Evolving An Autonomous Test and Evaluation Enterprise

Jack Ring
Educe LLC

prepared for
International Conference and Workshop
Enterprises “as” Systems
Hoffman Estates, IL, USA
August 24, 2009

--- to inform and elicit

- About an impending expedition

  Discover the route to T&E of Unmanned Autonomous Systems
- Intentions and Rationale → Reality Check → Plan
- Tenets
  - –Context-sensitive (implicit), Four-Agent System
  - –He who learns fastest wins.
  - –It's the People, stupid!

You Don't Know Jack?

- 20 years GE Aerospace, 10 years Honeywell Commercial and Industrial computer systems, 22 years mentor and entrepreneur in high tech ventures
- International Council on Systems Engineering, INCOSE:
  - Fellow, 2003, Intelligent Enterprises WG 2002-2007, Motor Sports Working Group, Autonomous Systems T&E Working Group
- Co-founder, 2008, EDUCE LLC for systemics of learning.
- Co-founder, 2008, OntoPilot LLC for Zero Defects Software
- Co-founder, 2006, Kennen Technologies LLC for General Purpose Set Theoretic Processor.
- Sole Proprietor, Innovation Management for commercialization of invention.
- Industrial Fellow, Stevens Institute of Technology,
- Sr. Analyst, Cyon Research Corp. (Congress on the Future of Engineering Software)
- Enterprise Architect, www.starshineacademy.com youth education of mind, body, spirit, health and wealth →peacemaking and the pursuit of happiness.
- Subject Matter Expert, Unmanned and Autonomous Systems Test Executive, Test Resources Management Center, Dept. of Defense
- Papers, presentations and tutorials at international conferences.

