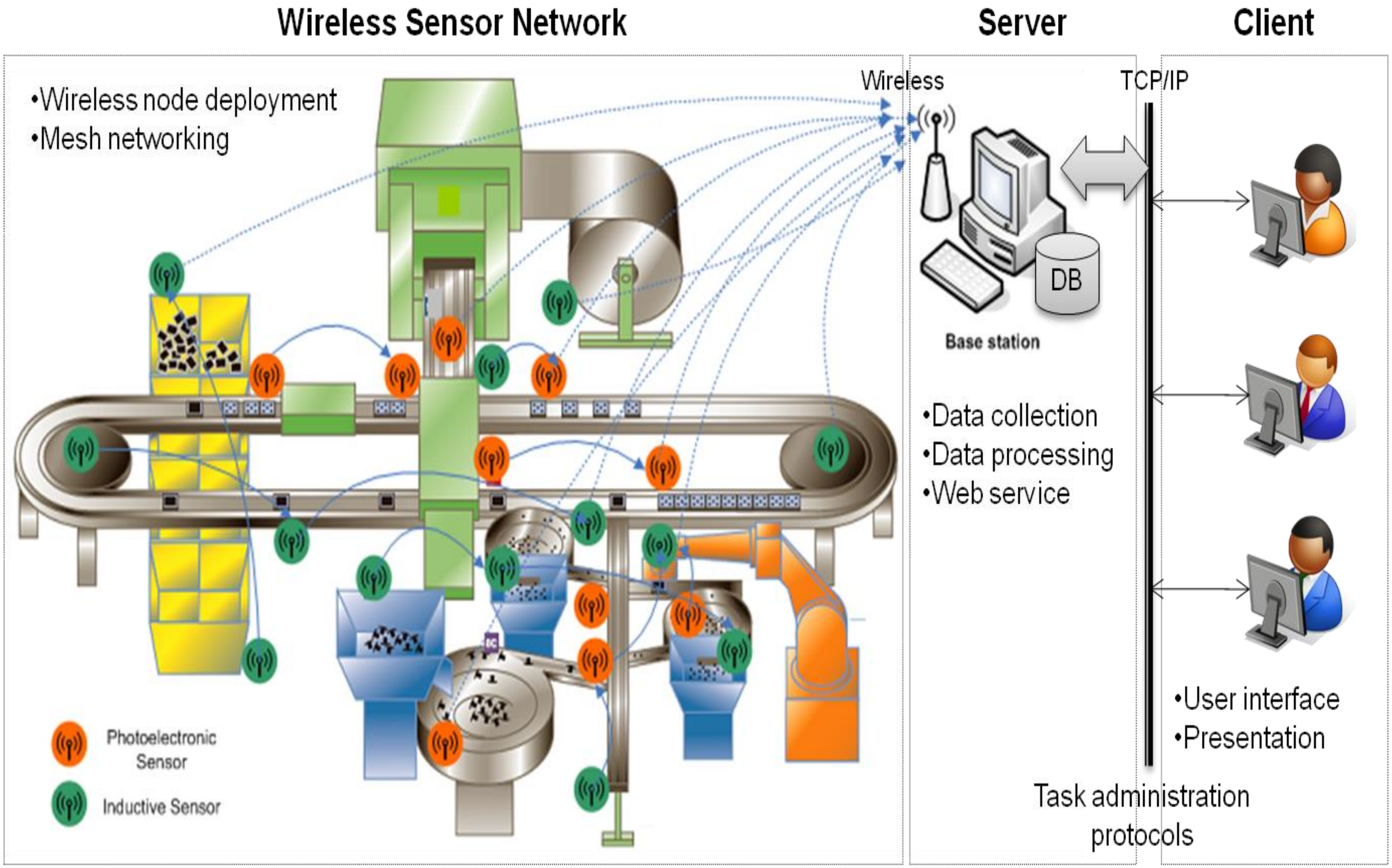
Benefits of demand and capacity sharing protocols *(Yoon & Nof, 2011)*

