Collaborative Robotics and e-Work

ISR 2003

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PRISM Center

Production, **R**obotics, and **I**ntegration **S**oftware for **M**fg. & **M**anagement

Purdue University, W. Lafayette, IN

"Cutting Edge research in Robotics"

Rosemont IL, June 2003

1. e-Work and collaboration ("Smart Teams")
2. Error recovery, conflict resolution
3. Fault tolerance in sensor arrays -- FTTP
4. Assembly-and-Test networks
5. Emerging challenges

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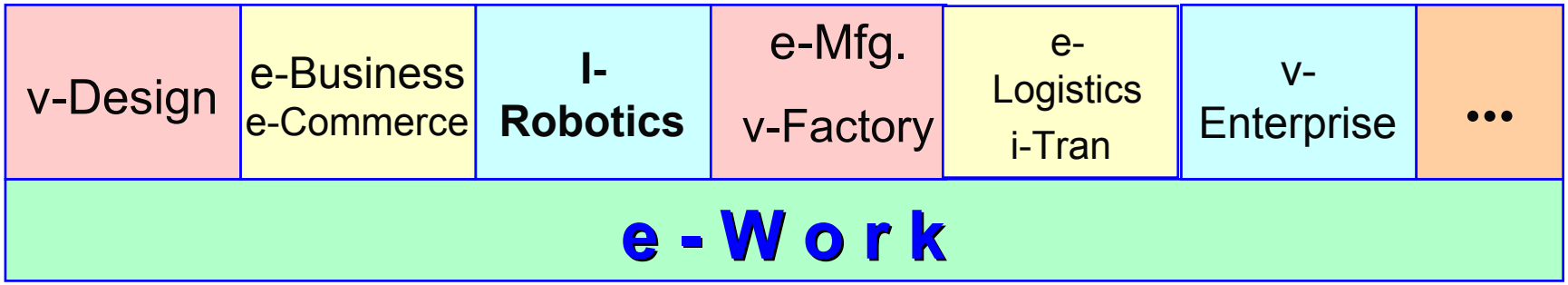
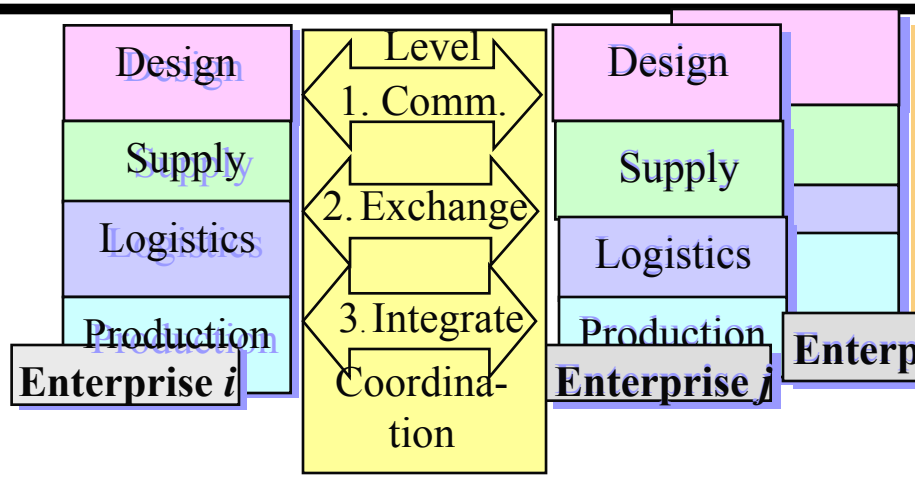
e-Work definition [PRISM, 1999]

- Collaborative, computer-supported, and communication-enabled operations in highly distributed organizations of humans / robots / autonomous systems
- Our goal: **Augment human abilities to work**

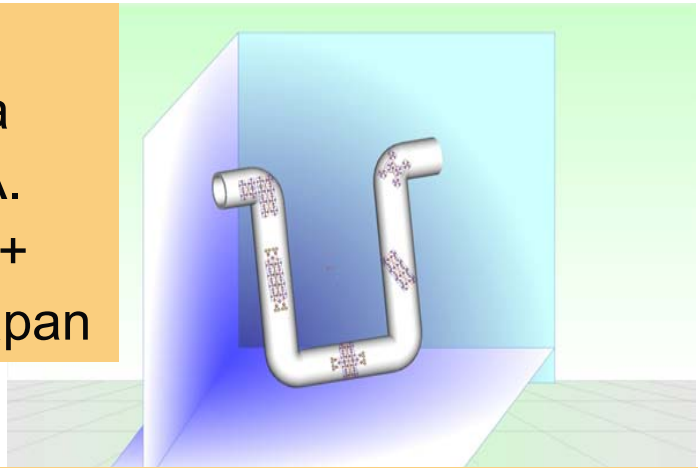


- Challenges: • Complexity • Dependence • Integrity • Communication • Coordination • Noise • Mismatch …

Examples: M.E.N optimization, scalability; MEMS sensor arrays/networks; GriTeam; FDL-CDR



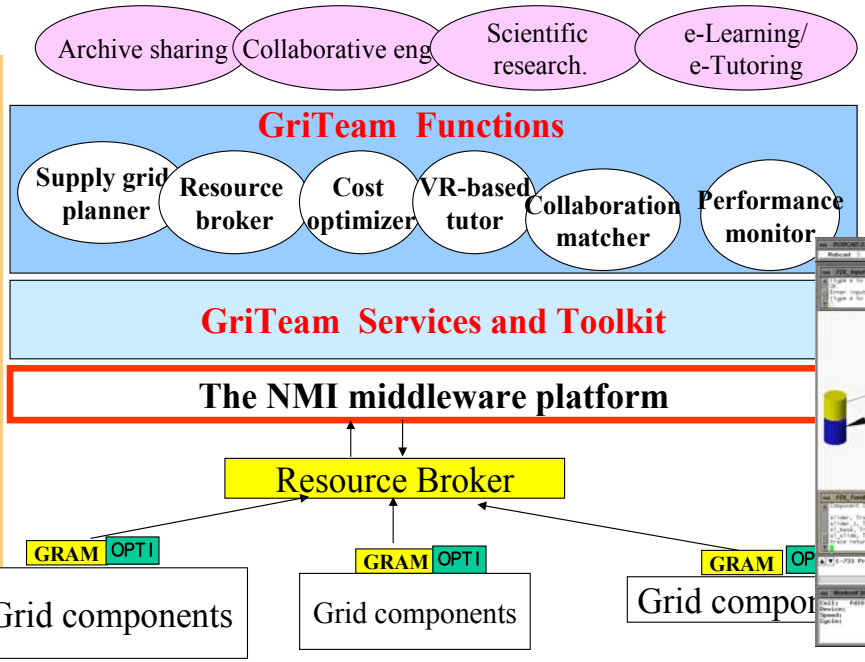
Tokyo--
Osaka
Italy—S.A.
PU+Chile+
Japan