Agenda

1. The Problematic Situation: Stakeholders vs. UAS's.
2. T & E Systems Implications
3. T&E Enterprise Implications:

A
four-agent,
implicit systems
challenge

1. The Problematic Situation

T&E Enterprise

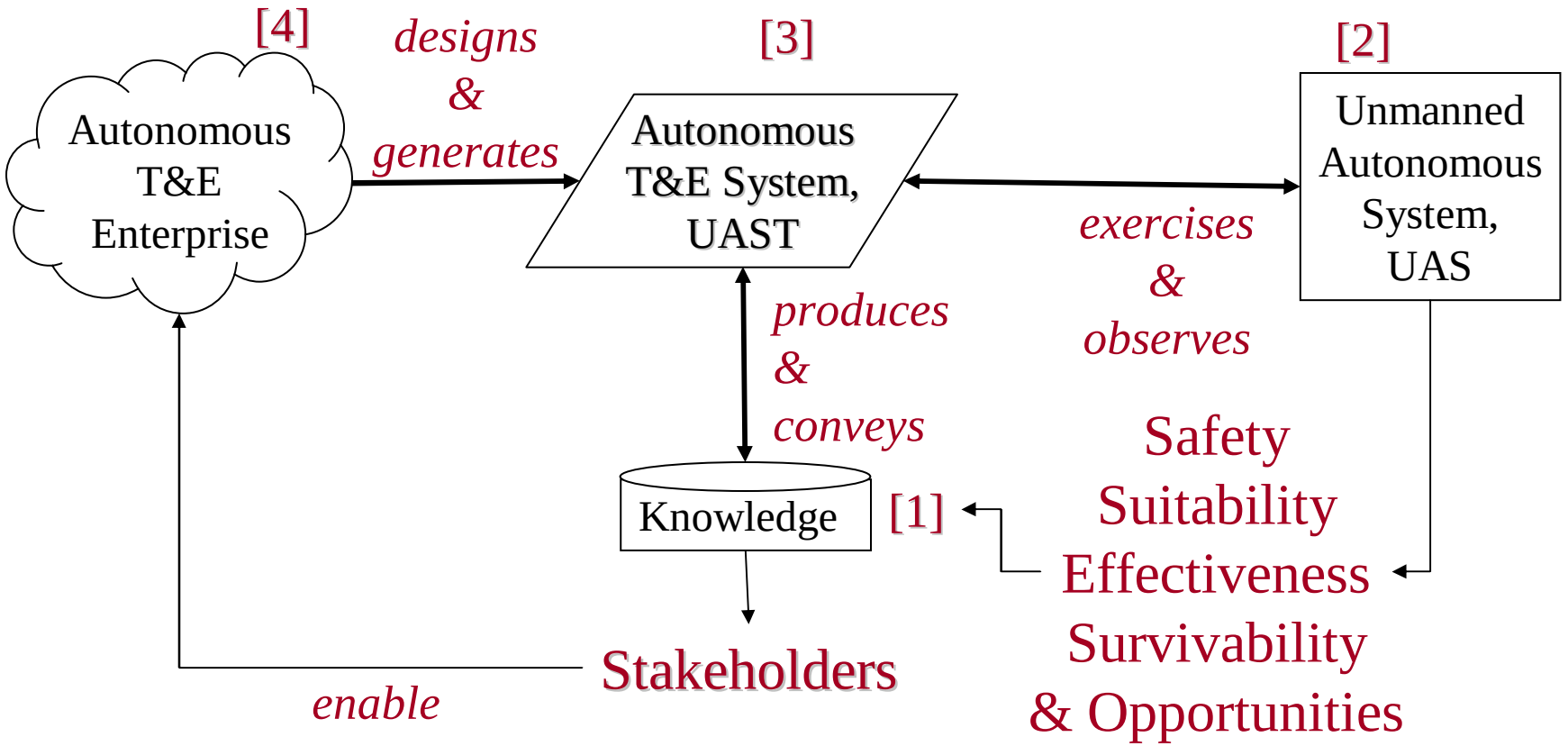
UAS T&E

UAS's

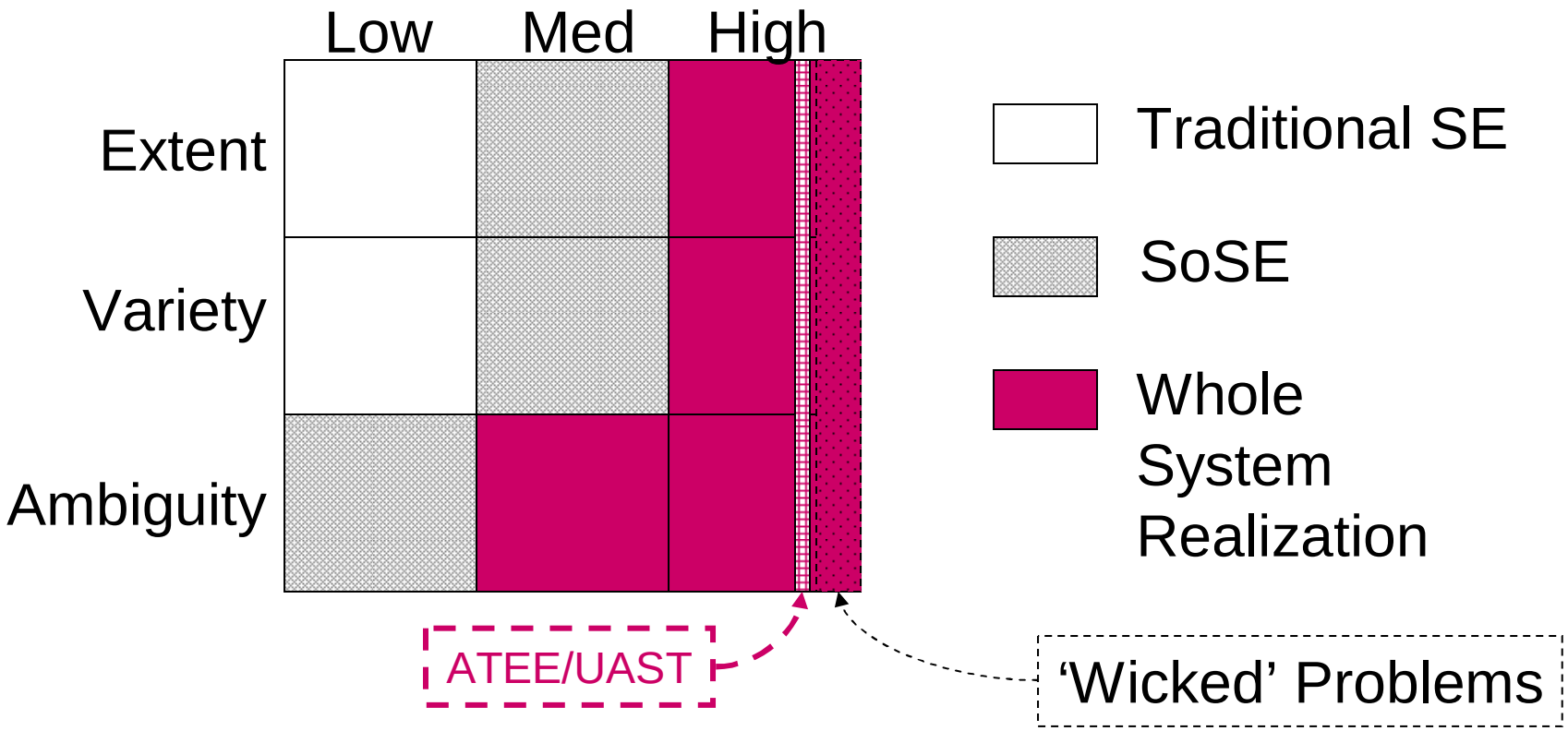
Stakeholders

Stakeholders in Context
(single thread view)

Requisite Variety C>B>A **Requisite Variety B>A** **Requisite Variety A**



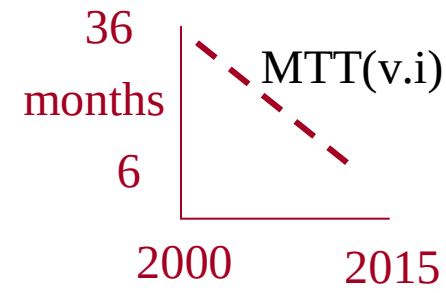
Situation Complexity Factors



Extent: # of cognates
Variety: # of unique cognates, both temporal and semiotic
Ambiguity: fog, conflicting data, cognitive overload

[2a] Exo-UAS

Extent: Expect 10,000 to 100,000 [1]'s by t+15 years.
Variety: See spectrum of attributes below
Ambiguity: Currently HIGH



Class, C
- Space
- Air
- Ground
- U/ground
- Marine
- Undersea
- Cyberspace

Type, T
- ISR
- C4
- Defense
- Offense
- Other

Stage, S
- Concept
- Design
- Acceptance
- Deploy
- Activate
- Operate
- Recover
- Refurbish
- Update
- etc.

Scope, E
- % of
- Whole
- System

Effectivity, t
- Date
- Knowledge
- Needed

[2]