Conclusions and Challenges

1. **Manufacturing "big picture" means service orientation**: For effective, quality delivery of manufactured products, and competitiveness
2. **Major opportunities for innovation through new and better service models** for knowledge-based, collaborative lifecycle management of manufacturing
3. **Need to design competitive** agents, protocols, and models (architectures) for **better collaboration services to overcome the "eight challenges."**
4. **Three challenging examples for emerging service orientation:**
    a. Collaborative production lines (CPL; ALB-TS*)
    b. Collaborative telerobotics (CTR*)
    c. Collaborative telepresence (HUB-CI*)

Facility sensor networks (FSN)

emerging in mfg., hospitals, airports, rail, …



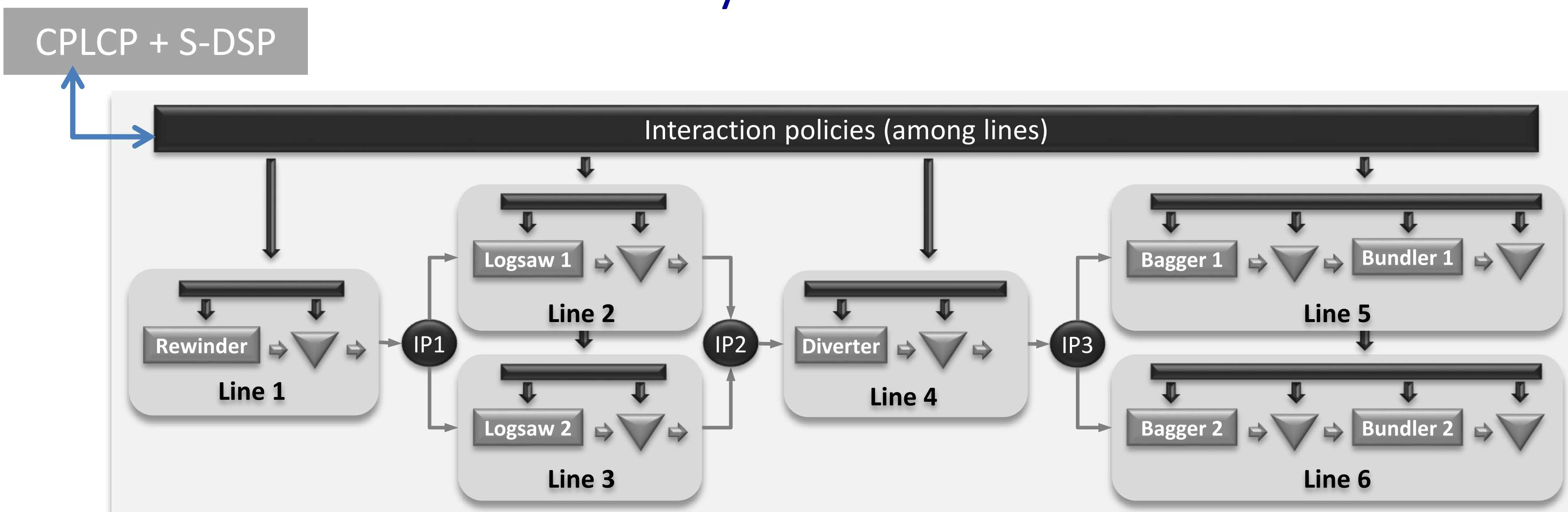
Jeong & Nof, 2009; Jeong et al., 2013

- Fundamental models of device collaboration services

Collaborative Production Line Control Protocol - CPLCP

Levalle et al. (2012)

- Tissue Converting Line Control with CPLCP
- Highly adaptive and anticipatory, by collaboration among different line(s) components to overcome failures
- Maintain sustainable throughput while keeping WIP low
- Better mfg. performance and efficiency for economic, social, and environmental sustainability

