Autonomic Administration:
HAL 9000 Meets Gene Roddenberry

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Chairman, Autonomic Communications Forum
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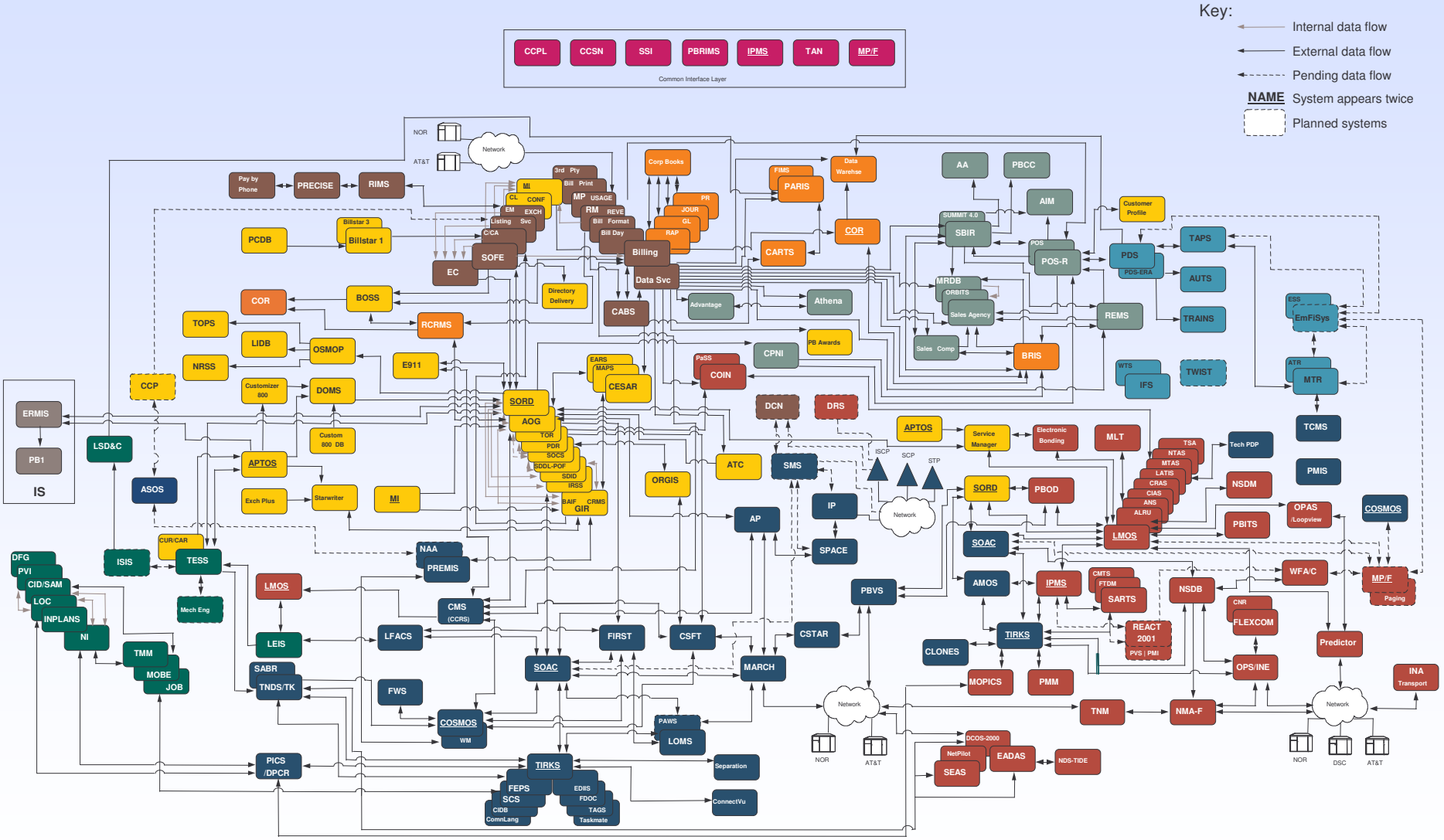
Strassner Presentation Styles

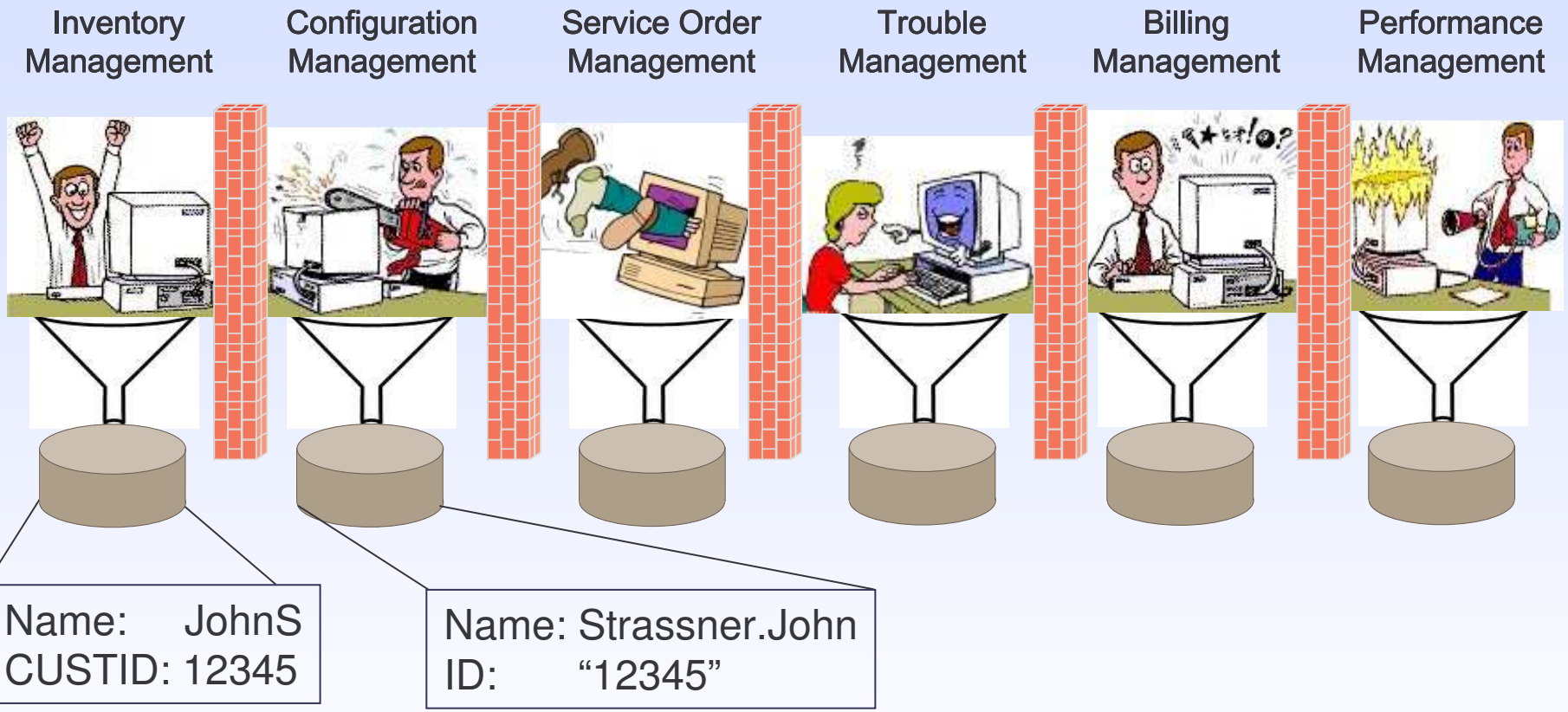
- Sunday
  - Mongolian Throat Singing
- Monday
  - Sock Puppets
- Tuesday
  - Interpretive Dance
- Wednesday
  - Microsoft PowerPoint™ Slides
- Thursday
  - Haiku
- Friday
  - Pantomime (no props!)
- Saturday
  - American Sign Language (ASL)

Motivation

A Traditional OSS/BSS



Shortcomings - Infrastructural



- Architectural issues
  - Data redundancy
  - Synchronization problems
  - Application authorization issues
  - Vendor and Application "lock in"
- Integration issues
  - Isolated Data Silos
  - Administrative nightmare
  - Integration/customization nightmare
  - Transition from legacy systems to a new OSS

Current Network Management Deficiencies

- Aggregates of elements may exhibit behavior not predictable from knowledge of individual behaviors
- Causal determinacy still limited by simple statistical analysis and rudimentary correlation approaches
- No ability of the system to “go beyond” precompiled knowledge and procedures
- All current techniques require “human-in-the-loop” back-end analysis

More Effects – Constituency Separation

- Different constituencies have different terms, grammars, and needs
  - Meaning of a Service Level Agreement ***changes***
- Relating network services and resources to business needs is ***hard!***
  - Not reflected in EMS and NMS design
  - Lack of ***policy*** controlling allocation
  - Cannot incorporate new knowledge
  - Cannot react in a timely manner to changes

Potential Loss of Revenue to Failure

Industry Sector	Revenue/Hour
Energy	$2,817,846
Telecommunications	$2,066,245
Manufacturing	$1,610,645
Financial Institutions	$1,495,134
Information Technology	$1,344,461
Insurance	$1,202,444
Retail	$1,107,274
Pharmaceuticals	$1,082,252
Banking	$996,802
Consumer Products	$785,719
Utilities	$643,250
Healthcare	$638,030

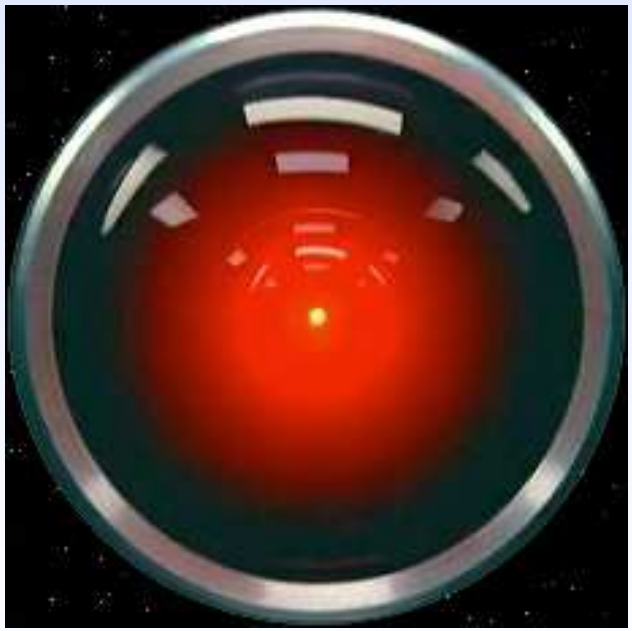
Source: *Disaster Recovery: Reaction, Not Reality*, Meta Group, February 2004

So What IS Autonomics?

Future Vision of Autonomic Computing?

Machines will take over all management tasks, rendering humans superfluous.

Hal 9000, *2001*



Wrong!

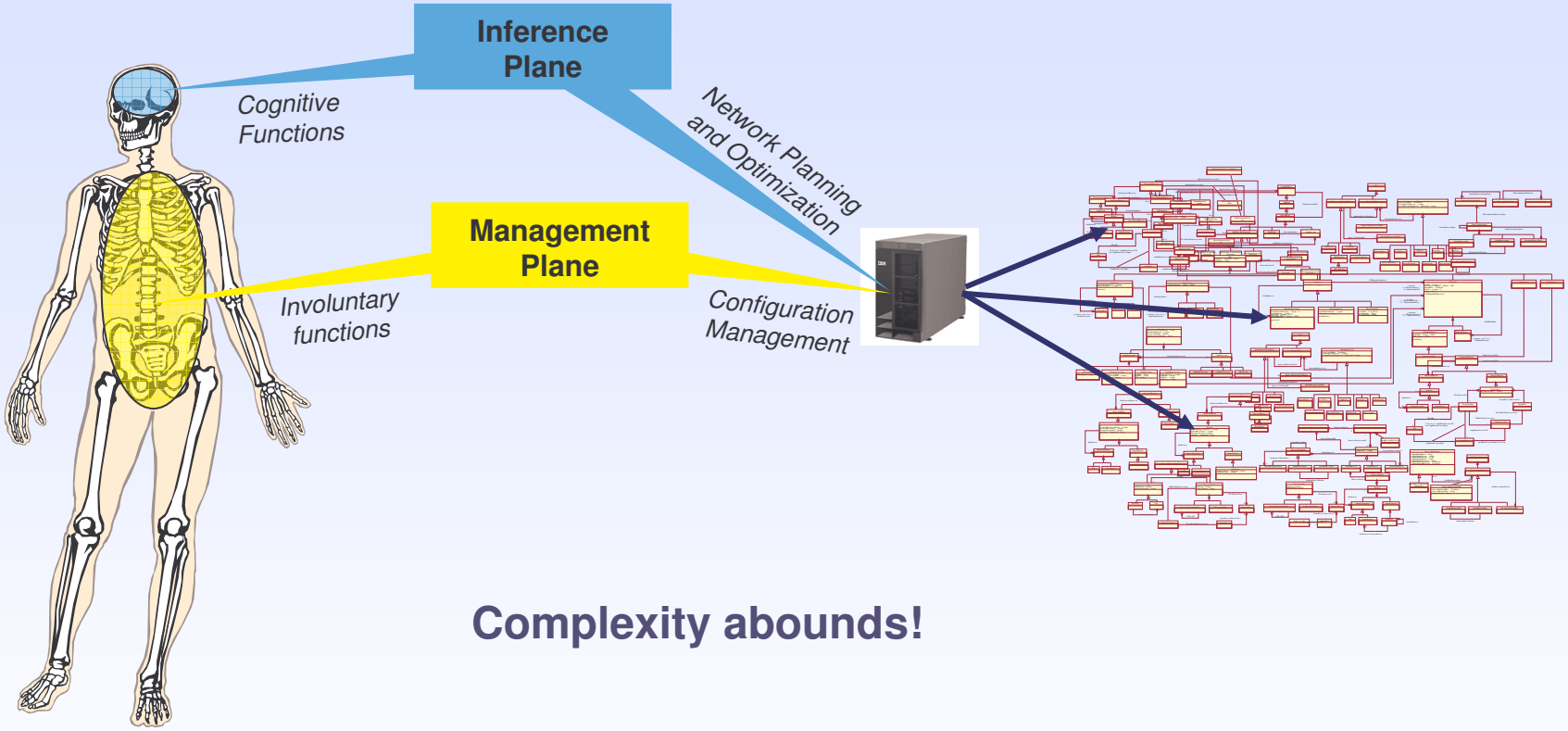
Future Vision of Autonomic Computing

Machines will free system administrators to manage system at a higher level

Right!