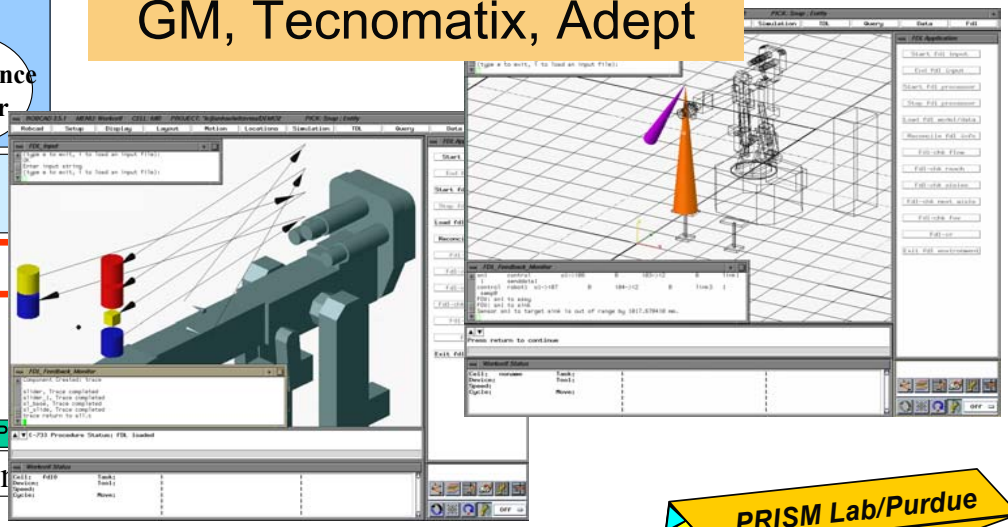


ATC, IN21stC, AAE+CS+IE+ME

GM, Tecnomatix, Adept

PU, UIC, ANL, IBM





GRAM : Globus Resource Allocation Manager **OPTI:** OptIPuter

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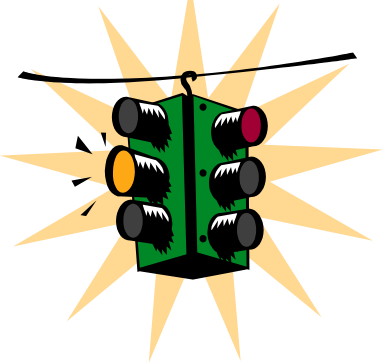
Task Administration Protocols (Regular; Active)

Definition (different from std. Comm. protocols):

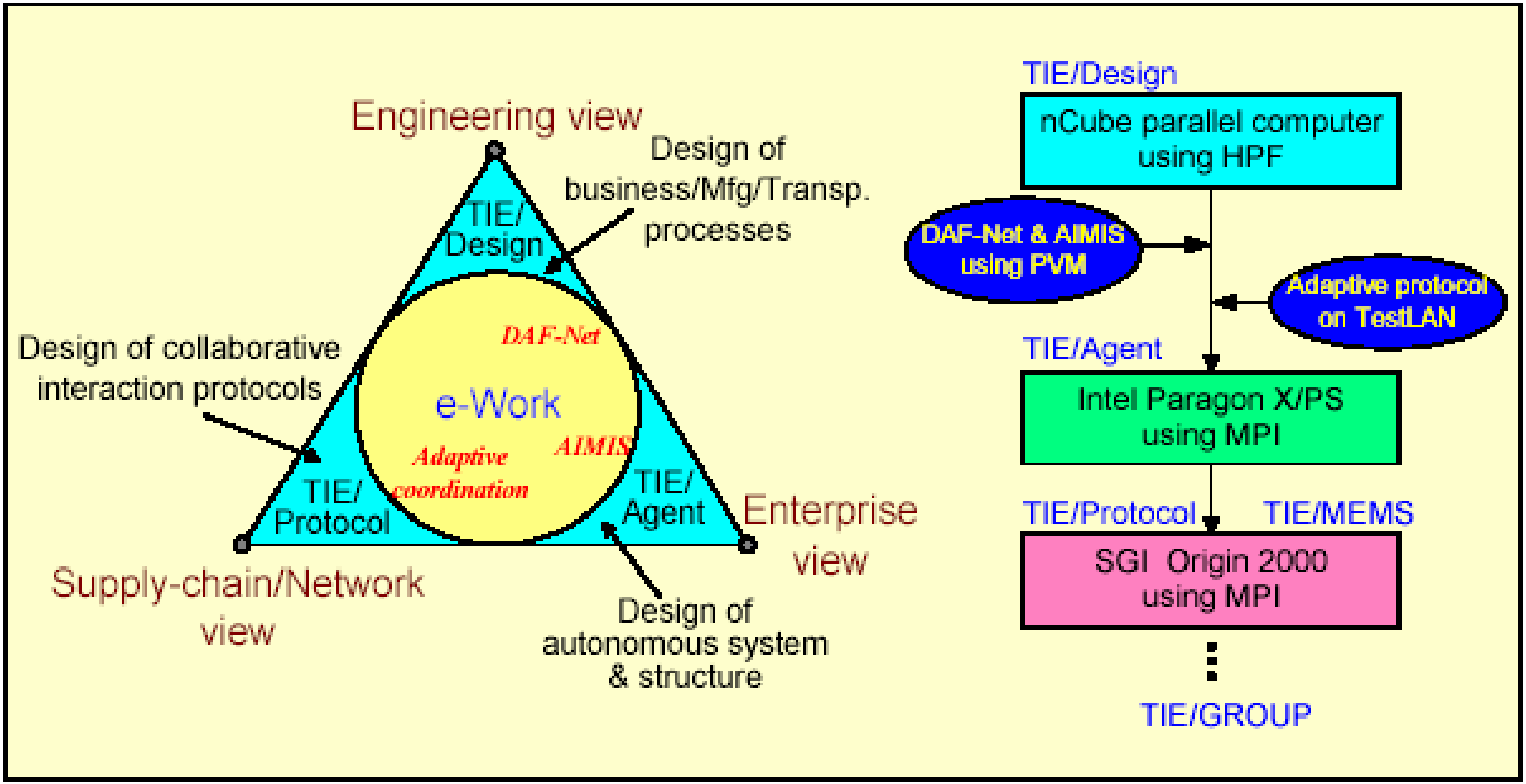
- Control rules that enable effective collaboration among agents and tasks
- *Active* TAP: Can trigger and initiate interactions to optimize performance