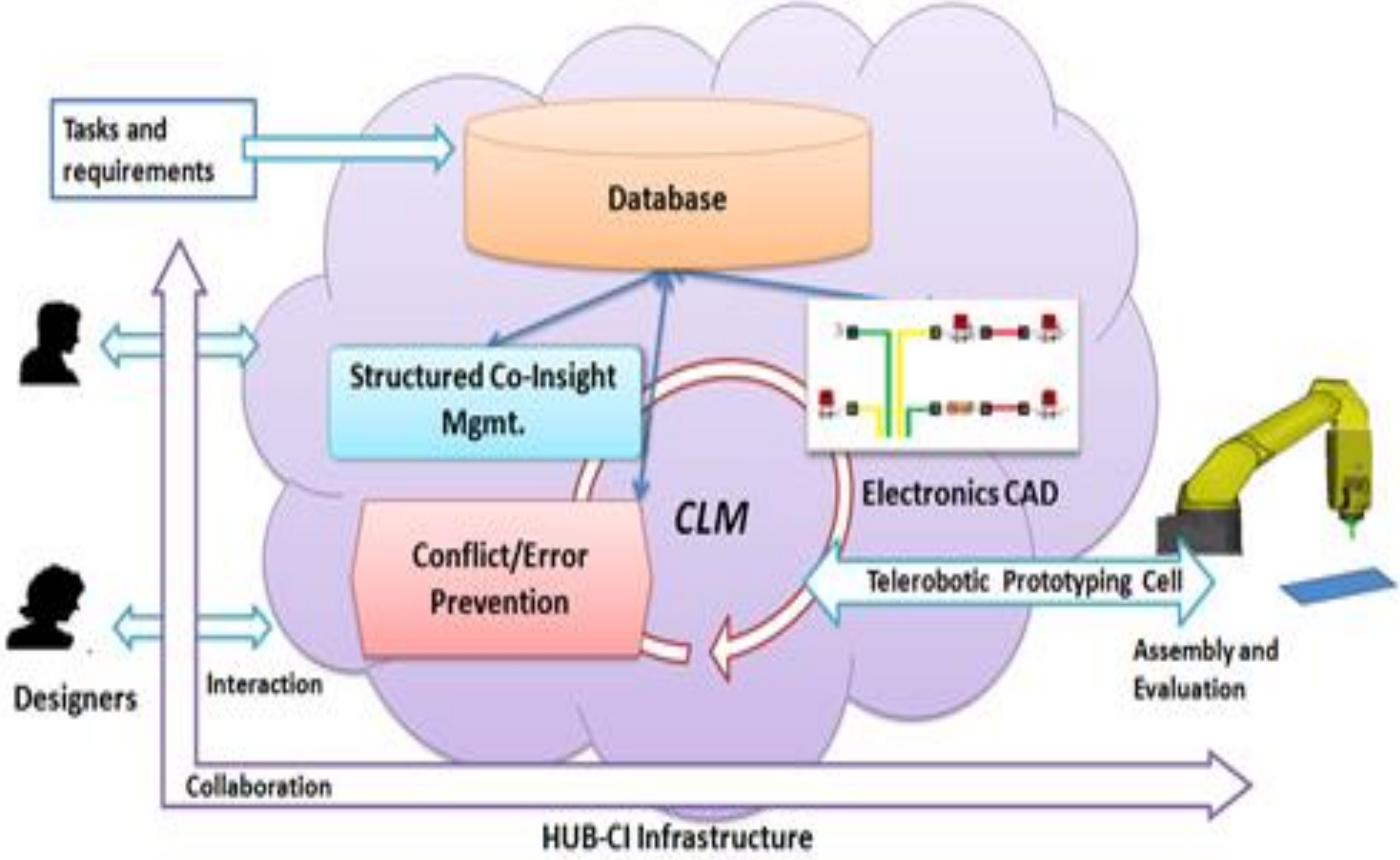


- Fundamental protocols for resource allocation

- Fundamental protocols for error and conflict detection, resolution, elimination

HUB-CI model for collaborative telerobotics (CTR):
Collaborative Lifecycle Management application

(Zhong & Nof, 2013)