Autonomic Networking

Biology, Sociology, and Economics can Inspire Better Networks!



Complexity abounds!

- *Technical* complexity: human body ⇔ technology, devices
- *Business* complexity: macro-economics ⇔ e- and m-Commerce
- *Behavioral* complexity: social interaction ⇔ service composition
- *Operational* complexity: healing ⇔ anti-virus, configuration management

What is Important About Autonomics

- The four (in)famous self-functions (self-configure, -protect, -heal, and –optimize are ***benefits***
- How do we get these four self-functions?
  - Knowledge
  - Understanding context
  - Ability to learn and reason
  - Link to business rules
  - ***Adapt*** offered services and resources

Autonomics and People

A Partnership

- People and autonomic systems will work together *iteratively*, ***in partnership***
  - People will still do what they're best at
  - Autonomic systems will ***gradually*** assume more management burden
    - » *As they become more competent to do so*
    - » *As people become more comfortable with this*

Automated Productivity: Self-Configuration

China Netcom Corporation Ltd

Need

- Provide effective call-center support for 138 offices
- Establish effective and efficient software distribution mechanism

Solution

- IBM Tivoli Configuration Manager
- IBM Tivoli Remote Control

Result

- Support 4,000+ staff across 138 offices with only 38 IT staff
- Self configuring function re-initiates software distributions that are not complete and removes undesirable applications
- Maintained IT staff-level even after an increase of 200 applications
- Efficient control of entire IT infrastructure from one location

"We rely heavily on information technology to drive business expansion and new levels of productivity and efficiencies. The self-configuring systems management delivered by Tivoli software is not only indispensable, it has so far been a key enabling force that has helped us bring such business and IT imperatives to success."

—Peng Jin Song, MIS Director, China Netcom Corporation Ltd

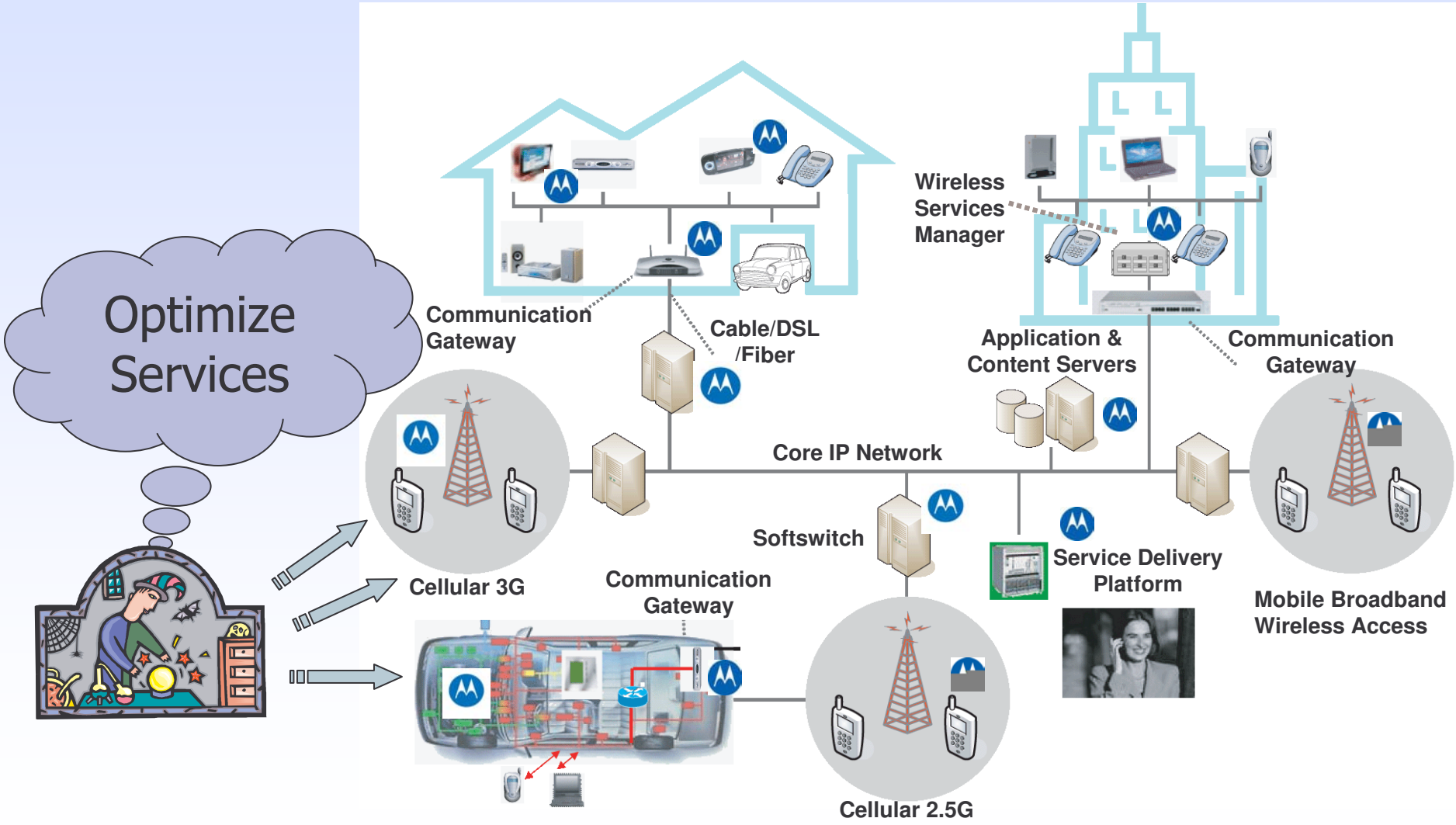
What is Autonomic Networking?

Autonomic Networking Definition

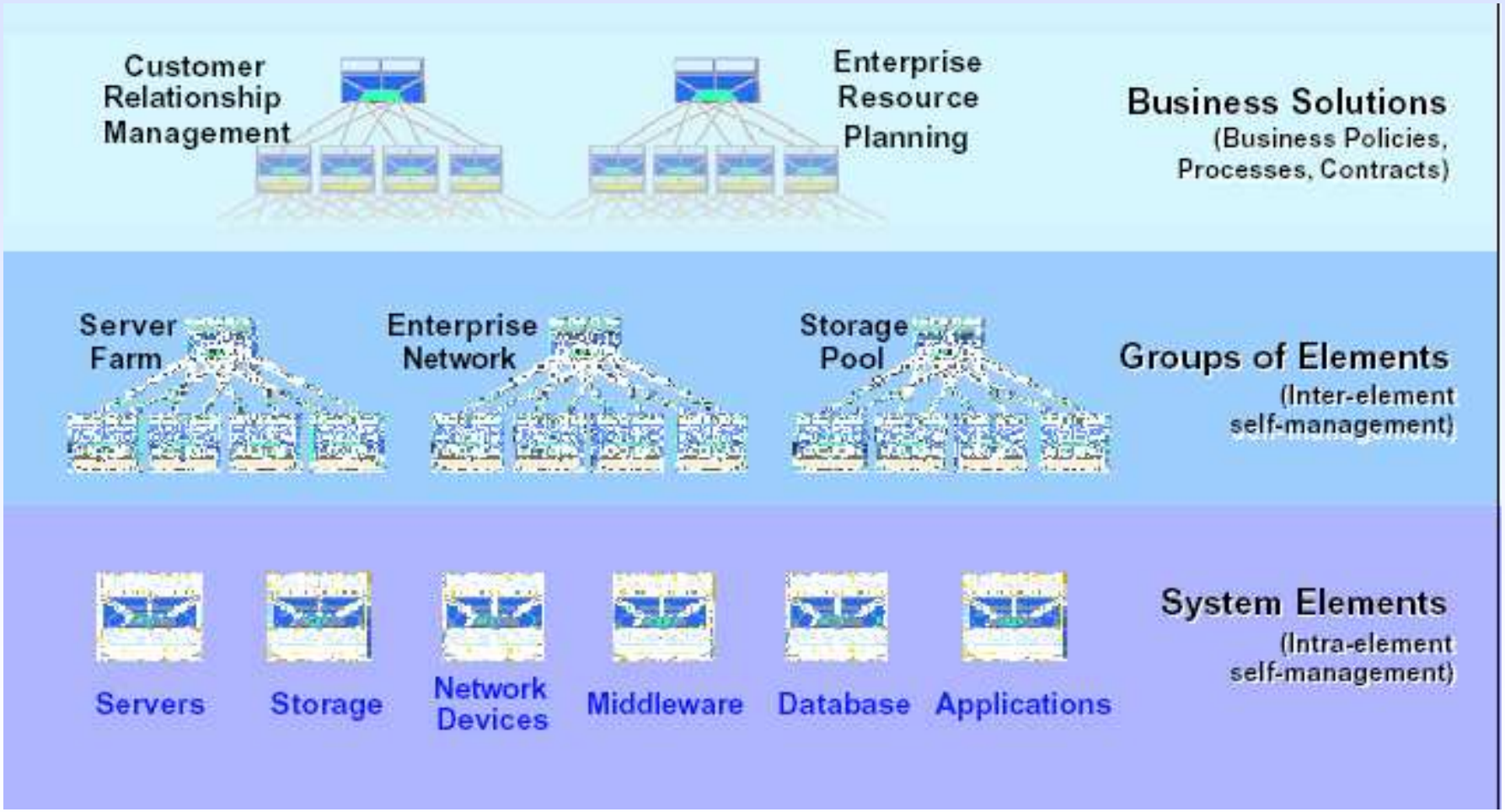
- An autonomic system is a *self-governing* system
- Closed control loops enable the system to
  - Sense changes in itself and its environment
  - Analyze changes to protect business goals
  - Plan reconfiguration if business goals are threatened
  - Execute those changes, and observe the result
- Control loop is ***augmented*** by learning and reasoning processes

Autonomic Networking Scenario

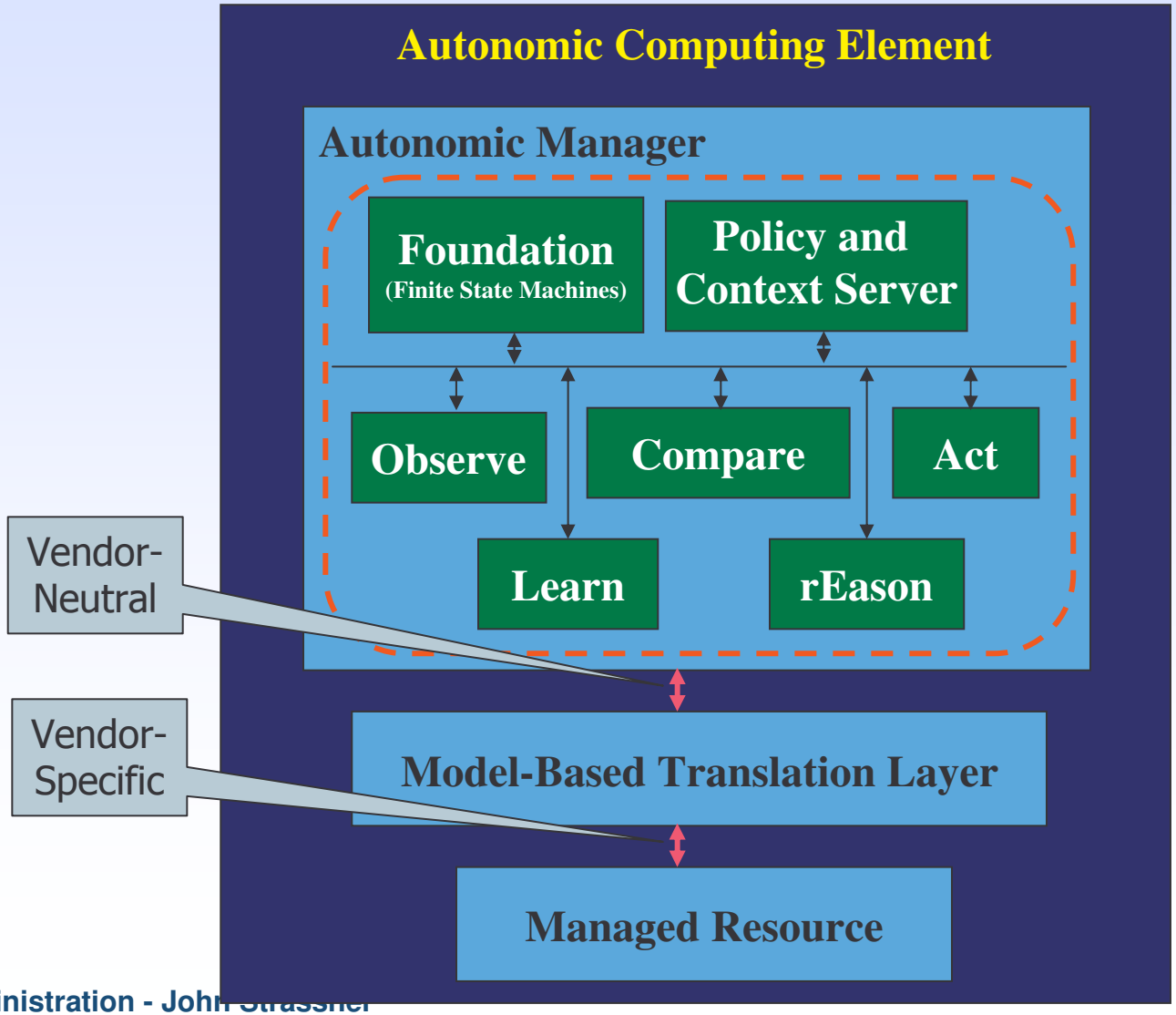
Managing this complexity requires a Paradigm Shift!