Ex. in e-Work: ***Time-out; negotiation; assignment***

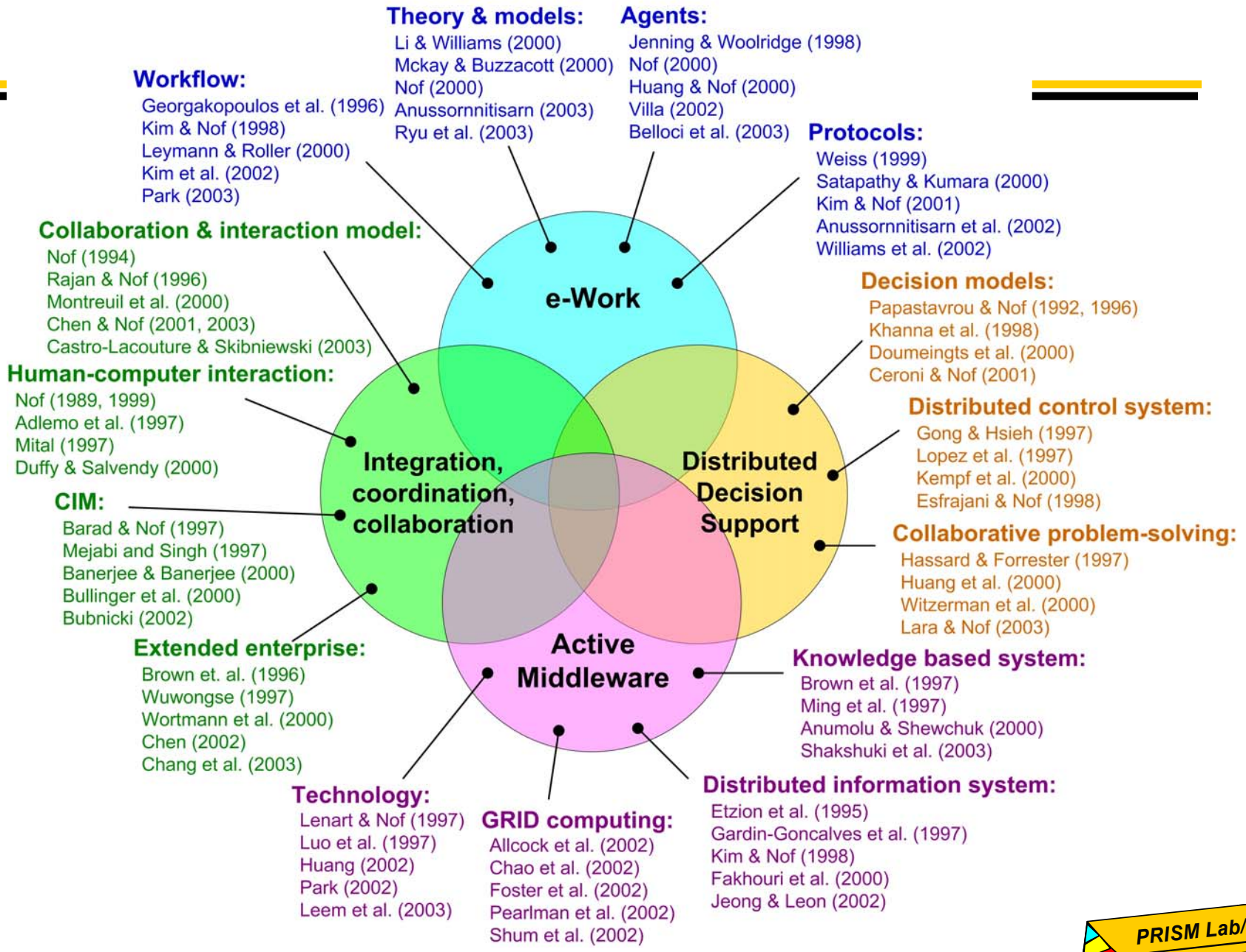
- TIE (Teamwork Integration Evaluator) Parallel simulators