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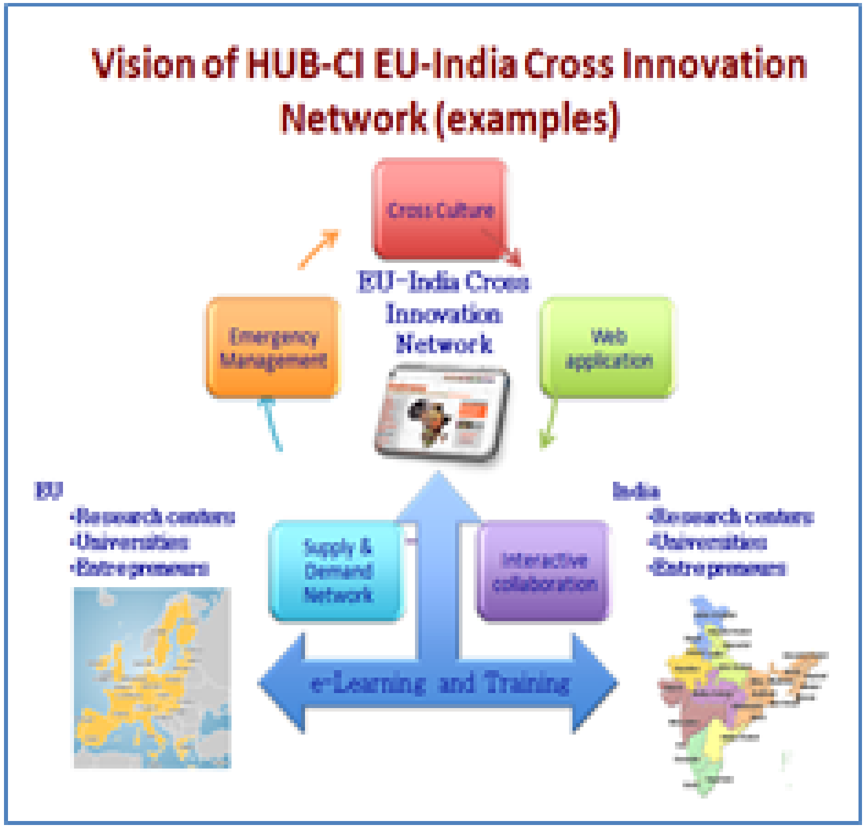
The HUB-CI model for collaborative telepresence

- Emerging global networks (hubs/clouds) to trade/adapt/engage/learn diverse ideas through collaboration with sustainability

- ...challenges:
  - Cross-culture capabilities?
  - Multi-cultural interaction and infrastructures?
  - Challenged web-based applications?
  - Asynchronous multimedia?