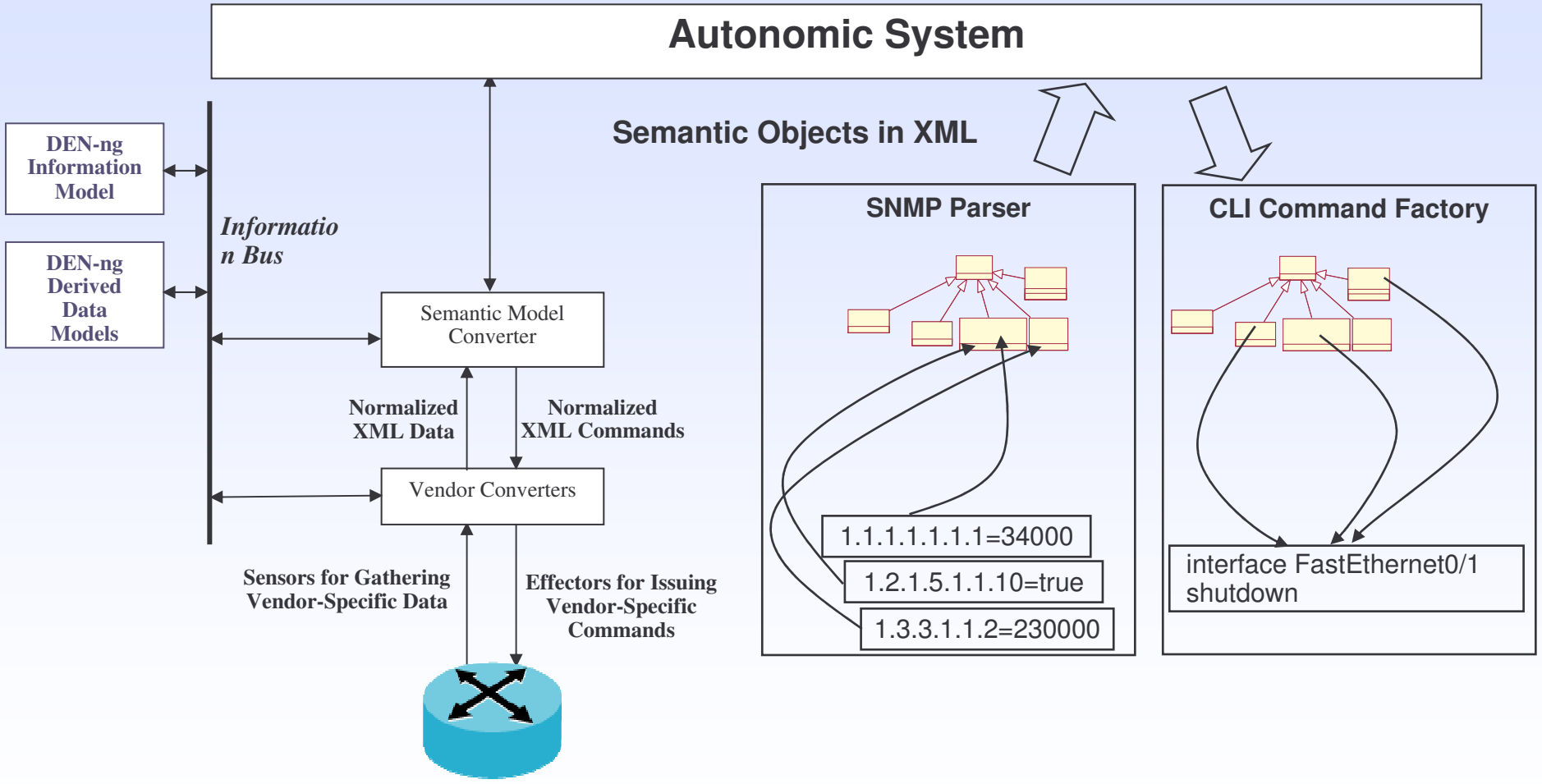
Autonomic Behavior Has Multiple Contexts



How to Make Something Autonomic

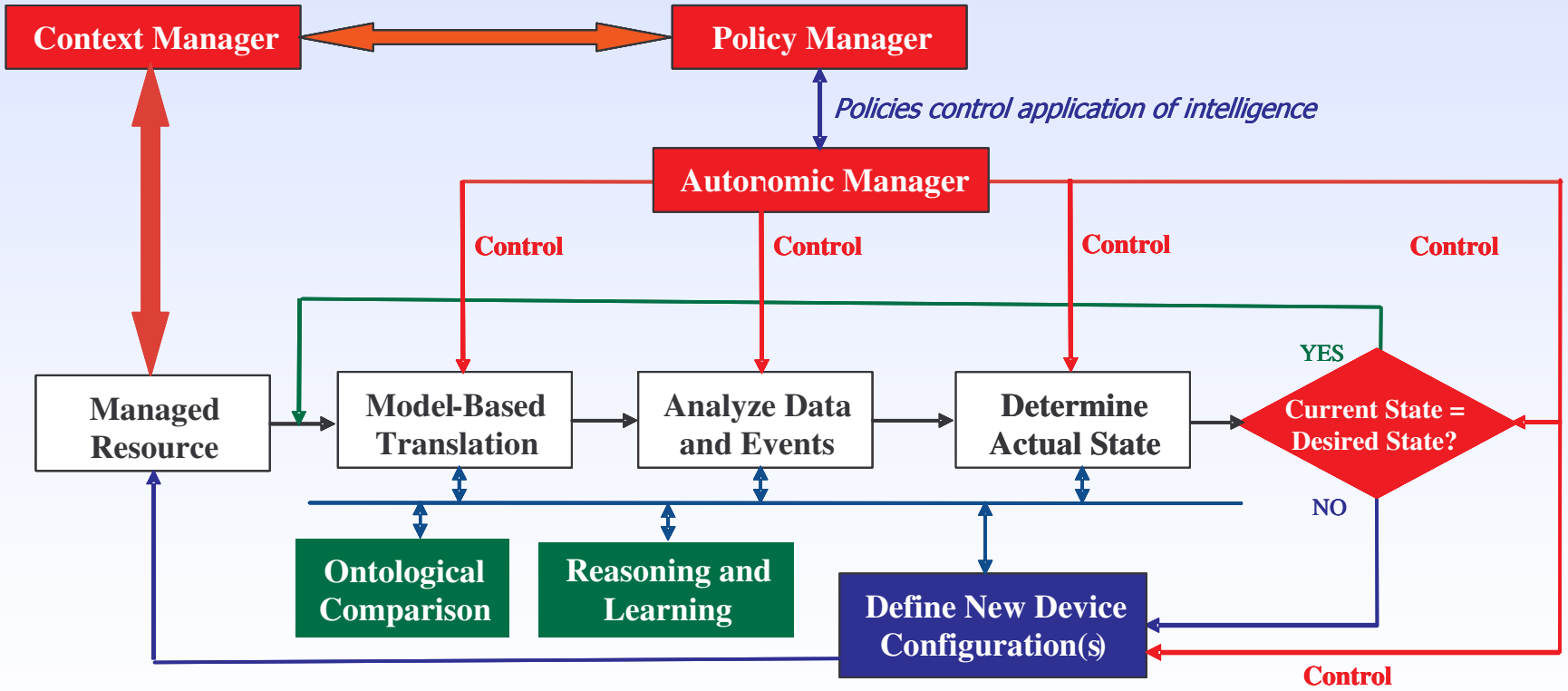


MBTL Using SNMP and CLI



So What Are We Doing About It? Here's Some Work in My Lab

FOCALE Architectural Roadmap

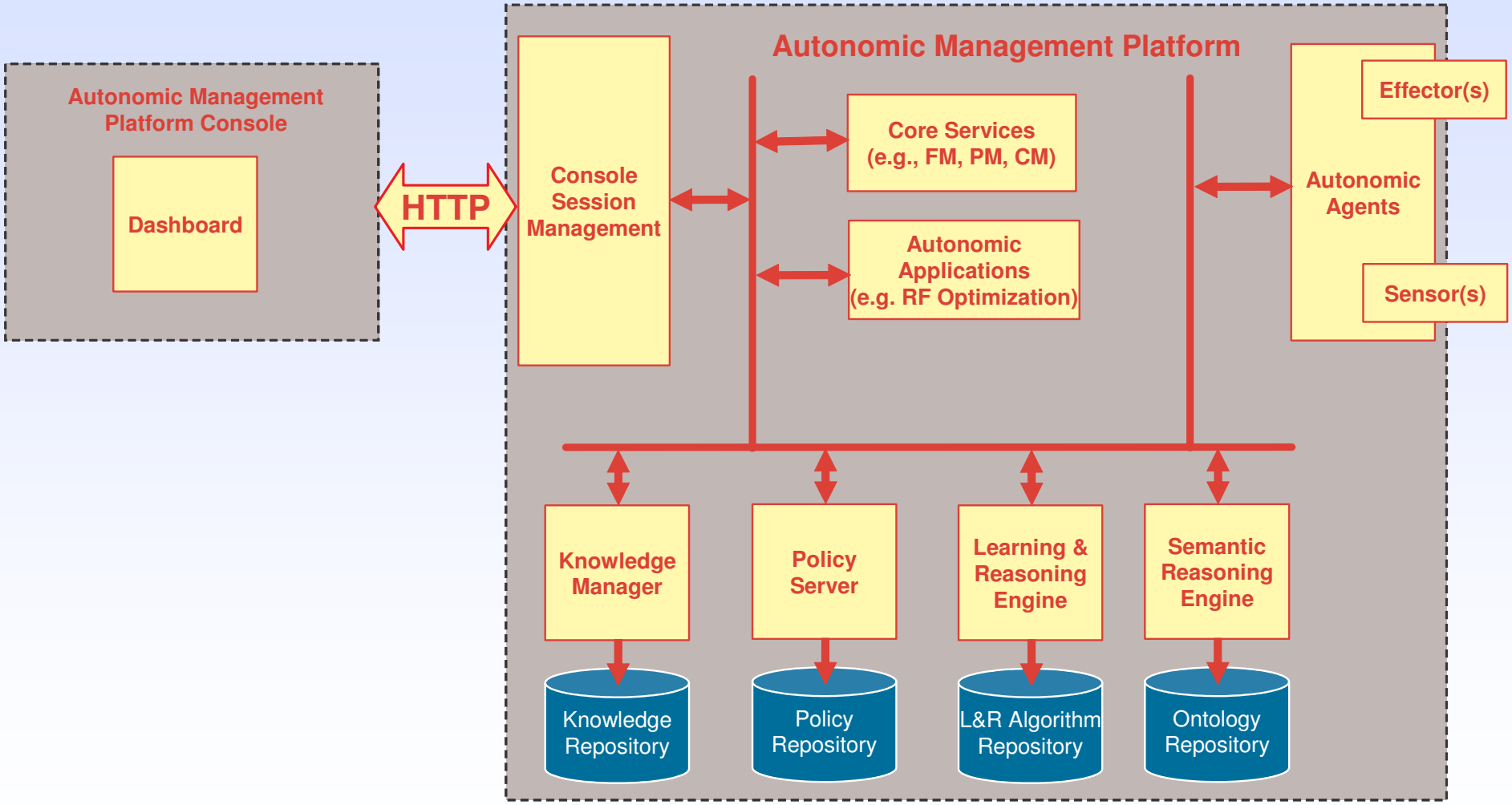


Genesis Autonomics Architecture

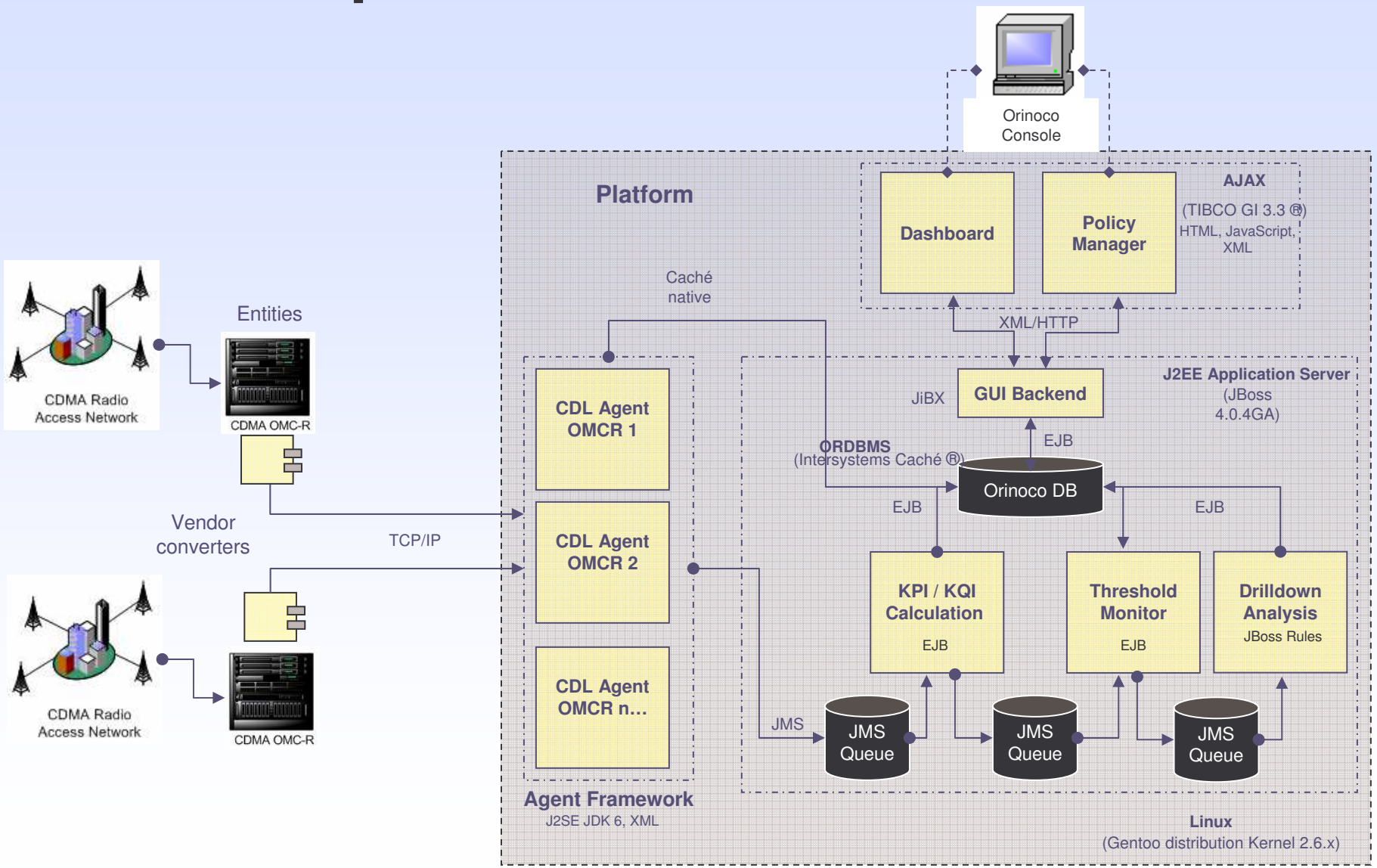
- Dynamic Federated Knowledge Base
- Model Transformation Engines
- Adaptive Control Loops