Overview of TIE development

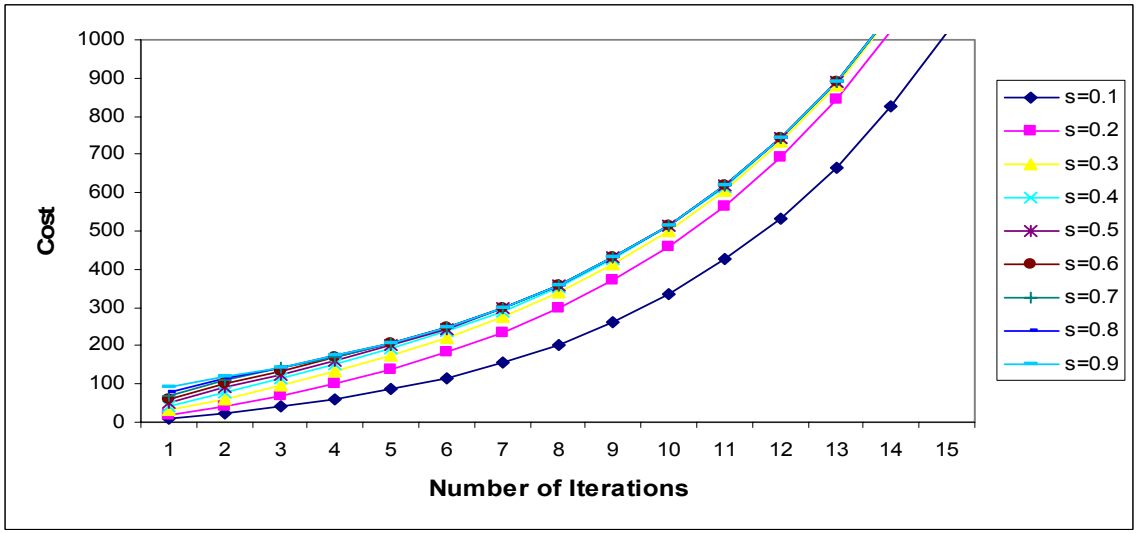


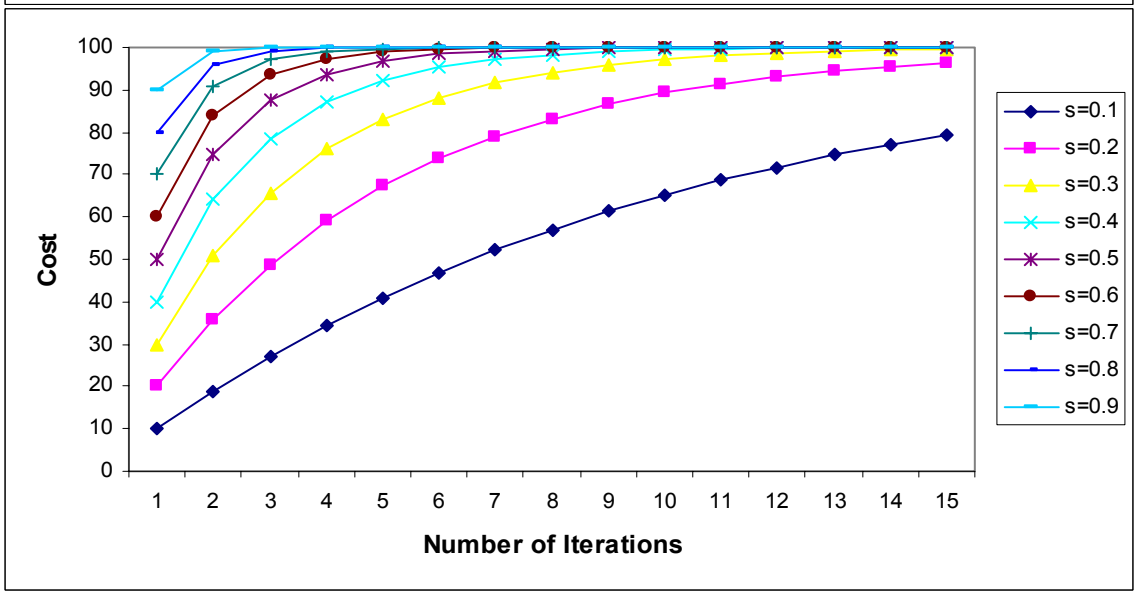
Sponsors: NSF, IBM, Caterpillar, SGI,
TAP, Tecnomatix, ATC, State of Indiana

e-Work: Foundations, Tools, and Emerging Discoveries



Cost of Error Recovery / Conflict Resolution





Increases exponentially when human communications and operations are applied (assuming *q*=0.2)

Reaches an upper bound when IT is Applied (assuming *q*=0.0)

q *= % of human involvement*

S *= rate of conflicts*

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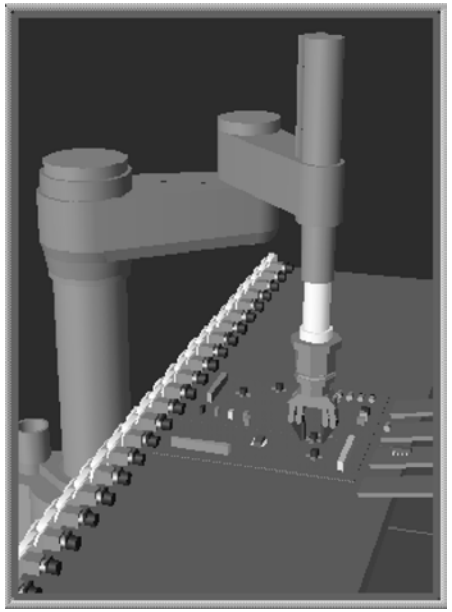
EDPR: Error Diagnostics, Prevention, Recovery



Example: Robotic assembly cell

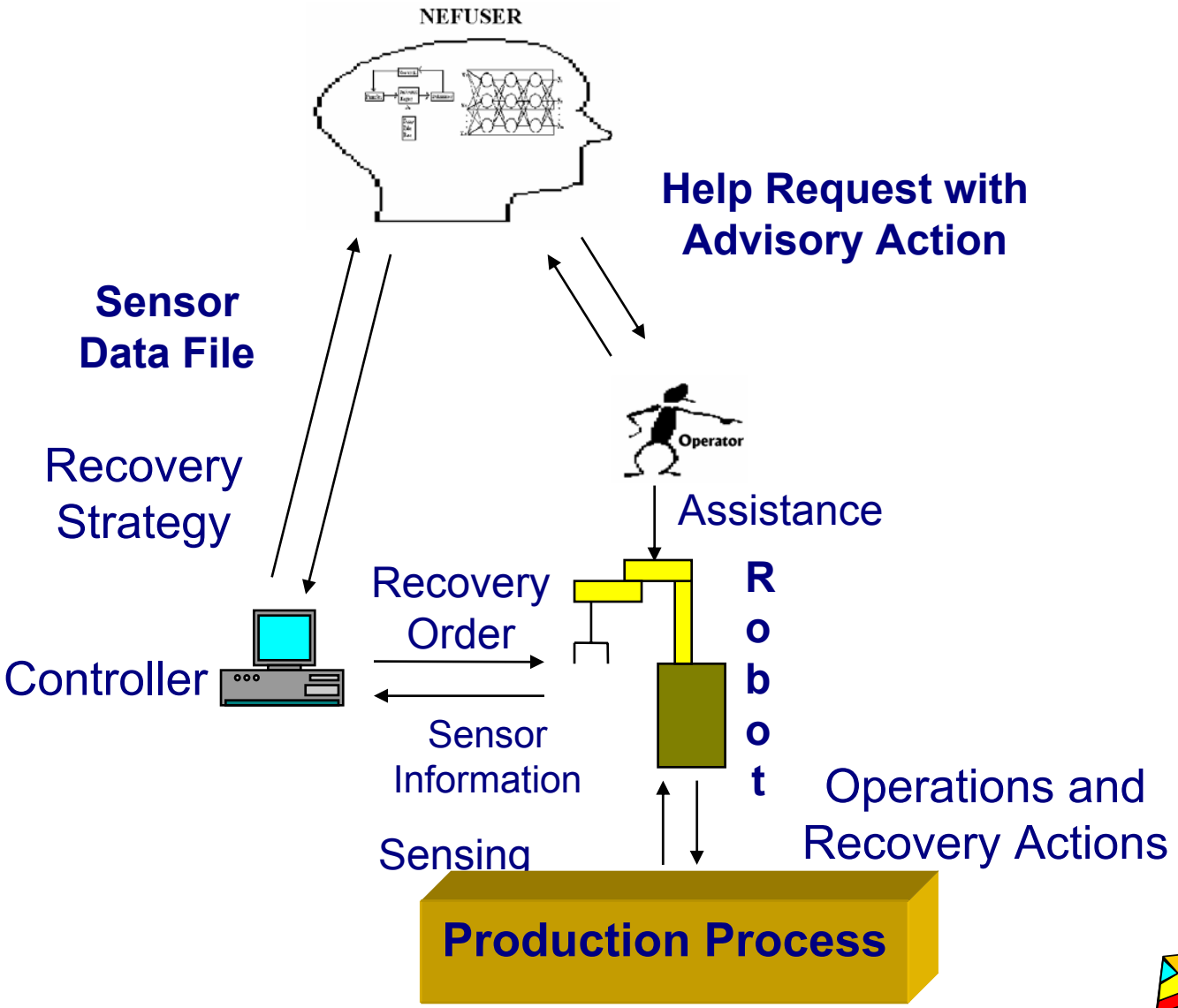
Detectable task errors:

1) Bad position of gripper, of part, of assembly base
2) Bad part orientation
3) Part arrives in incorrect order to the pick-up area
4) Part or assembly base is missing

What's new?

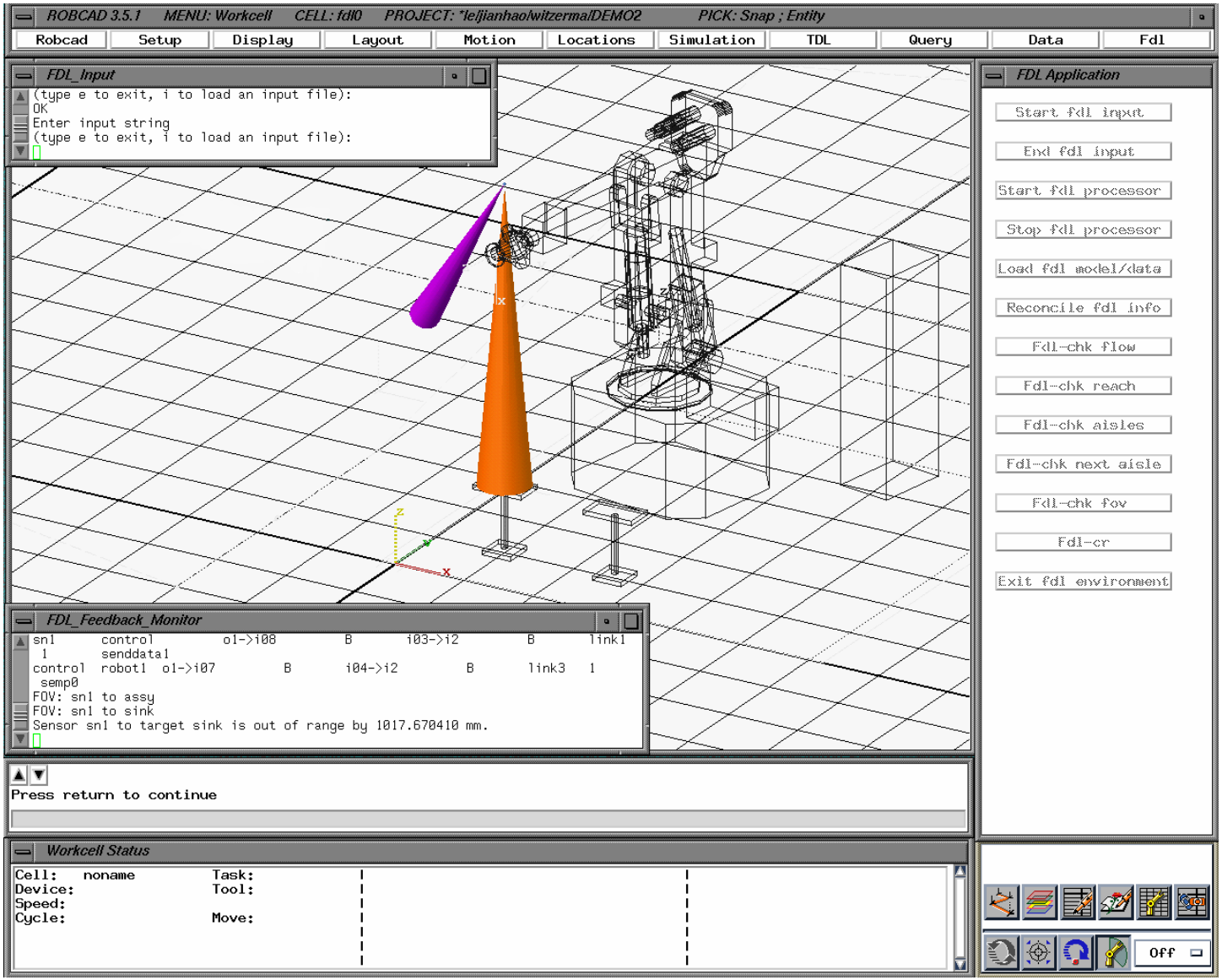
Machine learning to improve diagnostics and recovery strategies, success probability

NEFUSER: Neuro-Fuzzy System for Error Recovery Human-robot-computer Recovery Interactions