Challenges of EU-India Cross Innovation Network targeted by HUB-CI

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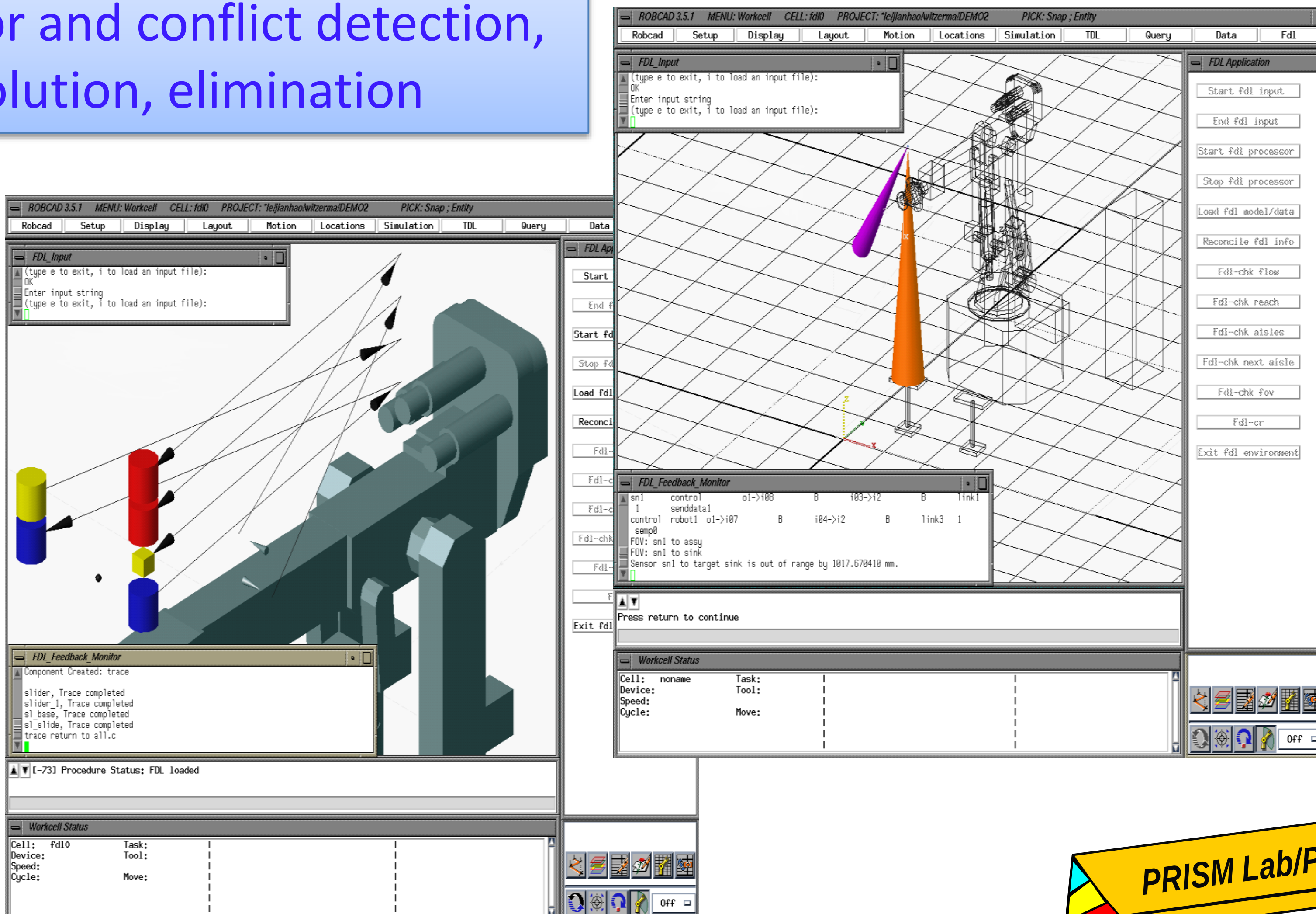
v-Design with CAD, CAE, CAVE, Augmented Reality

- Fundamental protocols for error and conflict detection, resolution, elimination