- ENABLE Autonomic Applications and Services

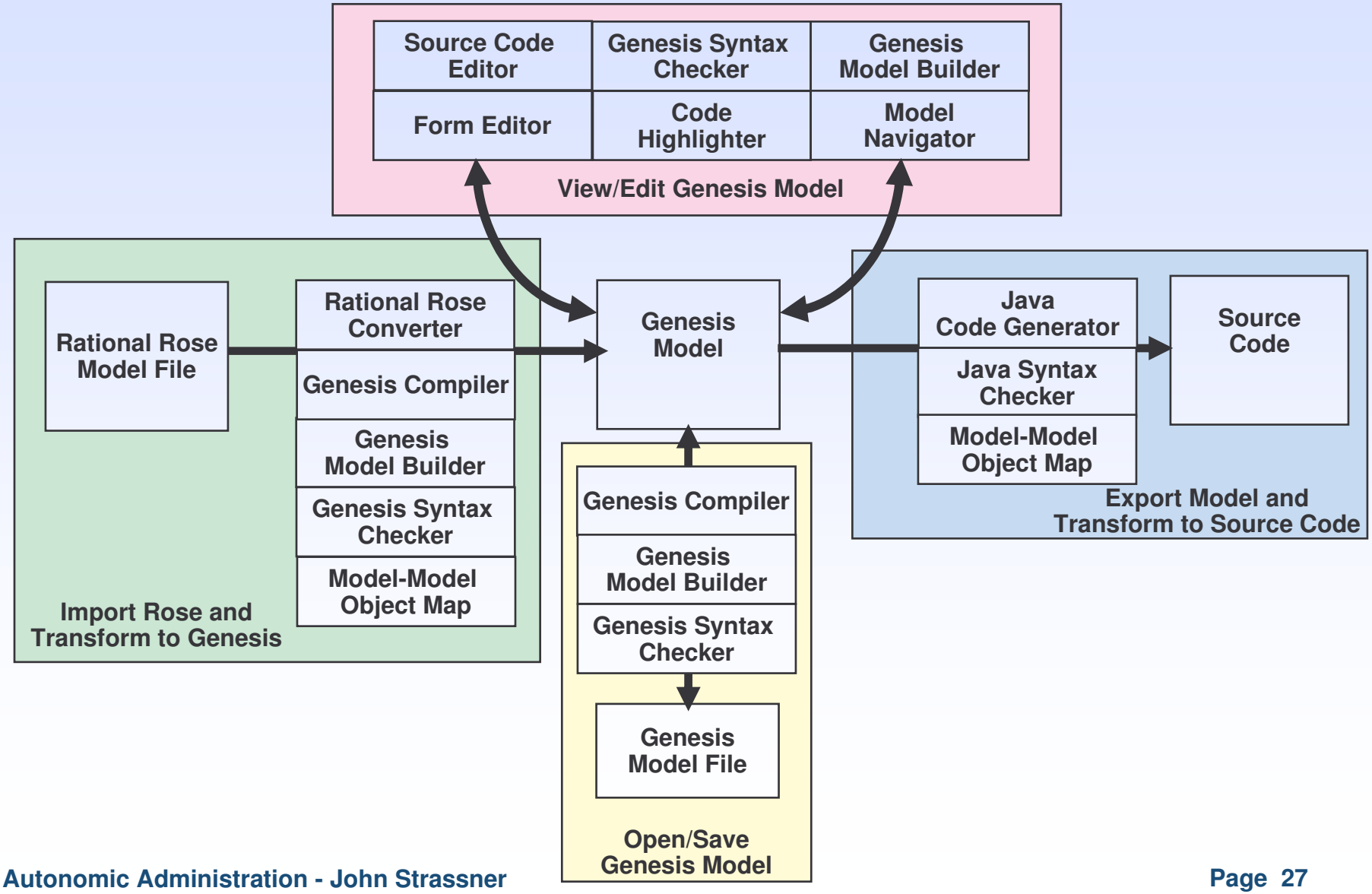
Genesis Architecture



Implementation of Genesis

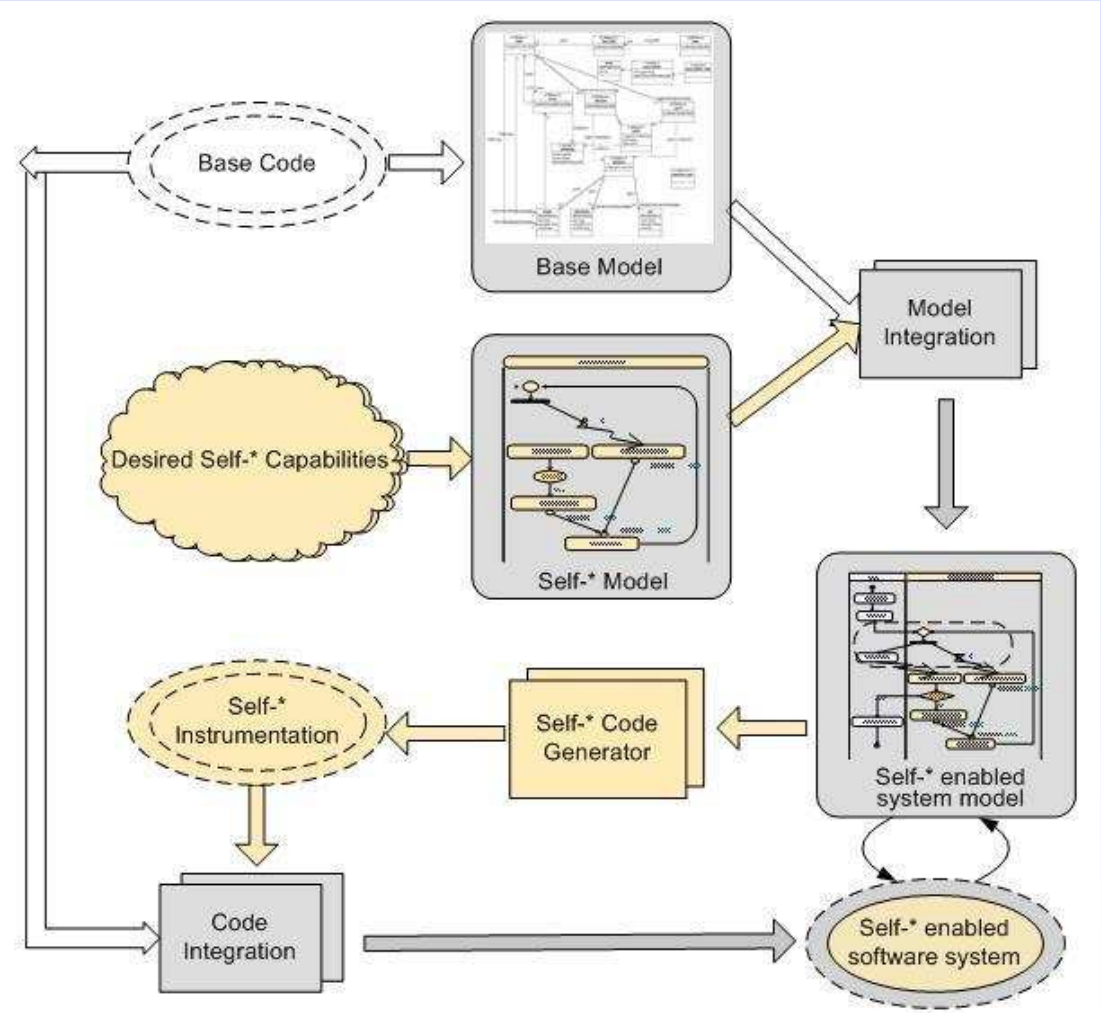


Tooling: Strategy and Importance



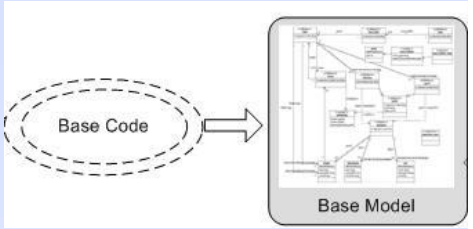
Tools to Build Legacy Models

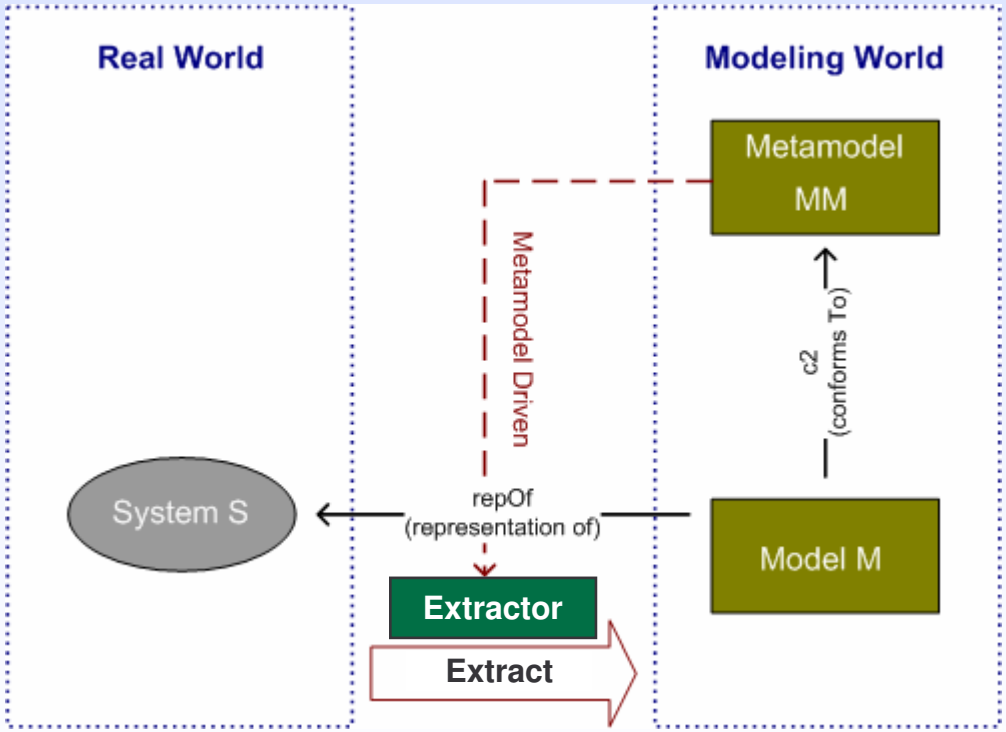
Legacy → Autonomics



Overall Innovation: To provide increased flexibility without having to retool legacy devices and systems

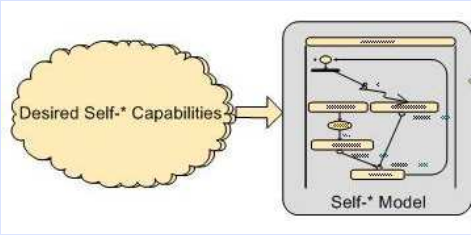
1. Metamodel-Driven Reverse Engineering Legacy Artifacts

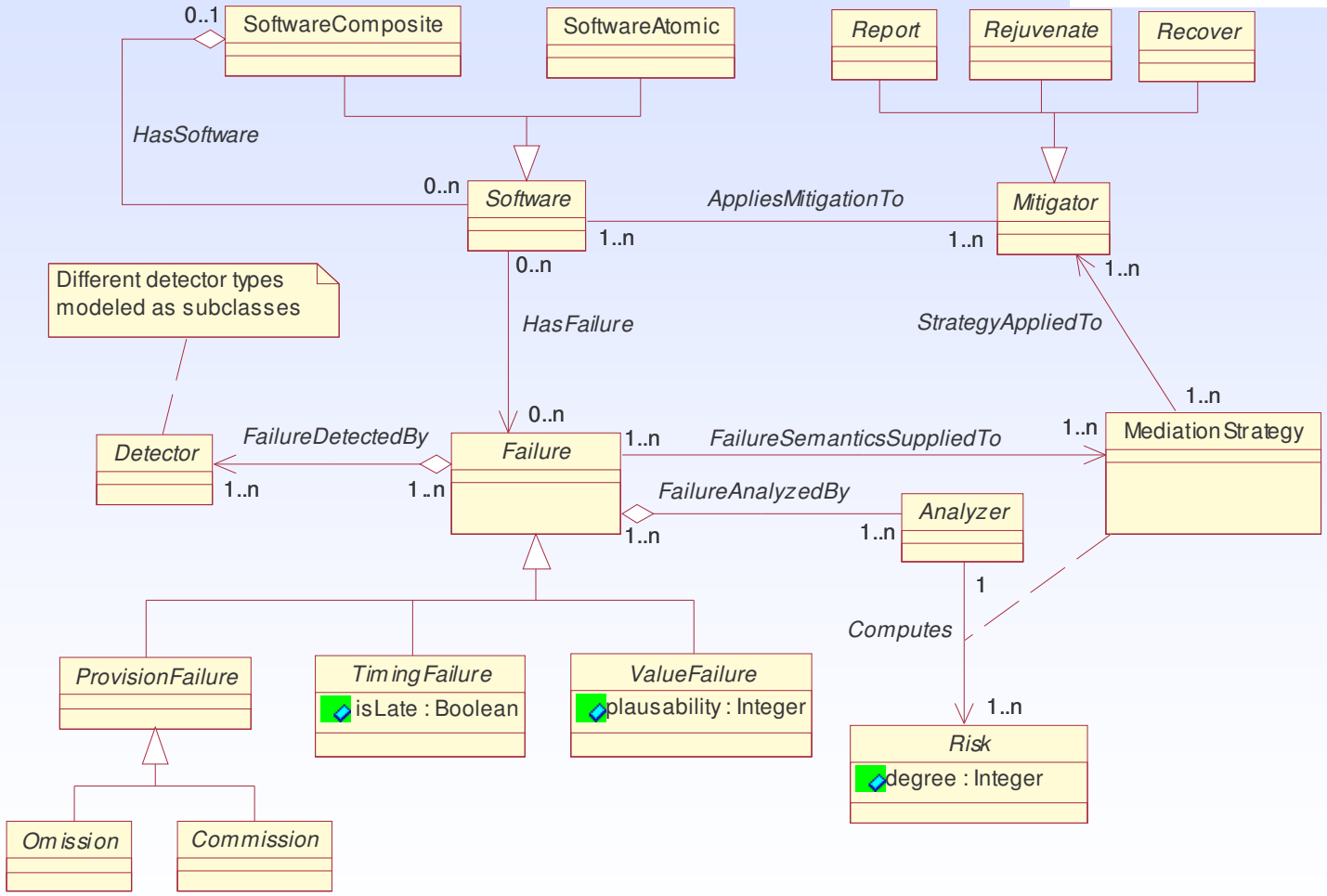




- **Step 1:**
  - Identify metamodel components that define the types of models to be extracted from the system
- **Step 2:**
  - Develop model extractor using appropriate means (e.g., parser, runtime model extractor, etc.)
- **Step 3:**
  - Extract model M from system S using model extractor