Computer-Supported Conflict Resolution

Example: FDL's Field-of-View Evaluation function



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Operation Logic of FDL/CR

Run FDL/CR

Graph Model of Conflict Resolution

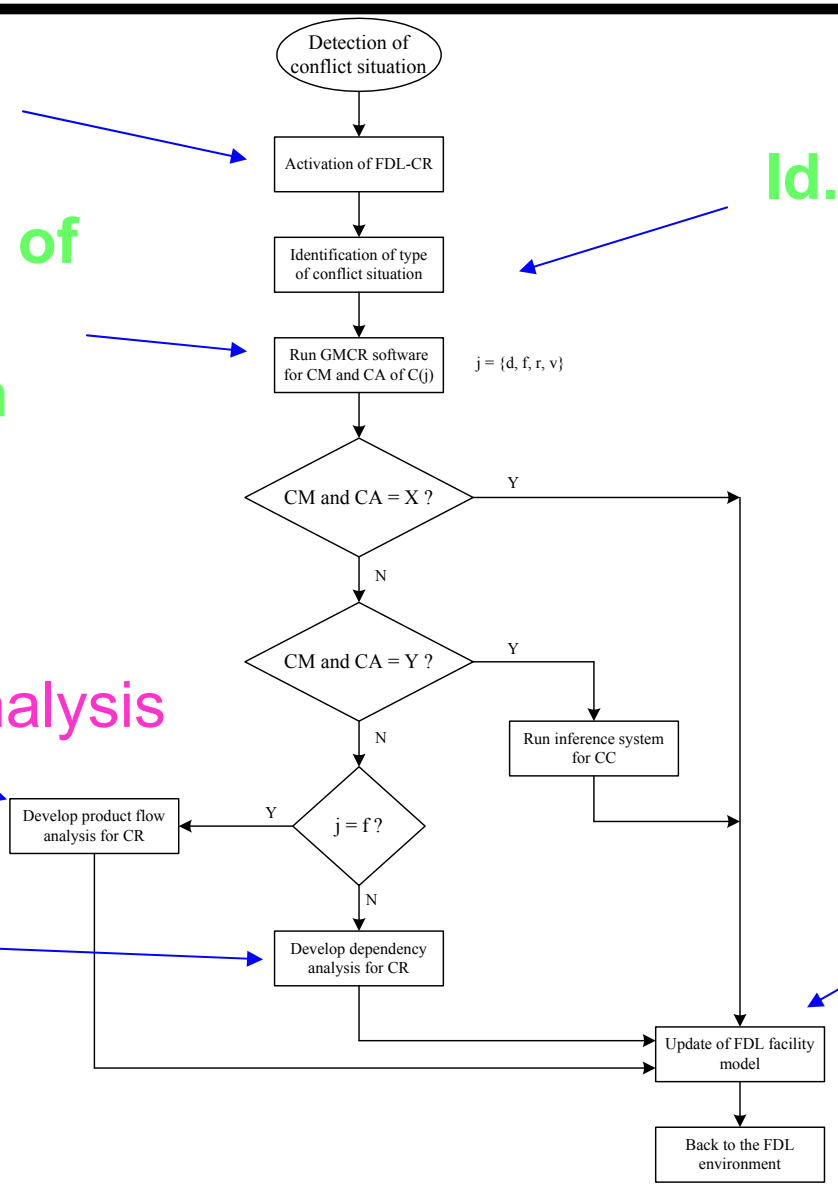
CAE tools

Product flow analysis

Dependency analysis