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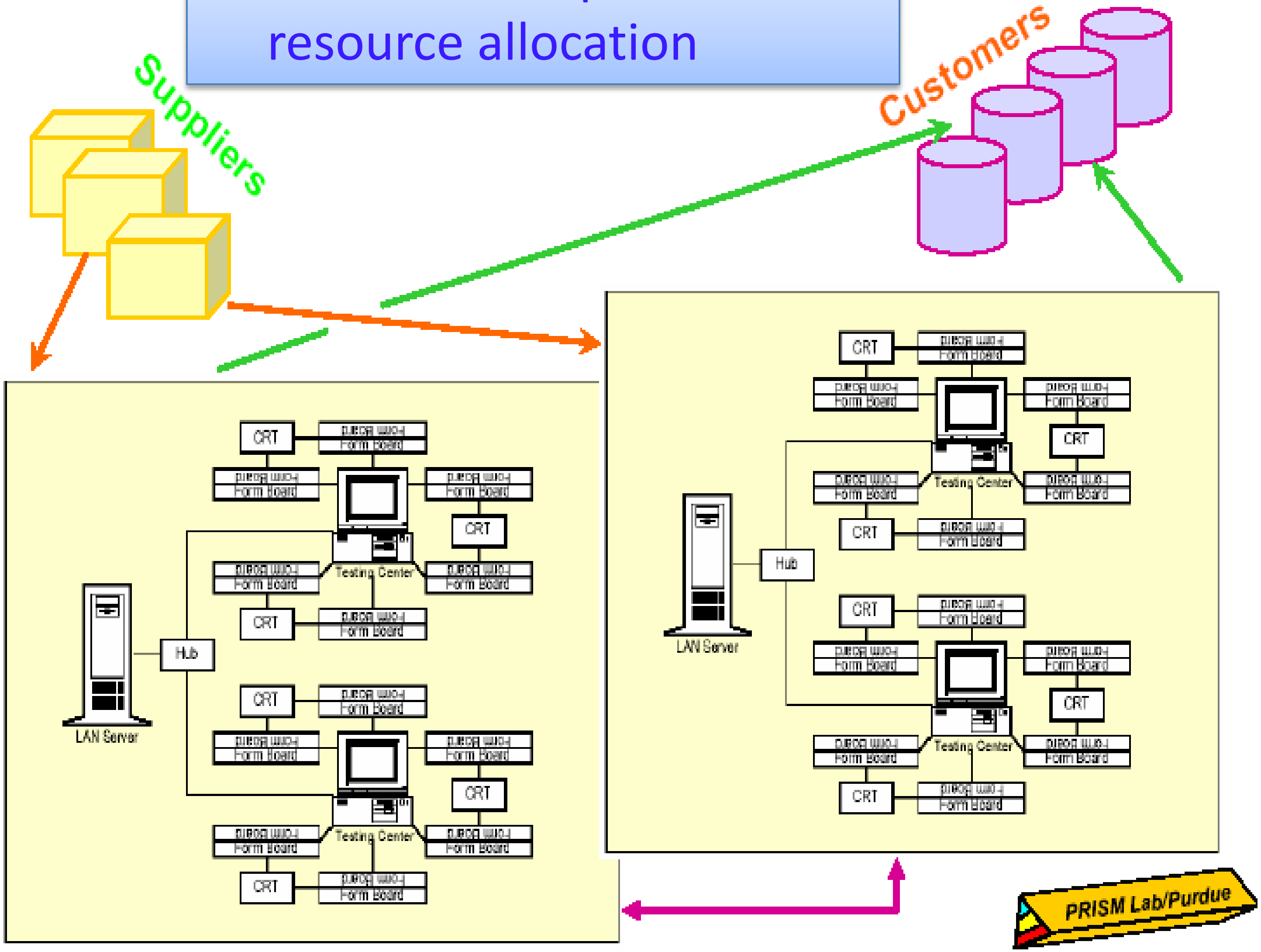
TestLAN e-Services inside assembly-&-test facilities, and across supply networks

Nof (2003; 2012)