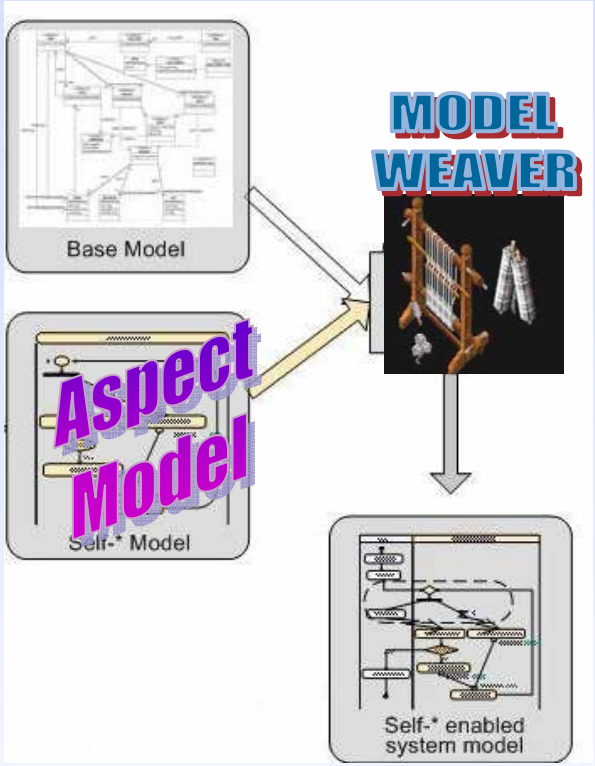
2. Design Self-* Models





An Example of a Self-Healing Model

3. Base Model and Self-* Model Integration Using Aspect-Oriented Modeling (AOM)



- Each self-* model is captured in one aspect
- A self-* model is constructed by weaving the base model with the self-* model

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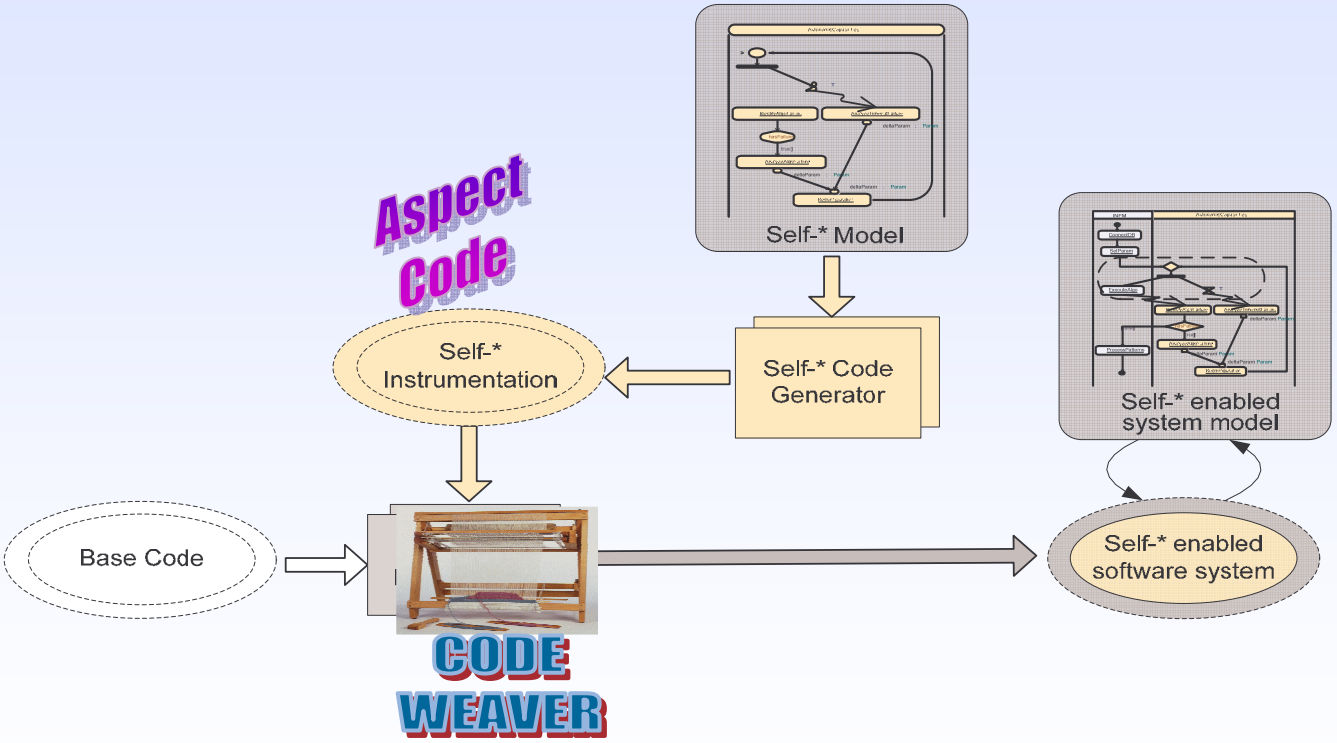
- AOM concepts:
  - Aspect: a modularization unit for encapsulating a specific concern, by applying advice (additional functionality to be woven into the base model) at various join points (locations in the base model)
  - Weaver: a model composer for integrating base model and aspect model
- Tool Support: C-SAW, Motorola WEAVR, AMW, Kompose, …

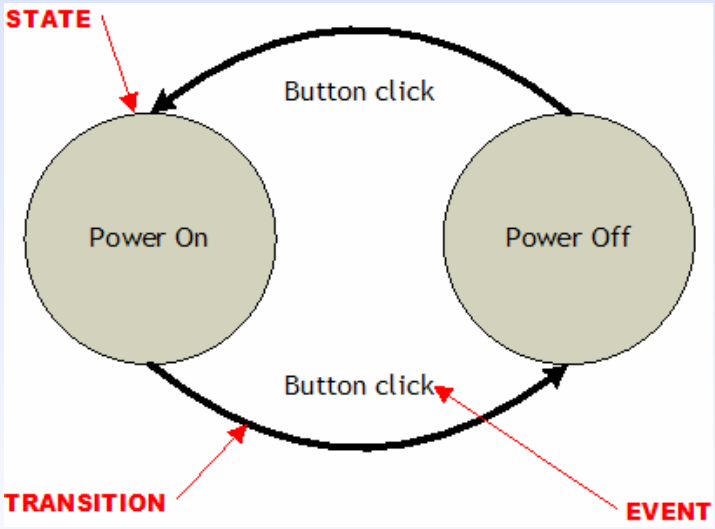
4. Base Code and Self-* Code Integration Using Aspect-Oriented Programming (AOP)



Managing Using State Automata

Traditional Finite State Machine Theory

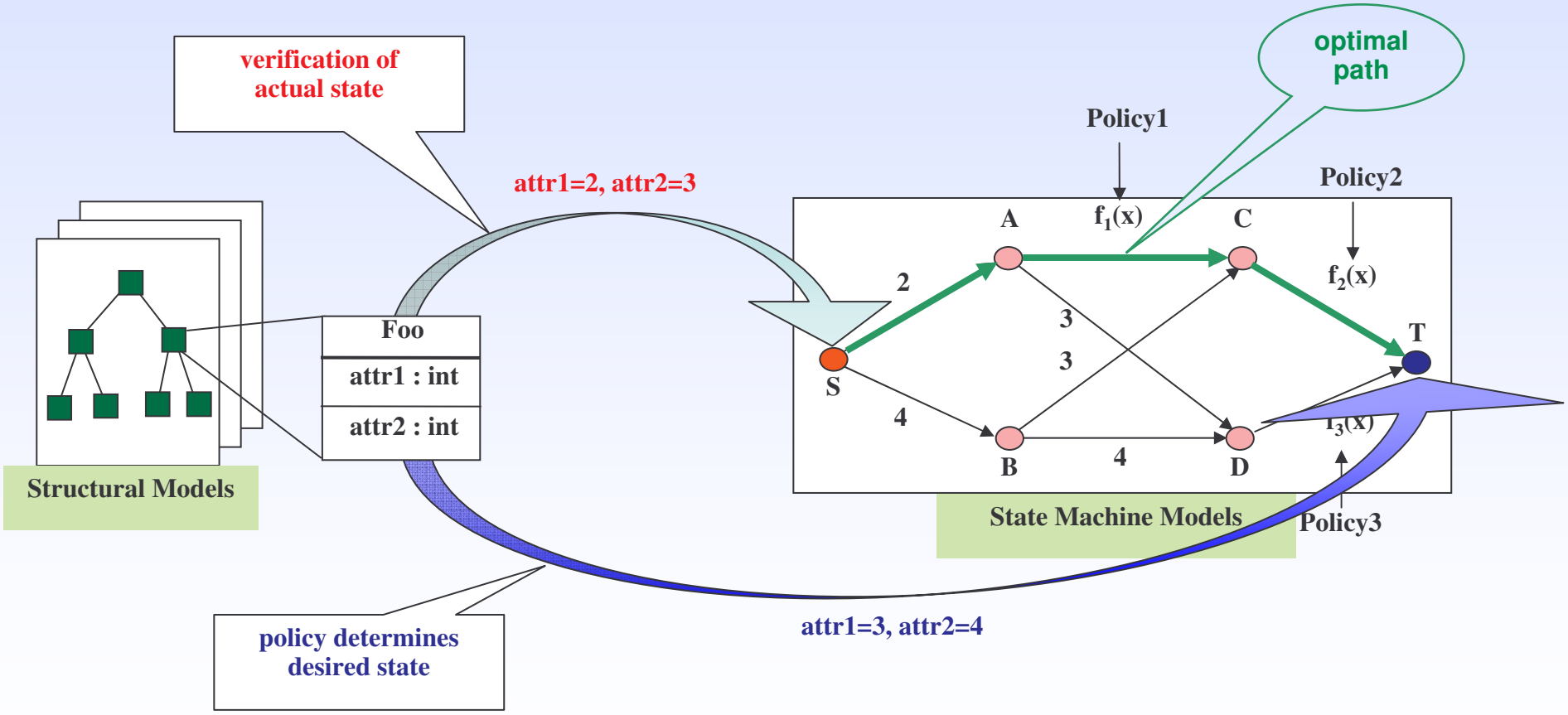
- Finite Automata
- Mealy/Moore Machines
- Harel's Statecharts
- SDL
- UML State Machine
- …



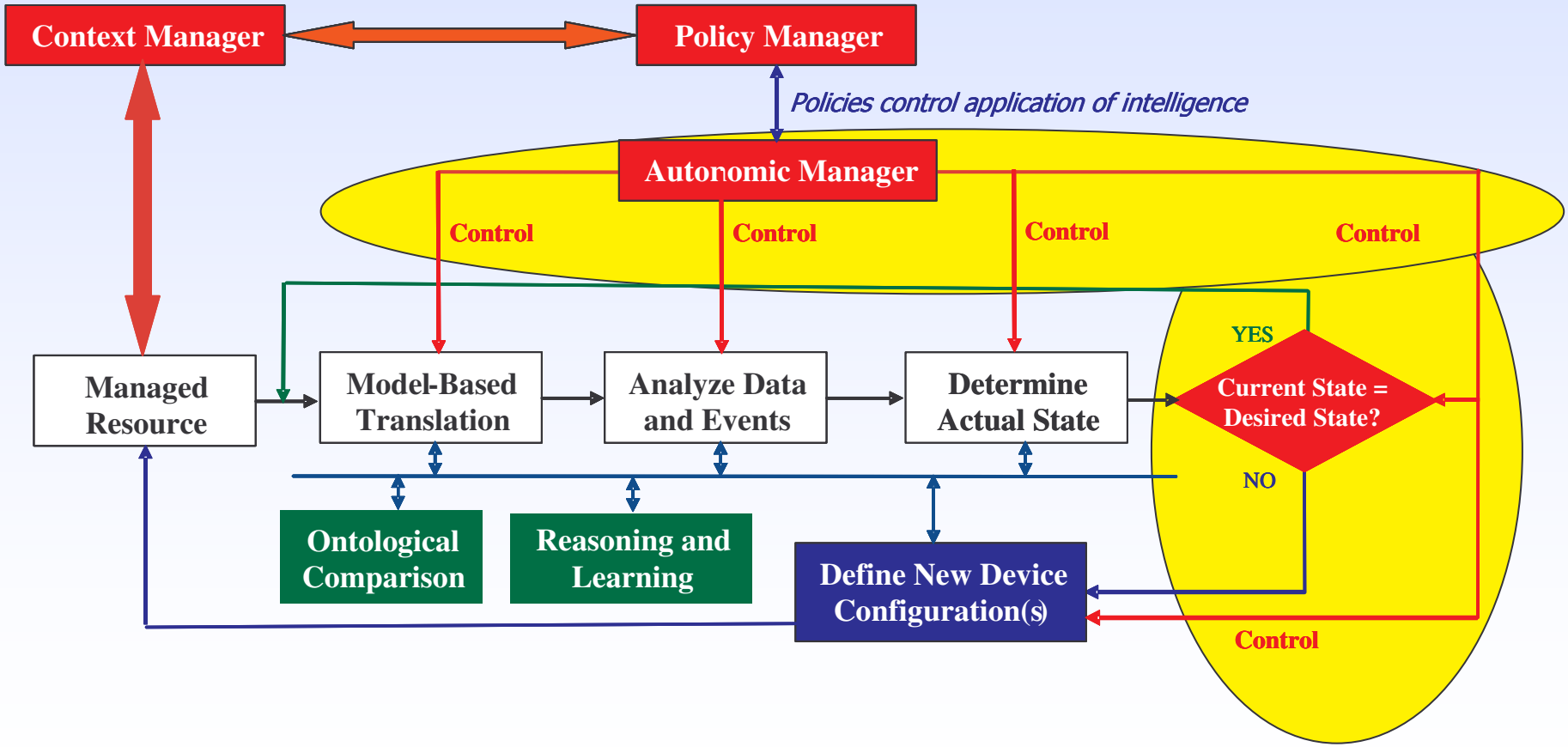
None of these relates a state to the information that it represents!