UAS

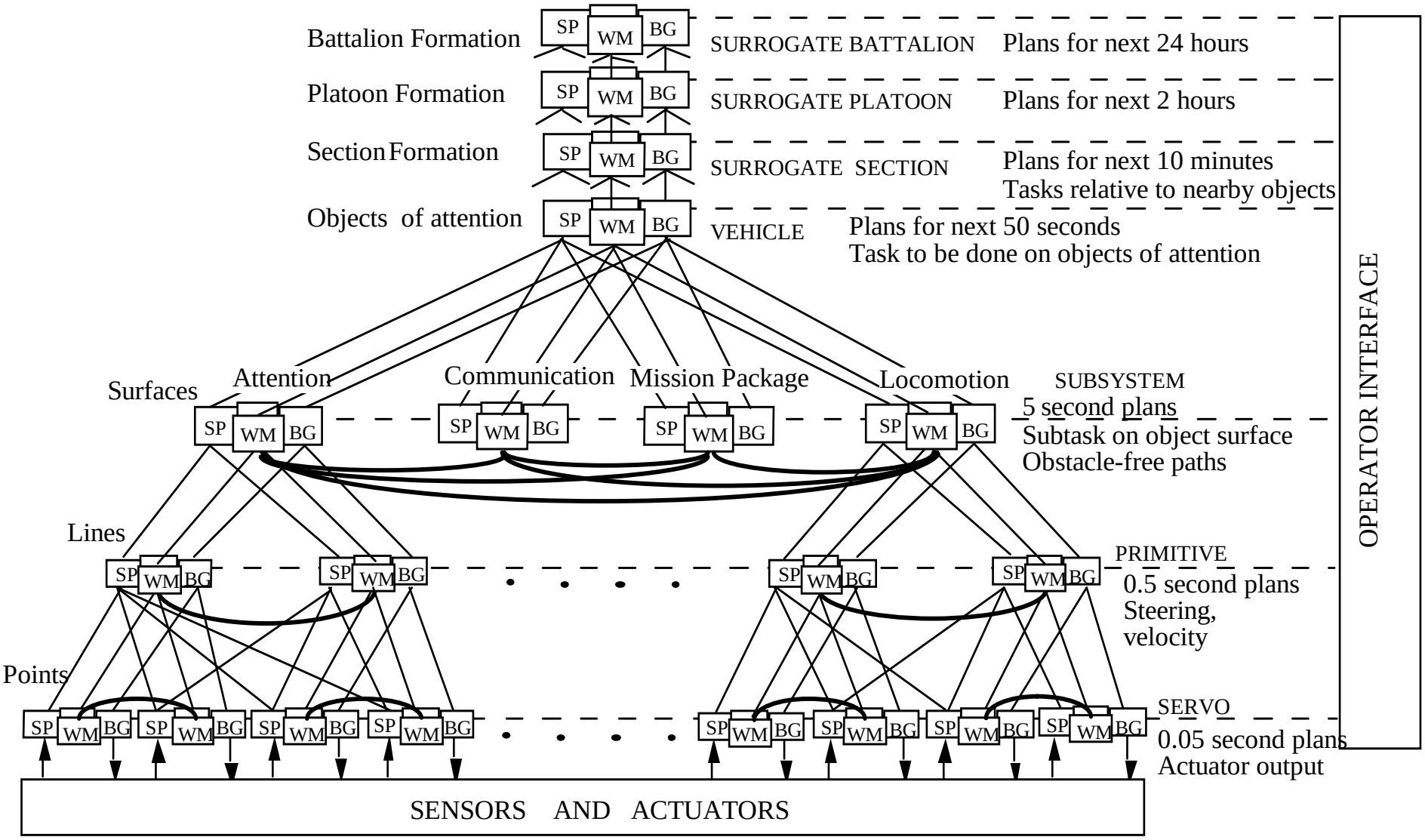
evolutionary acquisition

engaged in

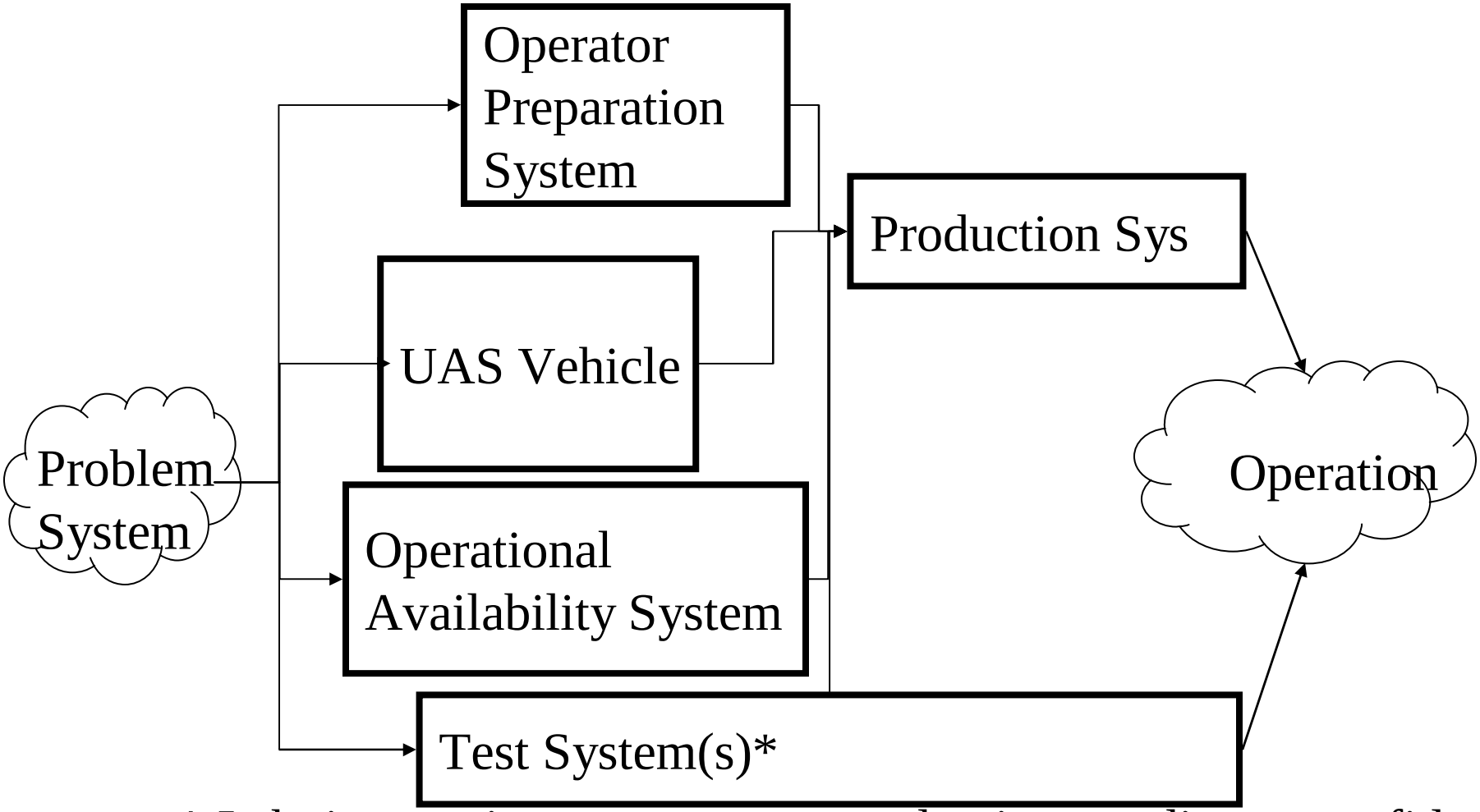
Mission

suitability

[2b] Endo-UAS


Battalion Formation
Platoon Formation
Section Formation
Objects of attention
SP WM BG
SURROGATE BATTALION
Plans for next 24 hours
SURROGATE PLATOON
Plans for next 2 hours
SURROGATE SECTION
Plans for next 10 minutes
Tasks relative to nearby objects
VEHICLE
Plans for next 50 seconds
Task to be done on objects of attention
OPERATOR INTERFACE
Surfaces
Attention
Communication
Mission Package
Locomotion
SUBSYSTEM
5 second plans
Subtask on object surface
Obstacle-free paths
Lines
PRIMITIVE
0.5 second plans
Steering,
velocity
Points
SERVO
0.05 second plans
Actuator output
SENSORS AND ACTUATORS