Id. conflict type

Inference system



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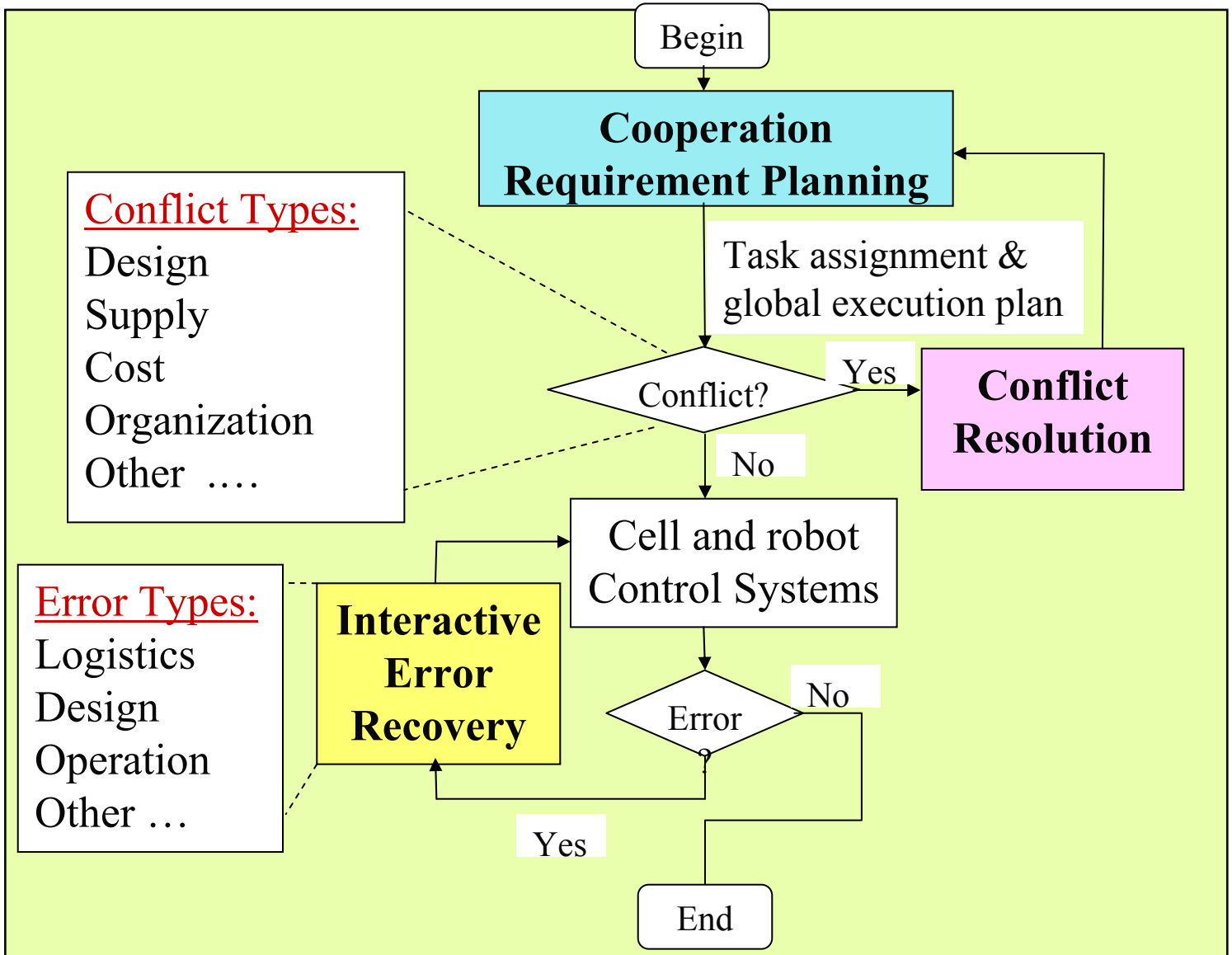
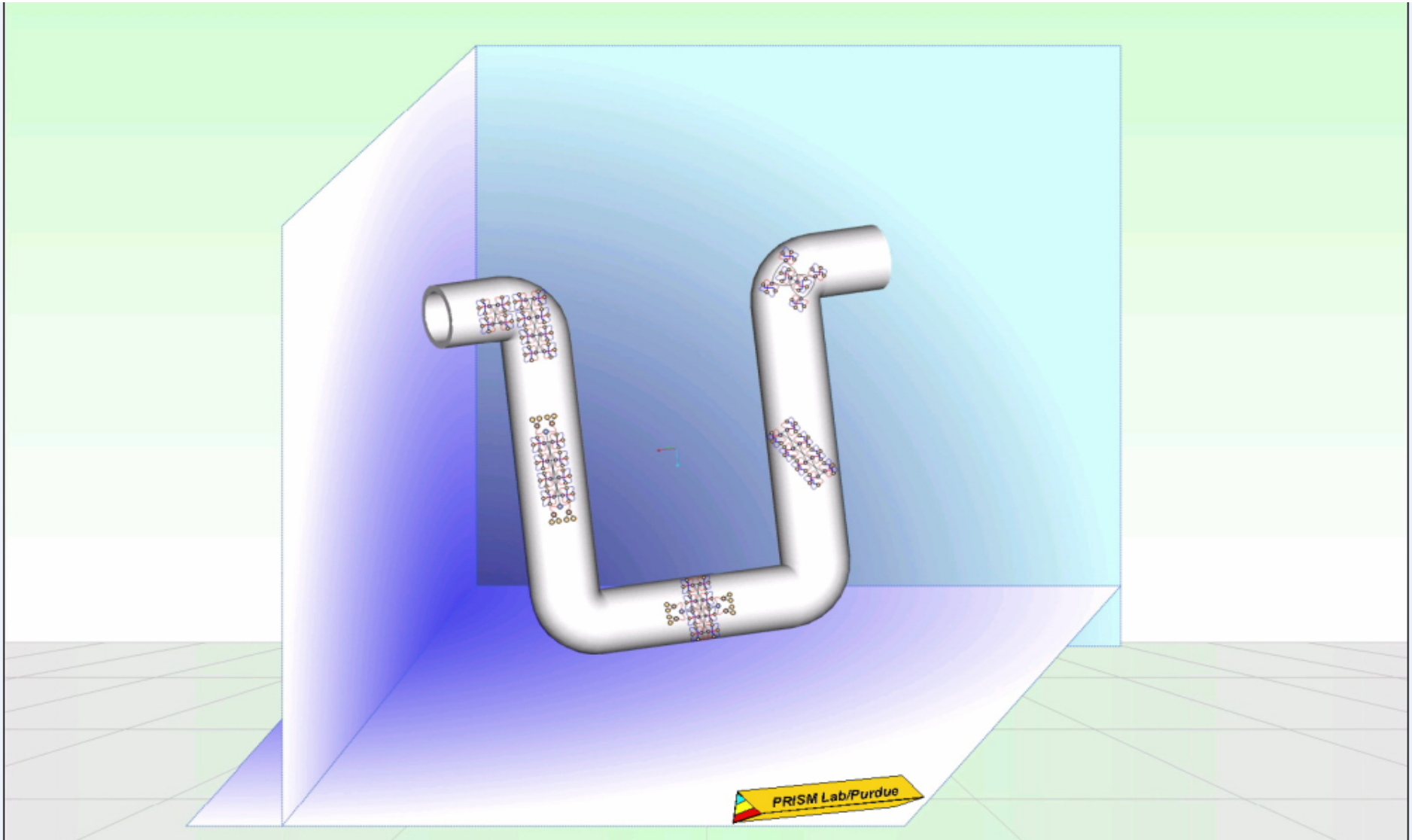
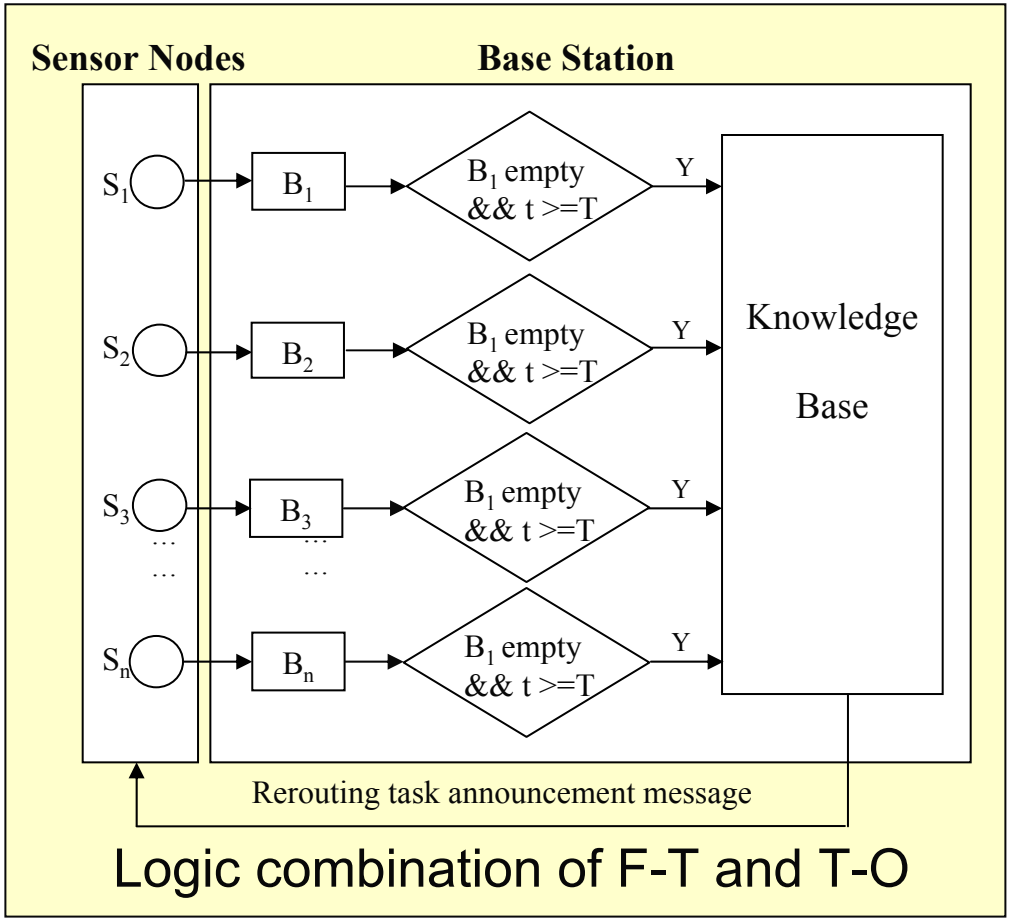
Robotic Assembly: Framework for **cooperation requirement planning with conflict resolution**