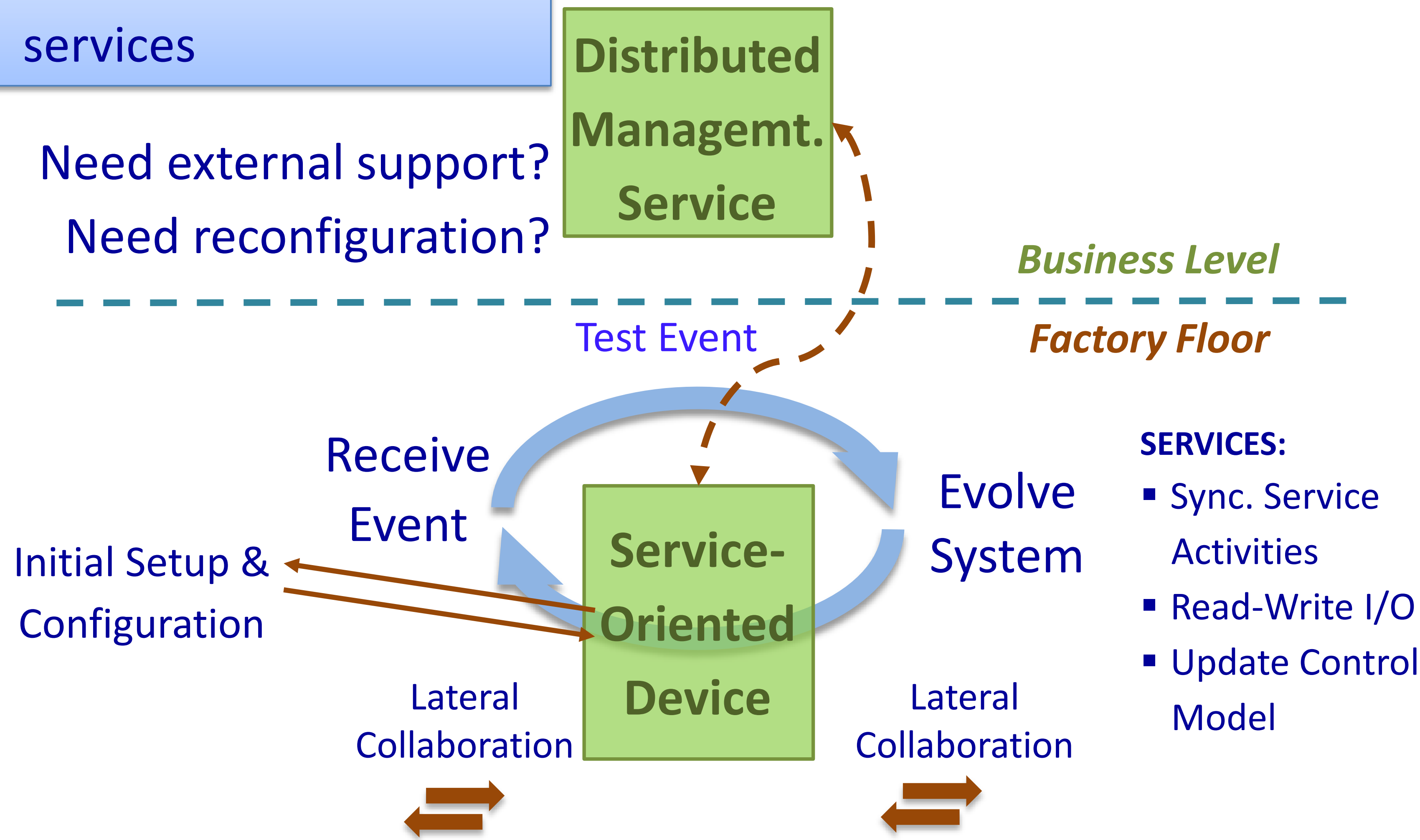
- Fundamental protocols for resource allocation