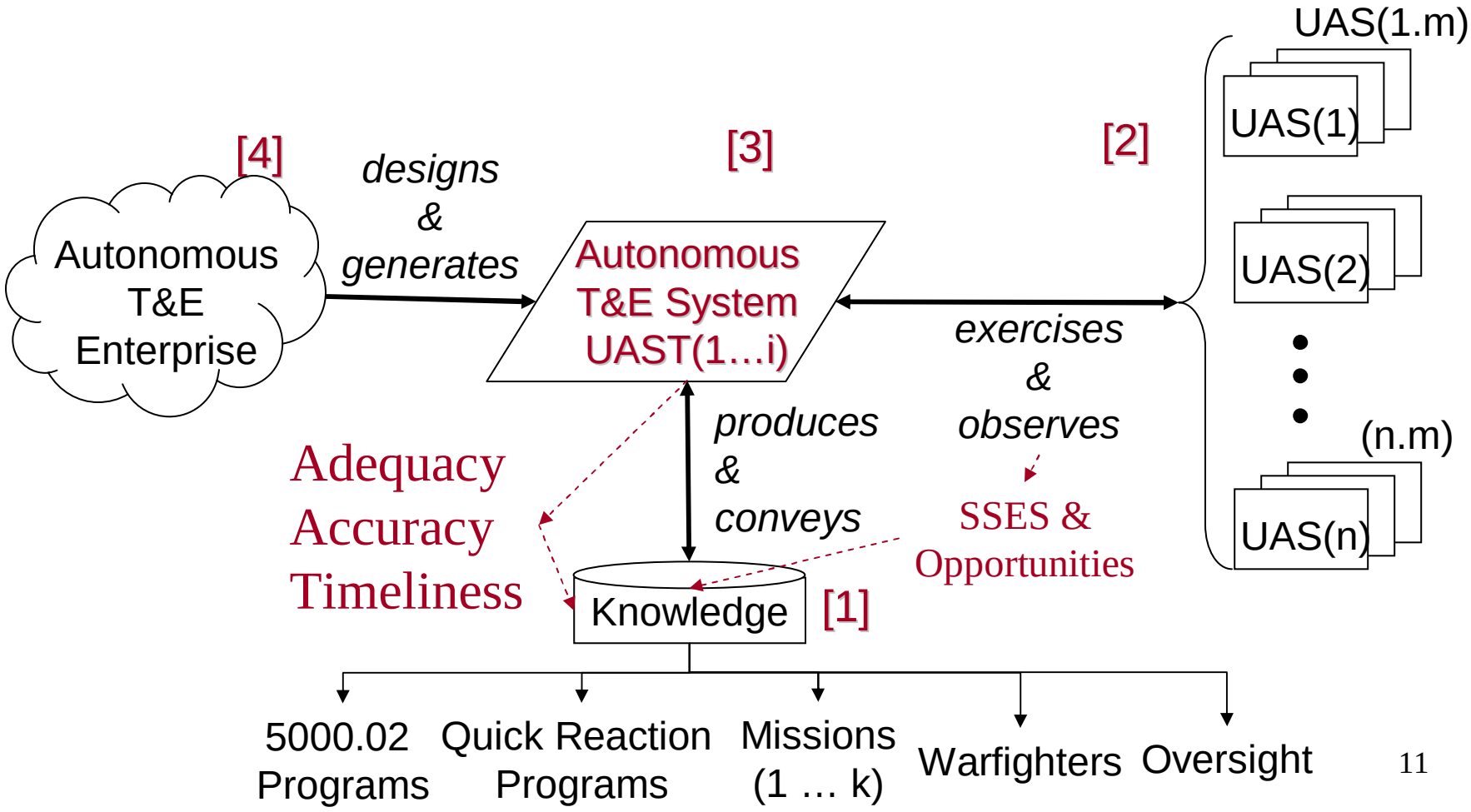
[2c] 100% of Whole System



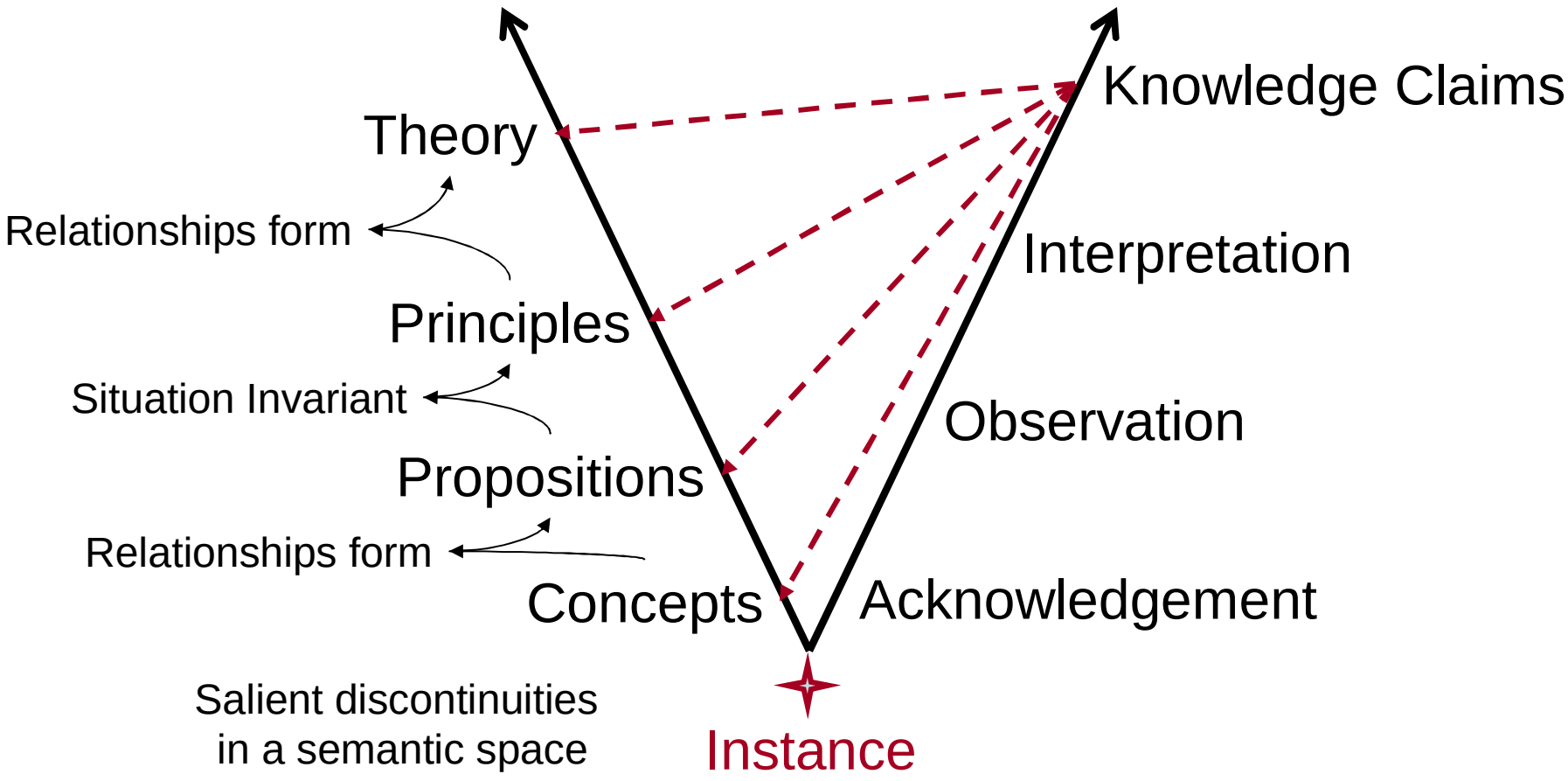
* Lab, integration, acceptance, production, readiness, confidence