Traditional FSMs don't consider semantics of behavior!

Policy-driven Behaviour Orchestration Using Motonomics State Machine

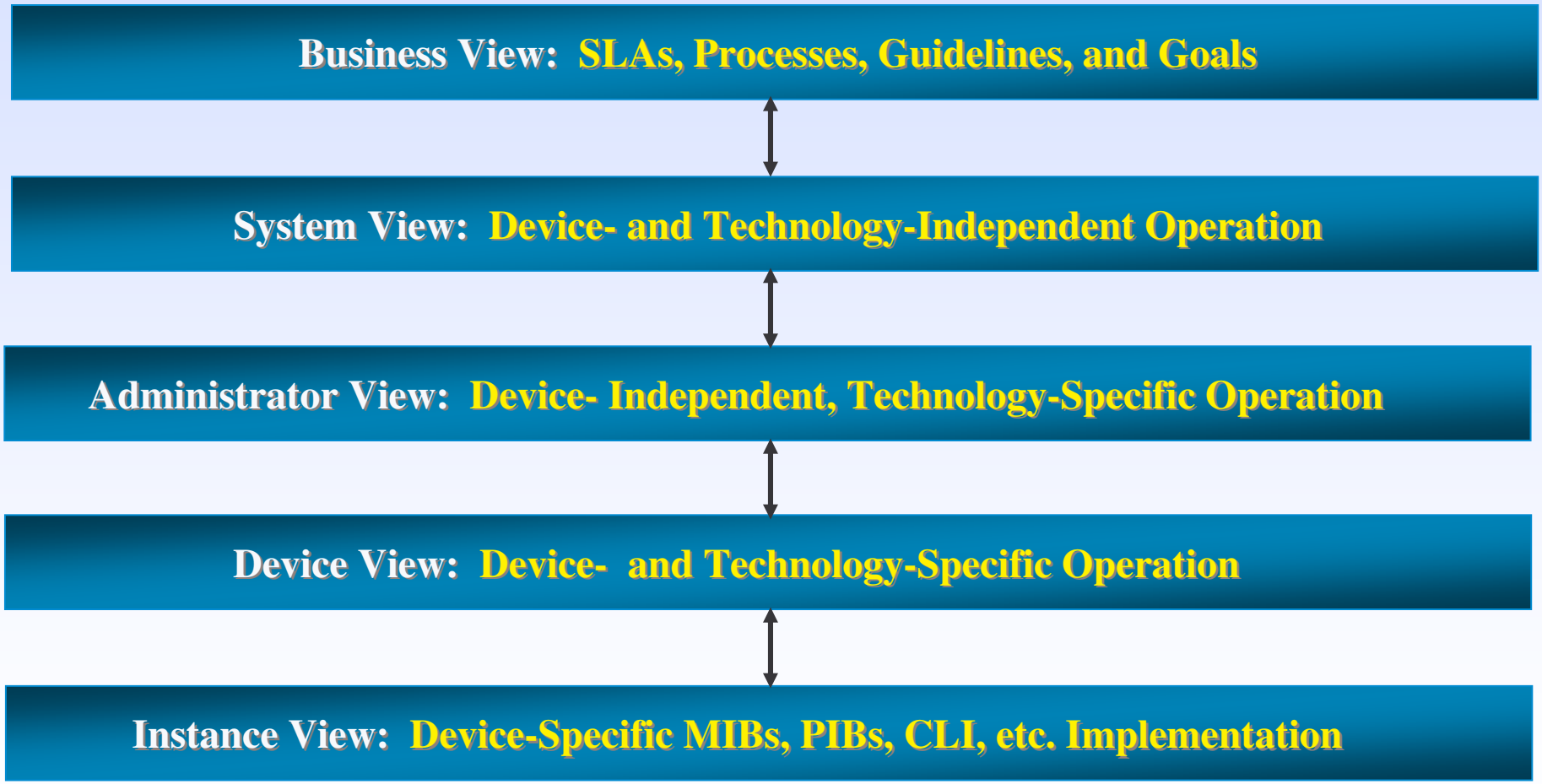


Adaptive Control Functions



Policy Management

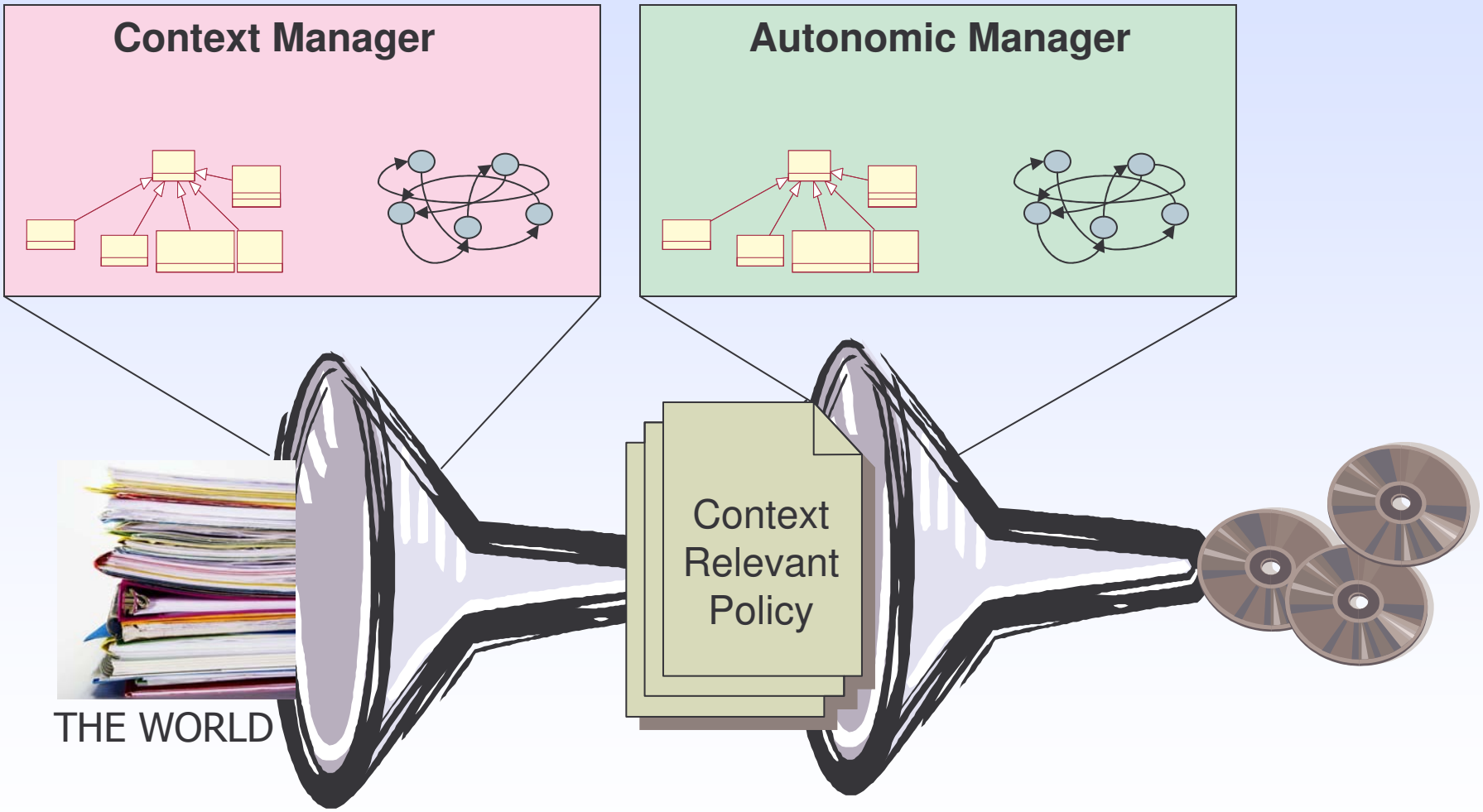
The Policy Continuum



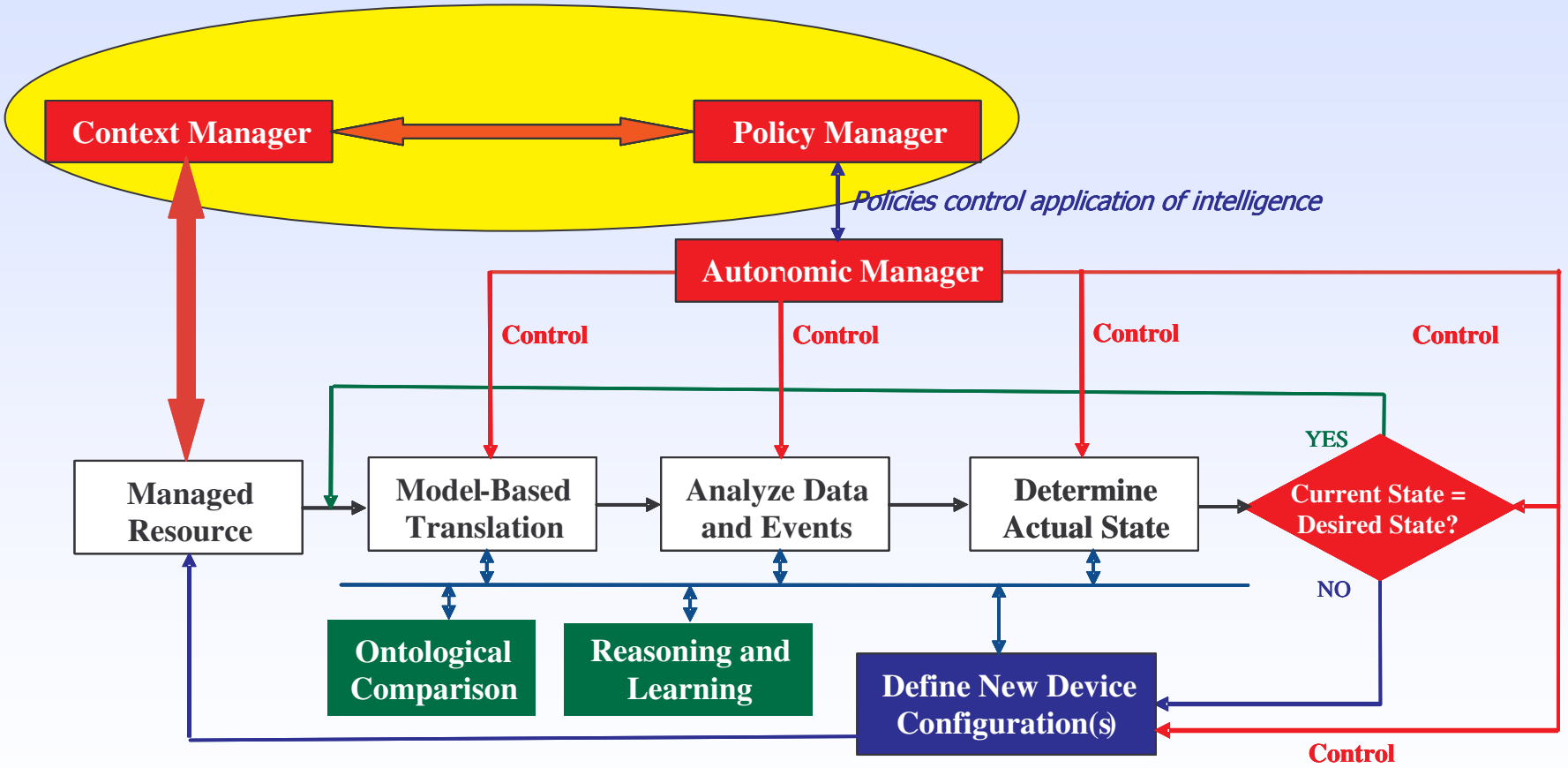
Mapping Examples

View	Sample Objective	Sample Objects
Business	*John gets Gold Service*	Customer; GoldService; GoldApplications
System	*Define three Class of Services*	Set of customer-facing services {Gold, Silver, Bronze}
Administrative	*Use DiffServ to define traffic conditioning for Gold, Silver and Bronze; use RSVP to reserve bandwidth when required*	Define mappings between devices that are DiffServ-aware and not DiffServ-aware
Device	*Pick specific devices and software releases of their operating systems that support the above requirements*	Define specific type of queuing objects used per device, and map between their functional differences
Instance	*Write the appropriate CLI, and monitor using the appropriate MIBs*	Define objects to represent CLI and MIBs, and define mapping between them

How Does Policy Fit In?