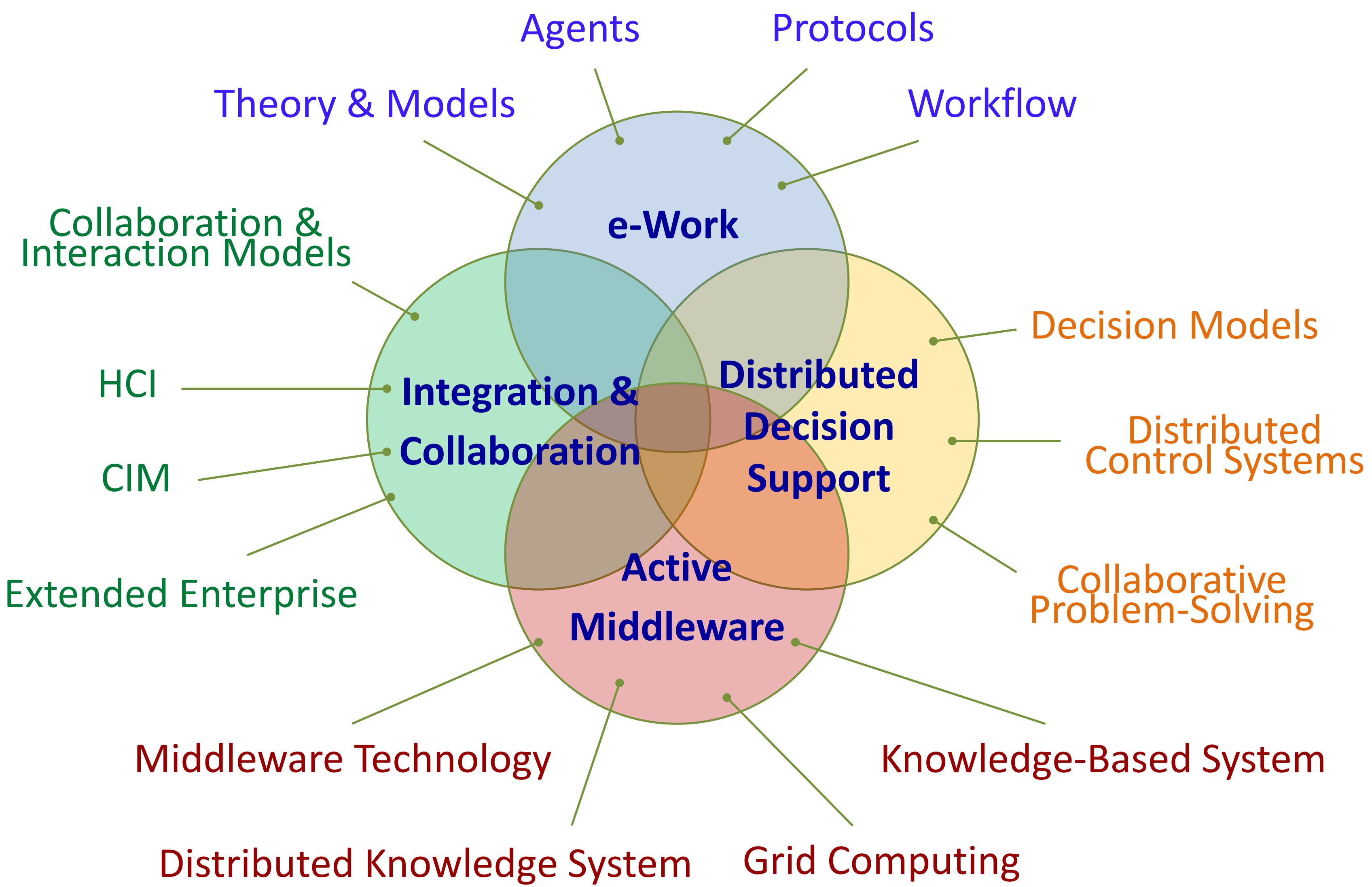
Independent, autonomous service-oriented devices

Colombo, Karnouskos, Mendes (2010)

- Fundamental models of device collaboration services



Collaborative e-Work



Intelligent manufacturing can often be viewed as collaborative e-Work and e-Mfg

Work

Human and Social Knowledge

→

e-Work

Computerized Knowledge Services

→

c-Work

Networked Knowledge Services

- Manual search
- Electronic assembly

- Database search
- Micro-electronics

- Search engine
- Nano-electronics

Error elimination; faster; higher integration complexity

Examples of **e-Work with e-Service** (not only Internet), and impacts on e-Mfg. and e-Logistics

e-Work Enabled by Communication and e-Services	**Impact on e-Mfg.**	**Impact on e-Logistics**
Distributed Computing, Information Exchanges, and Web Services		
1. Teleconference	✓	✓
2. EDI (data interchange)	✓	✓
3. EFT (fund transfer)		✓
4. Virtual reality for training	✓	✓
5. Virtual reality for design	✓	✓
6. GPS-based monitoring		✓
Collaborative CNC/Robotics/Human-Robot Teams		
1. Tele-robotic facility repair	✓	✓
2. Networked CNC, test, inspection	✓	✓
3. Tele-assembly in clean room	✓	
4. Diagnostics by sensor web	✓	✓
5. Robotic laser drilling	✓	
6. Robotic load/unload devices	✓	✓

Intelligent Manufacturing with e-Services

The ability to transform activities, processes, materials and products to being knowledge-based and intelligence-based implies --

Transfer of human knowledge and intelligence to them, through e-Services: Providing services via electronic communication networks

What do we get out of this presentation? What's new?

1. For us, manufacturing aficionados, what does "service oriented" mean?
2. How are e-Work and e-Mfg. related to "service orientation"?
3. How has this relation evolved, and where is it going?
4. (How) can we benefit from it?
5. What do we need to do about it? (Challenges)