[3] UAST in Context

Requisite Variety C>B>A Requisite Variety B>A Requisite Variety A

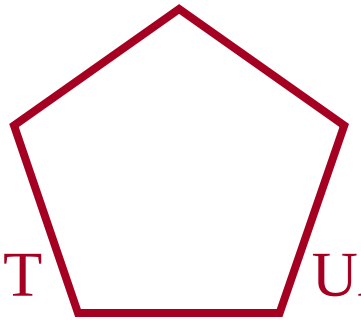


Produce and Convey [1] Knowledge Claims



Novak, Joseph, 1984 Learning How To Learn, Cambridge University Press

[3] UAST Content & Capabilities



Test Plan

ATEE/UAST Evolution

UAST/UAS Readiness

UAS/UAST Evaluation

UAST/UAS Operation

UAST Opportunities

Information Sources

UAST Engineering/ Construction

Data Analysis
Behavior Analysis
Conveyance Aids

UAST Configuration

UAS Configuration

Context
- Contrived
- Simulated
- *in situ*

Sensors
- Data Mgmt
- Comm/Net Mgmt

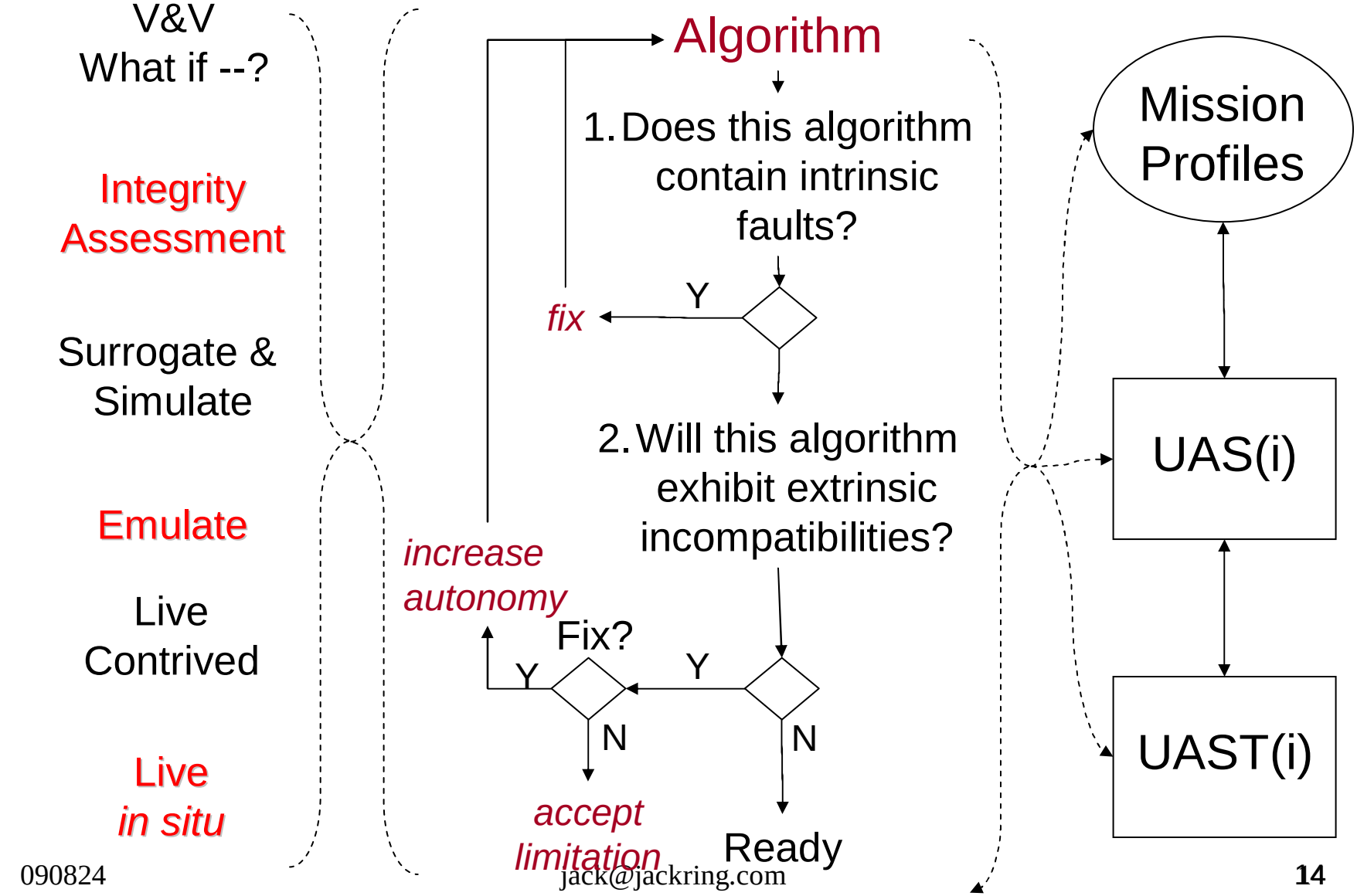
Decision
- Algorithms
- Rules
- Inference
- Synthesizer

Effectors
- Location
- Payloads
- Agility

Systems
- Protocol
- Operators

Platforms
- Power

T&E of Autonomy



Model-based System Engineering of UAST

The truth,
the whole truth,
and nothing
but the truth.