Context-Aware Policy Management



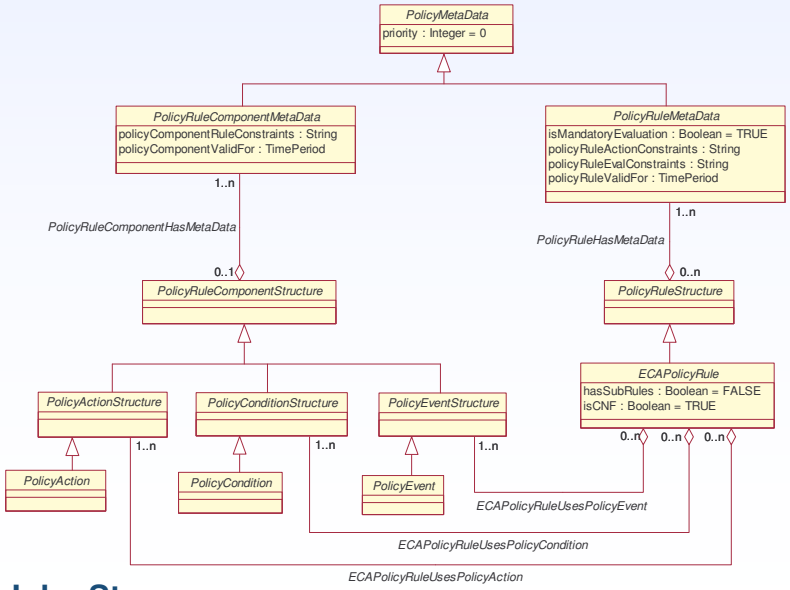
Knowledge Management

Diverse Knowledge Representations

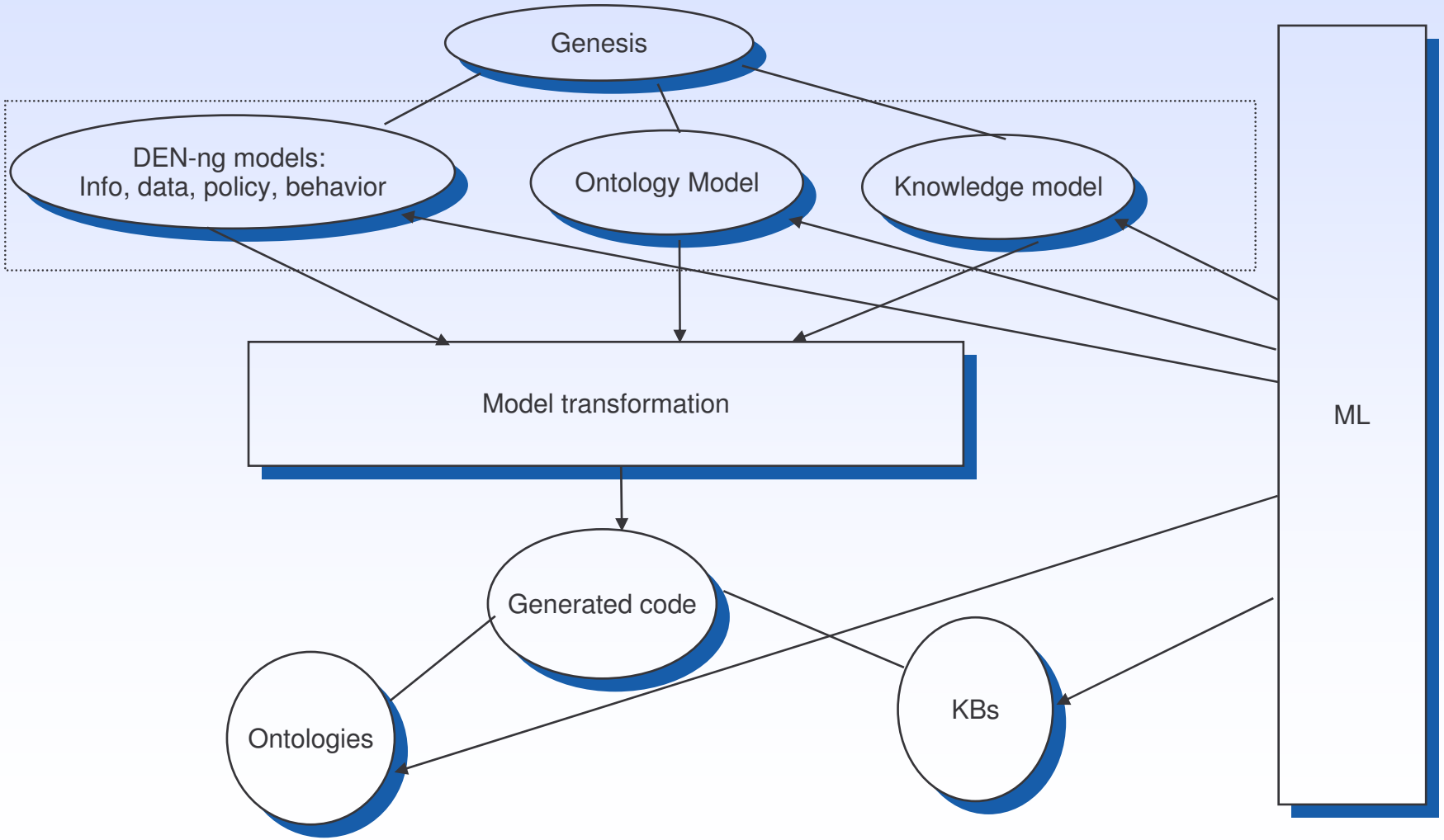
Sentence ::= AtomicS | ComplexS
AtomicS ::= True | False | RelationSymb(Term, . . .) | Term = Term
ComplexS ::= (Sentence) | Sentence Connective Sentence
| ¬Sentence | Quantifier Sentence
Term ::= FunctionSymb(Term, . . .) | ConstantSymb | Variable
Connective ::= ∧ | ∨ | ⇒ | ⇔
Quantifier ::= ∀ Variable | ∃ Variable
Variable ::= a | b | · · · | x | y | · · ·
ConstantSymb ::= A | B | · · · | John | 0 | 1 | · · · | ⊦ | . . .
FunctionSymb ::= F | G | · · · | Cosine | Height | FatherOf | + | . . .
RelationSymb ::= P | Q | · · · | Red | Brother | Apple | > | · · ·

```
(defrule propagate-goal ""
  (goal is ?goal)
  (rule (if ?variable $?)
        (then ?goal ? ?value))
  =>
  (assert (goal is ?variable)))

(defrule goal-satified ""
  (declare (salience 30))
  ?f <- (goal is ?goal)
  (variable ?goal ?value)
  (answer ? ?text ?goal)
  =>
  (retract ?f)
  (format t "%s%s%n" ?text ?value))
```



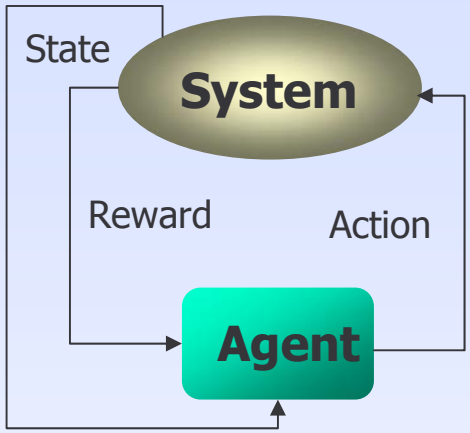
Model-based Knowledge Engineering & Transformation



Purpose of Machine Learning

- To enable the system to improve based on experience
- To gather information on executing processes and perform trending and other high-level analyses
- To refine the system's knowledge base

Reinforcement Learning



- A learning agent interacts with the environment
  - Observes environment's current (partial) state **s**
  - Takes an action **a**
  - Receives an (immediate) scalar reward **r**
- Agent learns a long-range value function **V(s,a)** estimating cumulative future reward: $R_t = \sum_{k=0}^{\infty} \gamma^k r_{t+k+1}$
  - A standard RL algorithm learns state-action value function

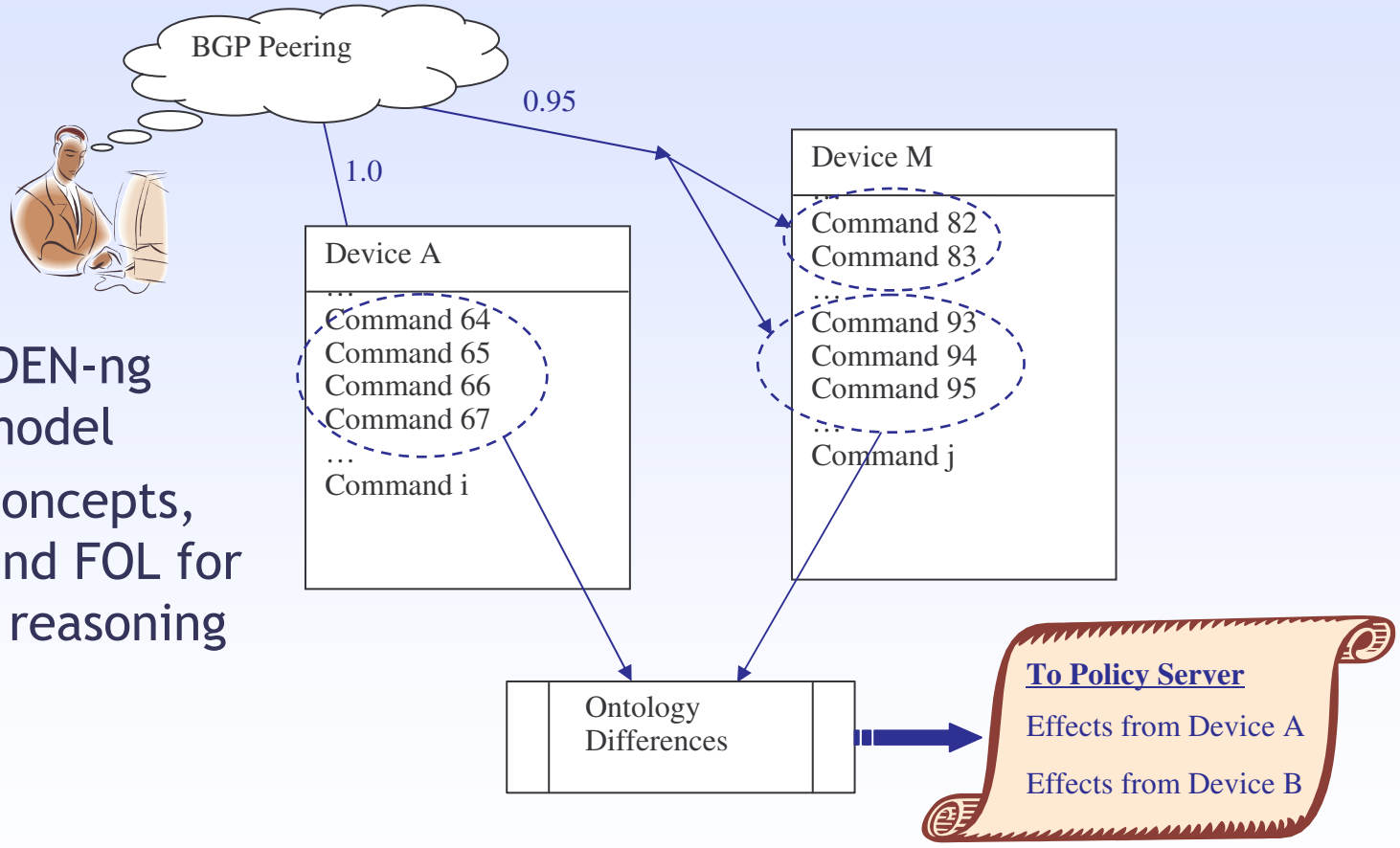
$$\Delta V(s,a) = \alpha\left(\{r + \gamma V(s',a')\} - V(s,a)\right)$$

- RL does "trial-and-error" learning without a model of the environment
- Naturally handles long-range dynamic consequences of actions (e.g., transients, switching delays)

Purpose of Reasoning

- Form a hypothesis or hypotheses for why something occurred in order to
- Monitor the set of known hypotheses in the system
  - Based on *experience*, if a hypothesis is continually proved true, elevate it to a theory
- Find things that are true which we cannot necessarily prove (*axioms)* and add to the knowledge base

Semantic Equivalence



- Infer from DEN-ng Info/data model
- Construct concepts, relations, and FOL for ontological reasoning

Machine Learning Model Selection

Characteristics	ANN	SVM	Trees	MARS	KNN
Natural handling of data of "mixed" type	Poor	Poor	Good	Good	Poor
Missing values data	Poor	Poor	Good	Good	Good
Robustness to outliers	Poor	Poor	Good	Poor	Good
Computational Scalability	Poor	Fair	Good	Good	Poor
Ability to handle irrelevant inputs	Poor	Poor	Good	Good	Poor
Feature extraction	Good	Good	Poor	Poor	Fair
Interpretability	Poor	Poor	Fair	Good	Poor
Predictive power	Good	Good	Poor	Fair	Good

There exist various learning models, each of which has strength and weakness.

The model selection always relies on some guidelines, expertise and empirical studies.

In an autonomic computing framework, the selection needs to be automated!