Alternative MEMS and Nano Sensor Arrays / Networks Optimized along an Artery for Measurement and Control



Distributed Sensor Network / Arrays: Fault-Tolerant & Time-Out Integration Protocols*



Logic combination of F-T and T-O

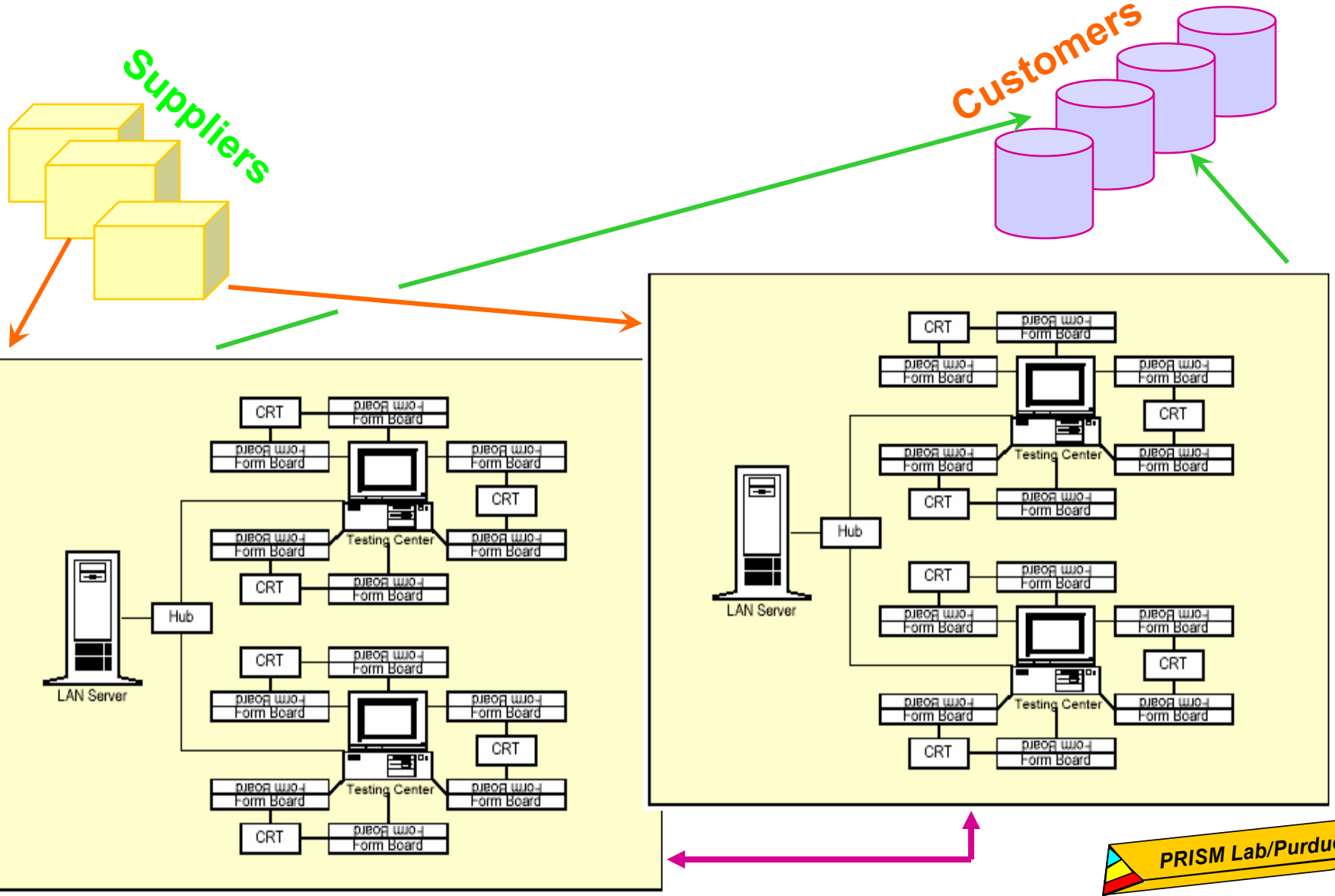
Sensor Node ID	Backup Node	Transmission Delay Time
1	2,3,4	T_1
2	1,4,5	T_2
…	…	…
n	1,2,n-1	T_n

Knowledge Base

Fault-tolerant time-out protocol (FTTP) **Patent Pending**

(Liu & Nof, 2002)

Assembly & Test – The Supply Network/Grid



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Assembly & Test: Adaptable TestLAN design recommendations (Williams et al., 2003)

Conditions	Actions Based on this Research
1. Job classes having similar inter-arrival patterns	Use Non-TestLAN
2. Inter-arrival patterns such that $it^1 << it^2 ... << it^n$ and few demand fluctuations or design changes	Use Non-adaptable TestLAN
3. Inter-arrival patterns with $it^1 << it^2 ... << it^n$ and periodic demand fluctuations or design changes	Use Adaptable TestLAN, with preferred adaptation characteristics of $0.2 \leq \Delta \leq 0.4$, ε_β, $\beta = 30$

Smart Robotics Teams: Challenges

1. Optimized coordination of e-Work interactions is key to competitiveness
2. Manage errors, conflicts, and interactions' complexity among team robots
3. Next generation collaborative robotics will depend on fault-tolerant, time-out integration, e.g., FTTP
4. Smart robotic teams will be able to interact even better than human teams

Other ideas?

The **PRISM** Center: Production, Robotics, and Integration Software / Systems for manufacturing & Management

Established in 1991, main lab: Grissom 126; sponsored by government and industry, over $7.5 mil. total

Graduated 28 MS/PhD students; 12 BSIE honors students; 8 international visitors. Current: 12 faculty and students researchers

Center Objective: Apply computer intelligence to most effectively improve the performance of industrial systems, particularly by computer-supported integration and collaboration. This area has been defined by PRISM as e-Work. Collaborative robotics is a key to e-Work.

Main Project Areas:	Assembly & Inspection Integration Engineering & Design Collaboration Distributed Models of Networked Enterprises International projects

http://gilbreth.ecn.purdue.edu/~prism Contact: nof@purdue.edu

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