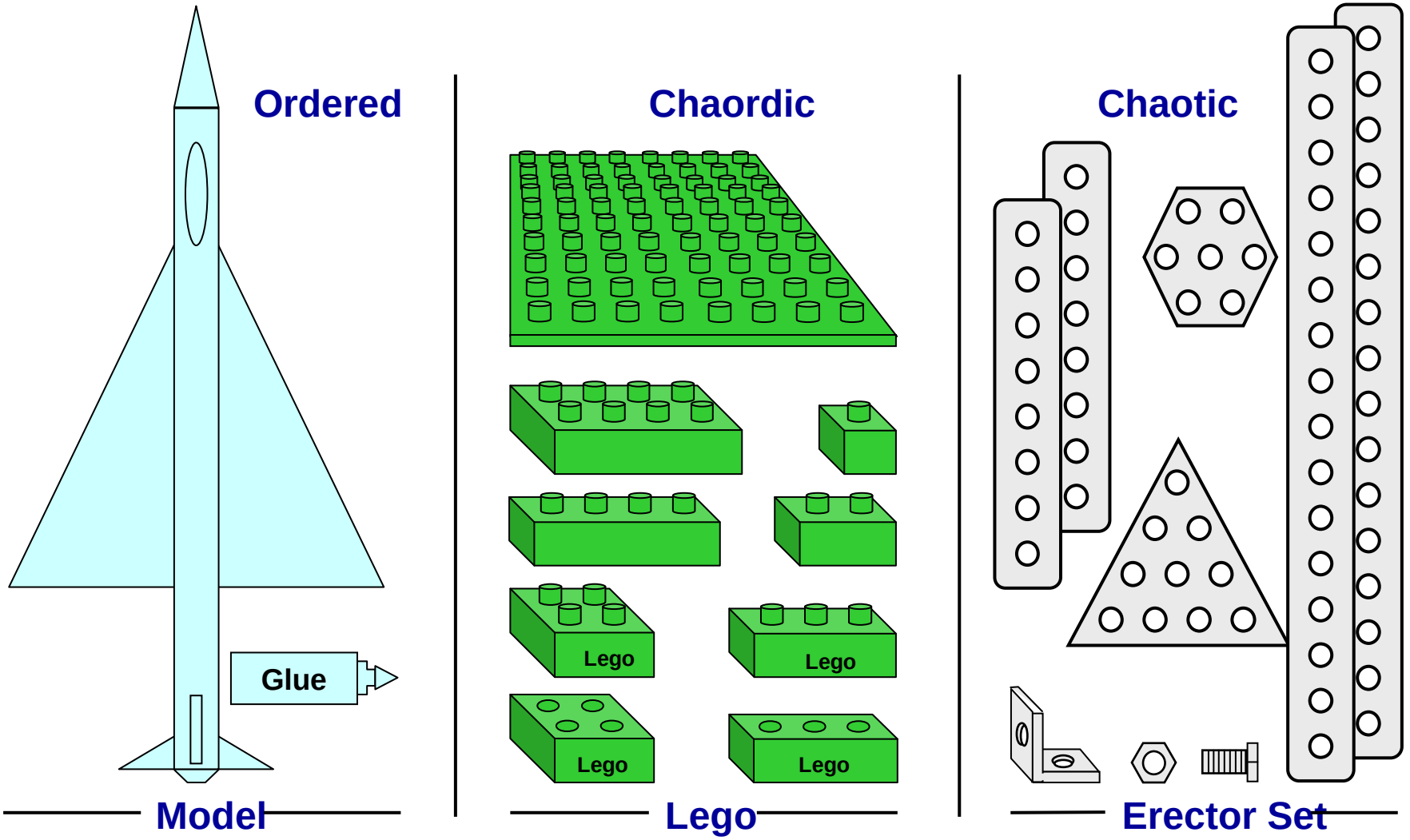
Informatics
Thermodynamics
Biomatics
Teleonomics
Social Dynamics
Economics
Ecologics

Minimal Implicate Order

Relevant Emergence

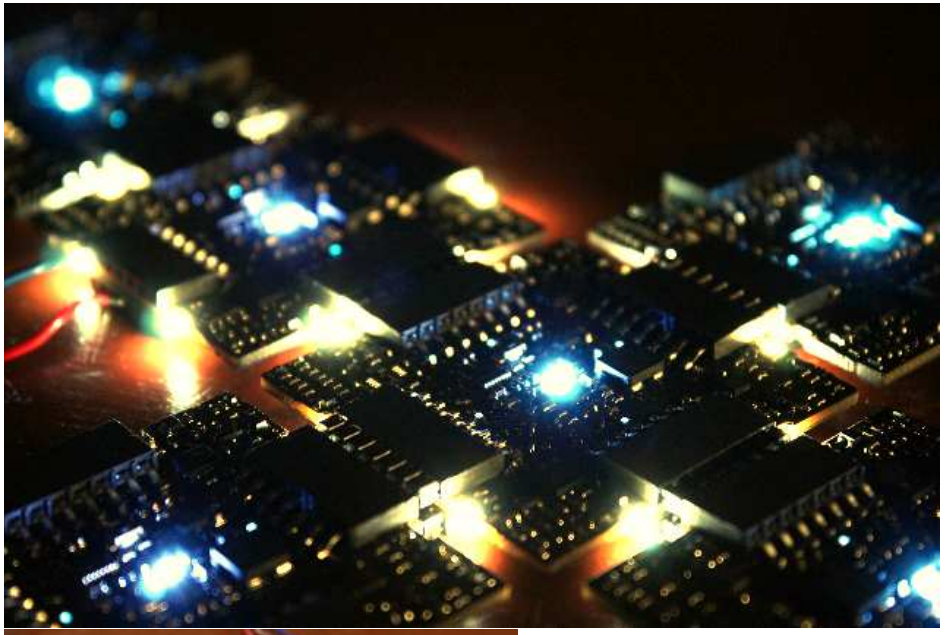
SysML

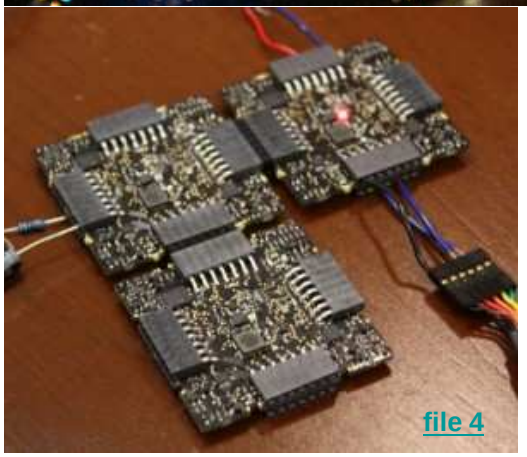
[4] UAST Agile Infrastructure



jack@jackring.com

Illuminato X Machina





Each module

a) includes processor, memory and storage,

b) serves as a mini-motherboard and network node,

c) can allocate power and decide to accept or reject incoming transmissions and programs,

d) become member of a networked cluster,

e) has four edges, and each edge can connect to its neighbors,

f) uses a reversible connector (vs. sockets, standardized interconnects or a proprietary bus). Knows it is plugged into a neighbor and can establish the correct power and signal interfaces.