RL based learning selection

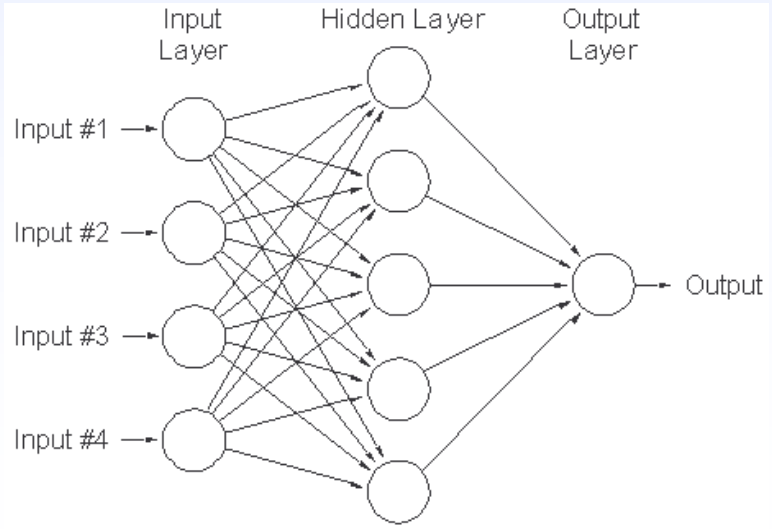
Problem: Impact Prediction for a BTS controller Failure

Solution: Neural Network predictive models that are proven to be universal function approximators

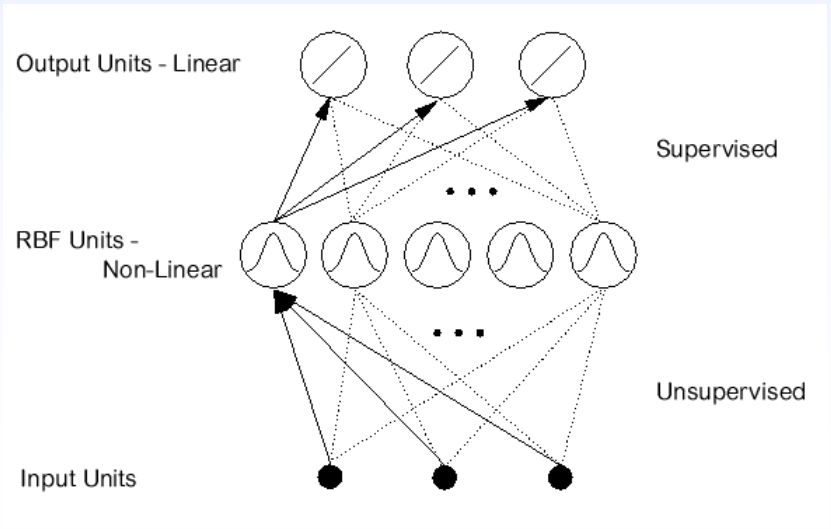
Decision Making Criteria:

- **A relatively *stable* environment prefers a *global approximator***
- **A relatively *dynamic* environment prefers a *local approximator***

Multi-Layer Perceptron (global)



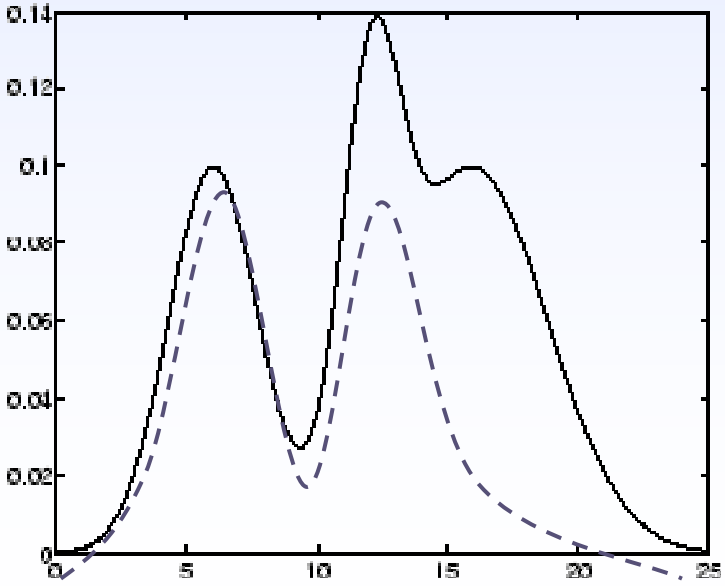
Radial Basis Function (local)



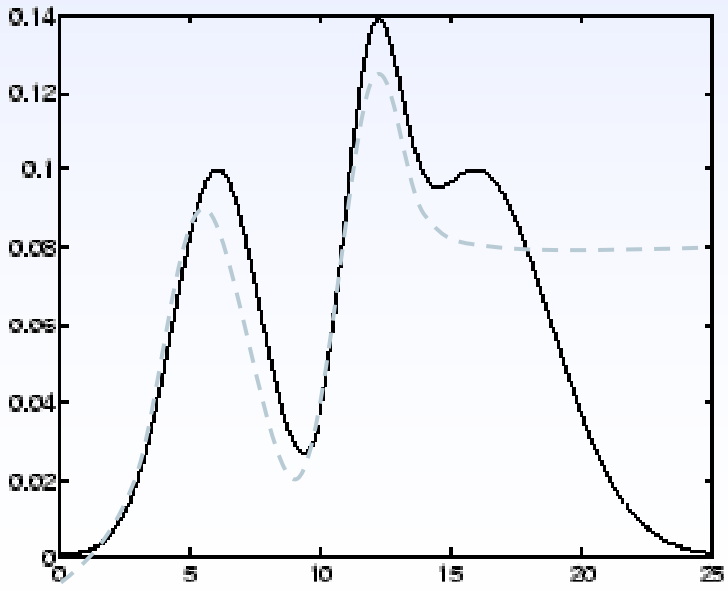
Global vs. Local – No Universal Answer

- Offline use provides very similar performance with proper training and validation
- Online use reveals significant differences under time constraints
  - MLP is less sensitive to change in its learning data
  - RBF is much more sensitive to change because of its use of unsupervised learning in the input space

MLP (global)



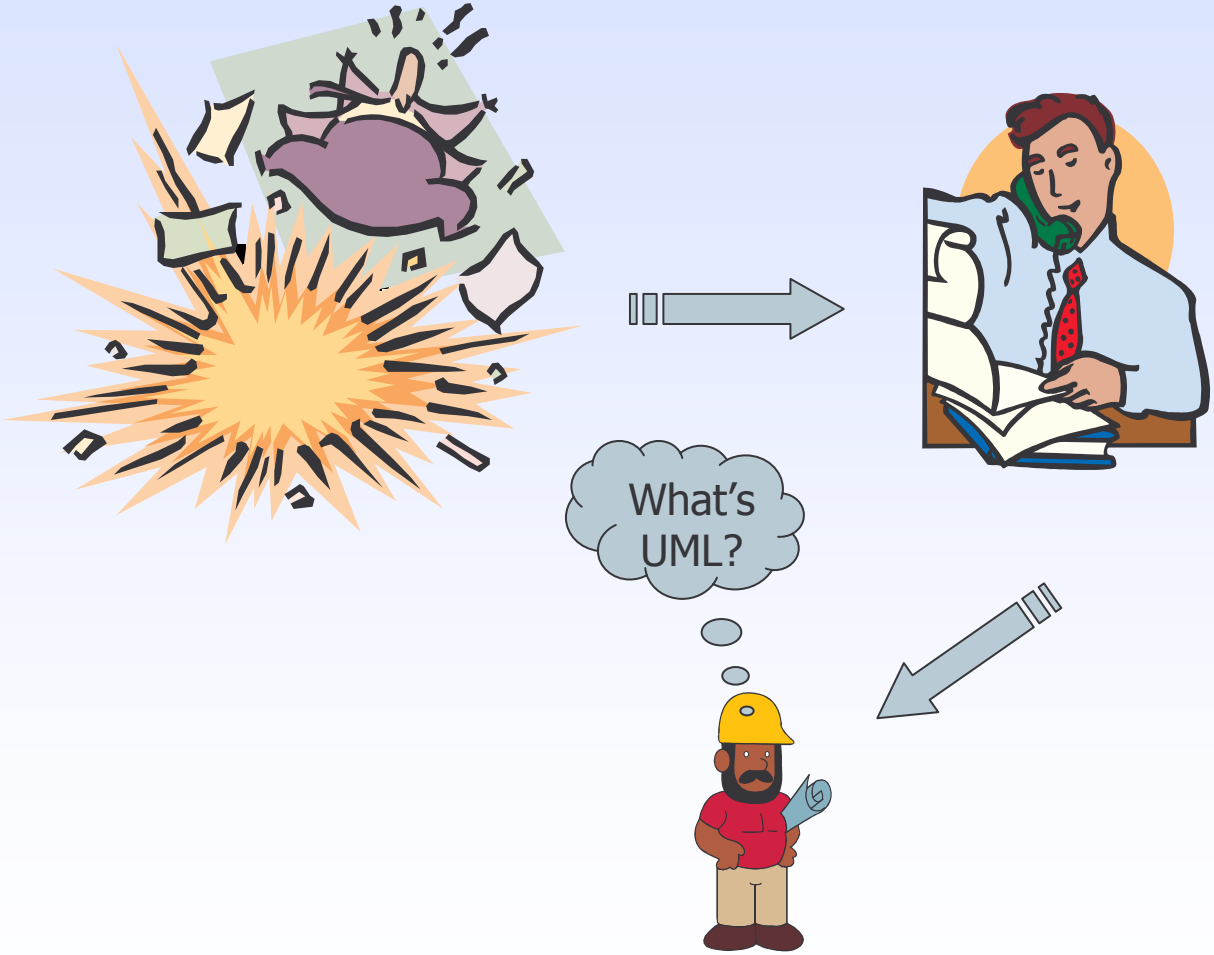
RBF (local)



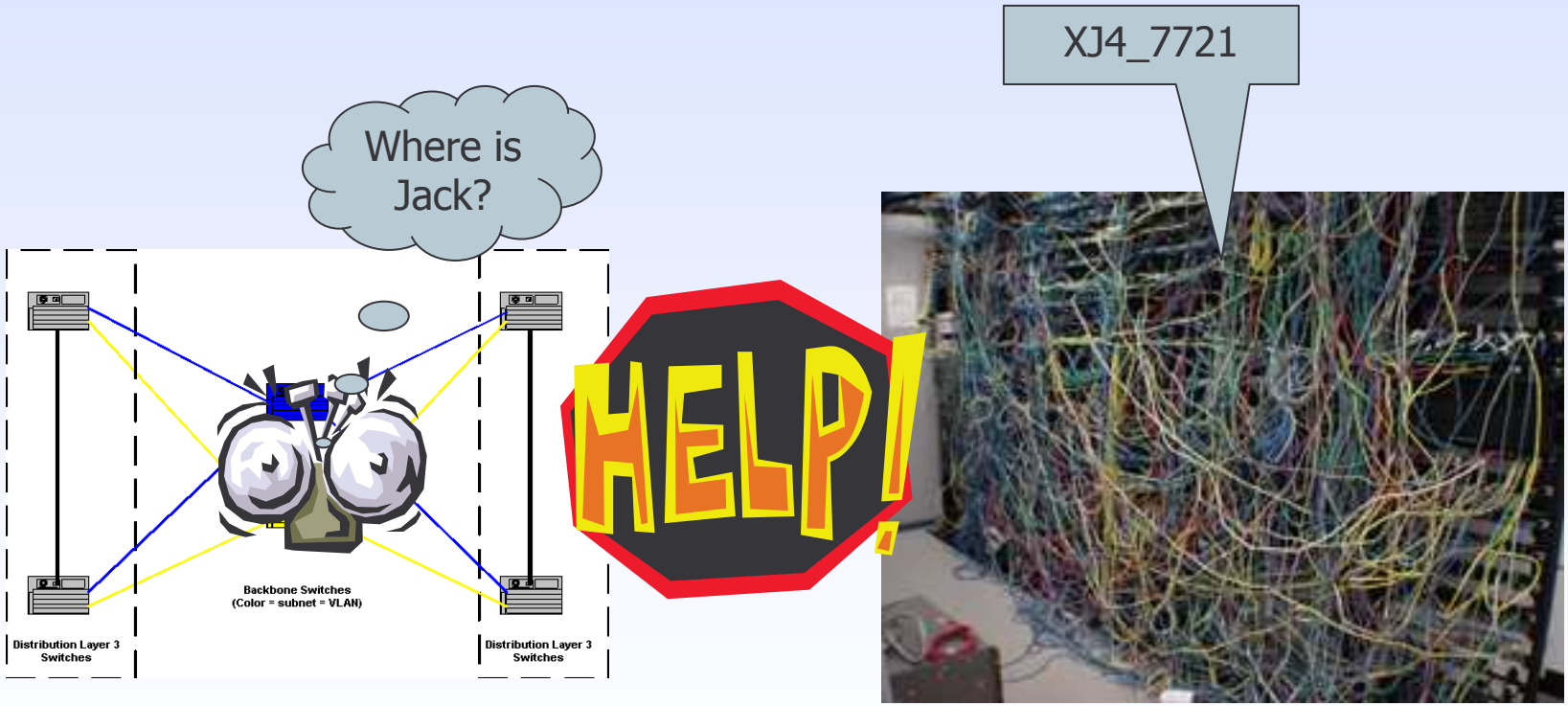
Summary

It is NOT "Just" About Technology!

Networking Scenario – Service Maintenance



Is Harder Than It Looks...



It's a True Paradigm Shift

- "Everything should be as simple as possible, *but not simpler*"
- We need to embrace a new way of administration, where software can help network and system admins be better leveraged

Because Autonomics is Good Enough,
It's Smart Enough,
and Doggone it, People LIKE it

Questions?

Questions?

“Create like a god. Command like a king. Work like a slave”

- Constantin Brancusi

Autonomic Networking References

- http://dnac.org/autonomic-networking/
- http://www.ana-project.org/
- http://www.cascadas-project.org/
- http://www.haggleproject.org/index.php/Main_Page
- http://www.beyond-the-horizon.net/central.aspx?sId=29I88I204I323I118338
- http://www.netlab.nec.de/acnm07/
- http://www.netlab.tkk.fi/IWAS2007/
- http://project.iu.hio.no/aims.html
- http://ehpclab.stfx.ca/~atc07/
- http://xiaglow-research.org.uk/CODS2007/
- http://www.acis.ufl.edu/~icac2007/

Conferences and Web Sites

- International Conference on Autonomic Computing (ICAC 2007)
  - June 11-15, 2007 in Jacksonville, Florida
  - http://www.acis.ufl.edu/~icac2007/
  - Can find programs and presentations from ICAC '04 – '06
  - Several AC workshops held in conjunction with ICAC 2007
    - Hot Topics in Autonomic Computing
    - Adaptive Methods in Autonomic Systems
    - Engineering Emergence in Decentralized Autonomic Systems
    - QoS in Autonomic Communication Networks
    - Policy-Based Autonomic Computing
- Web sites
  - General: www.autonomiccomputing.org
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  - Standards: autonomic communications forum

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