g) has software-controlled switches to gate the power moving through the system on the fly and a ‘jumping gene’ ability, which means executable code can flow directly from one module to another without a PC-based program downloader,

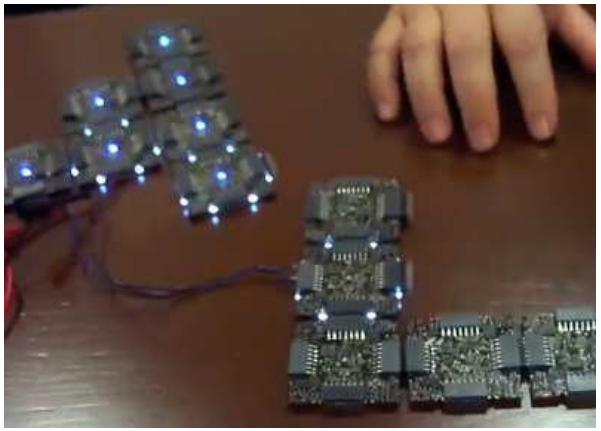
h) has a custom boot loader software that allows it to be programmed and reprogrammed by its neighbors, even as the overall system continues to run.

19Aug09, text:
www.wired.com/gadgetlab/2009/08/modular-motherboard/
also 20Aug09:
www.liquidware.com/shop/show/IXM/Illuminato+X+Machina

Illuminato X Machina

1 Cell – $ 56.89

- Weight: 24g
- L x W x H: 1.87” x 1.87” x 0.25”
- General Purpose I/O: 24 pins
- Total I/O: 56 pins
- Processor Type: 32-bit ARM
- Processor Name: LPC2368
- Processor Speed: 72 MHz @ 64 Dhrystone MIPS
- EEPROM: IC SRL EEPROM; 128 KB
- Senses: Current, Voltage
- Reflexes: Neighbor Shutdown,
- 4 Blue LEDs, 1 RGB LED, 4 White LEDs
- Input: Switches



•These units, or ‘cells’ can combine to form a modular, scalable computer capable of adapting its performance to the task at hand.

•Each cell, is equipped with a 72 MHz ARM-based microprocessor, a dedicated EEPROM chip for data storage, and RAM, in four square inches..

•LEDs serve as a simple output mechanism, and 14 I/O pins line each of its four edges for maximal node-to-node connectivity.

•Each IXM board is blacked out with gold vias and surface mount components for a slim profile. The surface is lined with multiple symmetrical sets of RGB LEDs, which serve as status lights or a desktop light show.

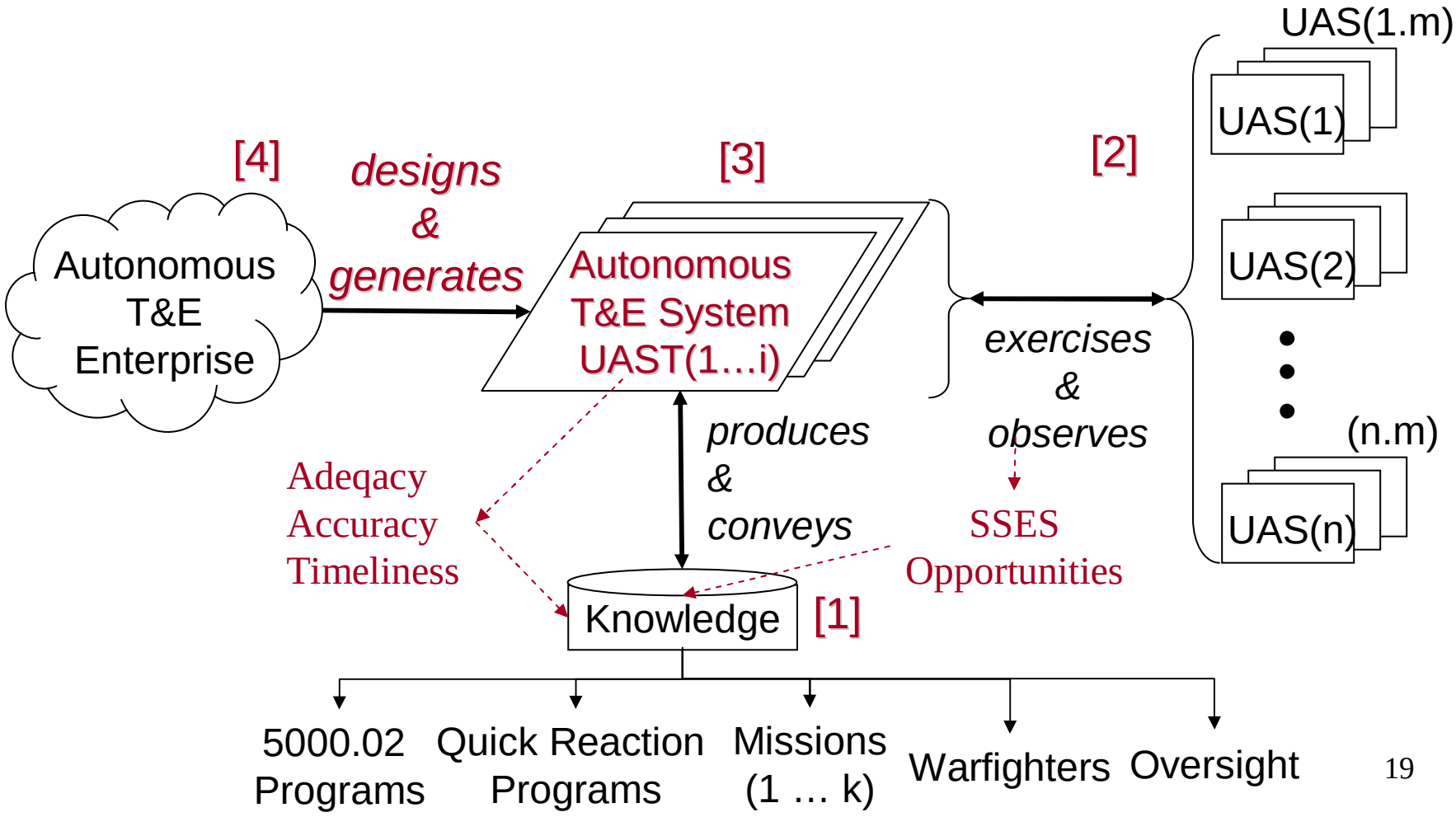
•Knows whether it’s plugged into a neighbor rightside up, upside down or sideways.

•If a cell detects a faulty neighbor, it can attempt to reprogram its neighbor and reboot its neighbor (because the distinction between the system’s firmware, software, and hardware are intentionally ambiguous and one). If this fails, each cell can then elect to disconnect power to its neighbors and “terminate” it from the network, like a cell would do if it detected cancerous growth in its neighbor.

•Can be attached to the computer via USB using a special cable or connector board, and a grid can accept as many USB inputs as it has free edges.

[4] ATEE in Context

Requisite Variety C>B>A Requisite Variety B>A Requisite Variety A



[4 now] Current T&E Enterprise

Goal: Robust and flexible T&E capabilities to support the Warfighter.

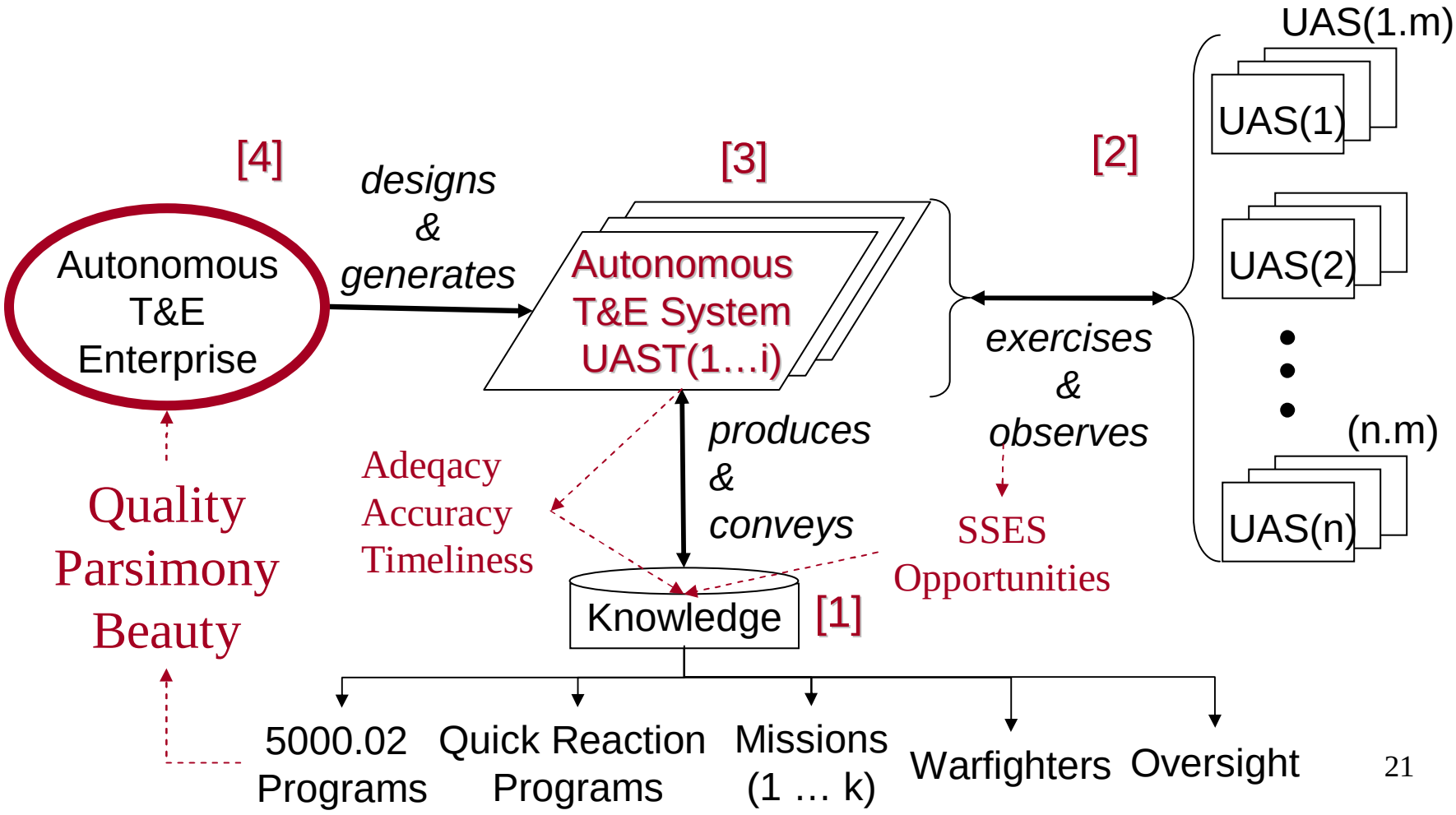
Some of the DoD Test Facilities

Test Resources Management Center

Method: Plan and conduct science and technology projects that supply needed components to the various test facilities.

[4] ATEE MOE's

Requisite Variety C>B>A Requisite Variety B>A Requisite Variety A

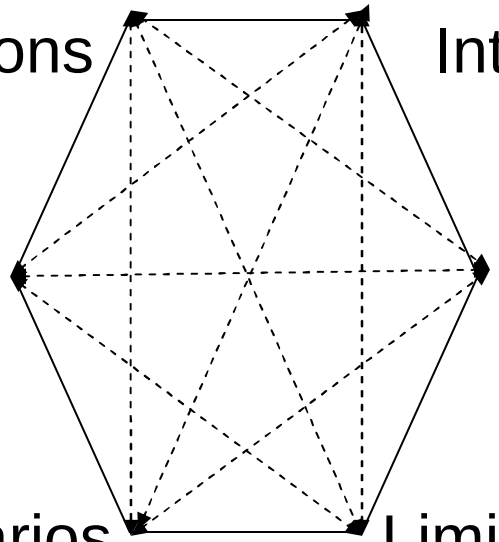


[4] ATEE Problematic Situation[1]

>1,000 kinds of UAS's
>10,000 test sessions

Adequate, Accurate, Timely
Intelligence re: UAS, UAST

Extent, Variety,
Ambiguity of Test
Context



Limits of Safety, Suitability,
Survivability, Effectiveness,

Variety of scenarios

- Single
- Homogeneous
- Heterogeneous
- Swarming
- Joint

Limits of Technologies

- Thermodynamics
- Informatics
- Biomatics
- Teleonomics
- Human Social Dynamics
- Economics
- Ecologics

1 Simplified

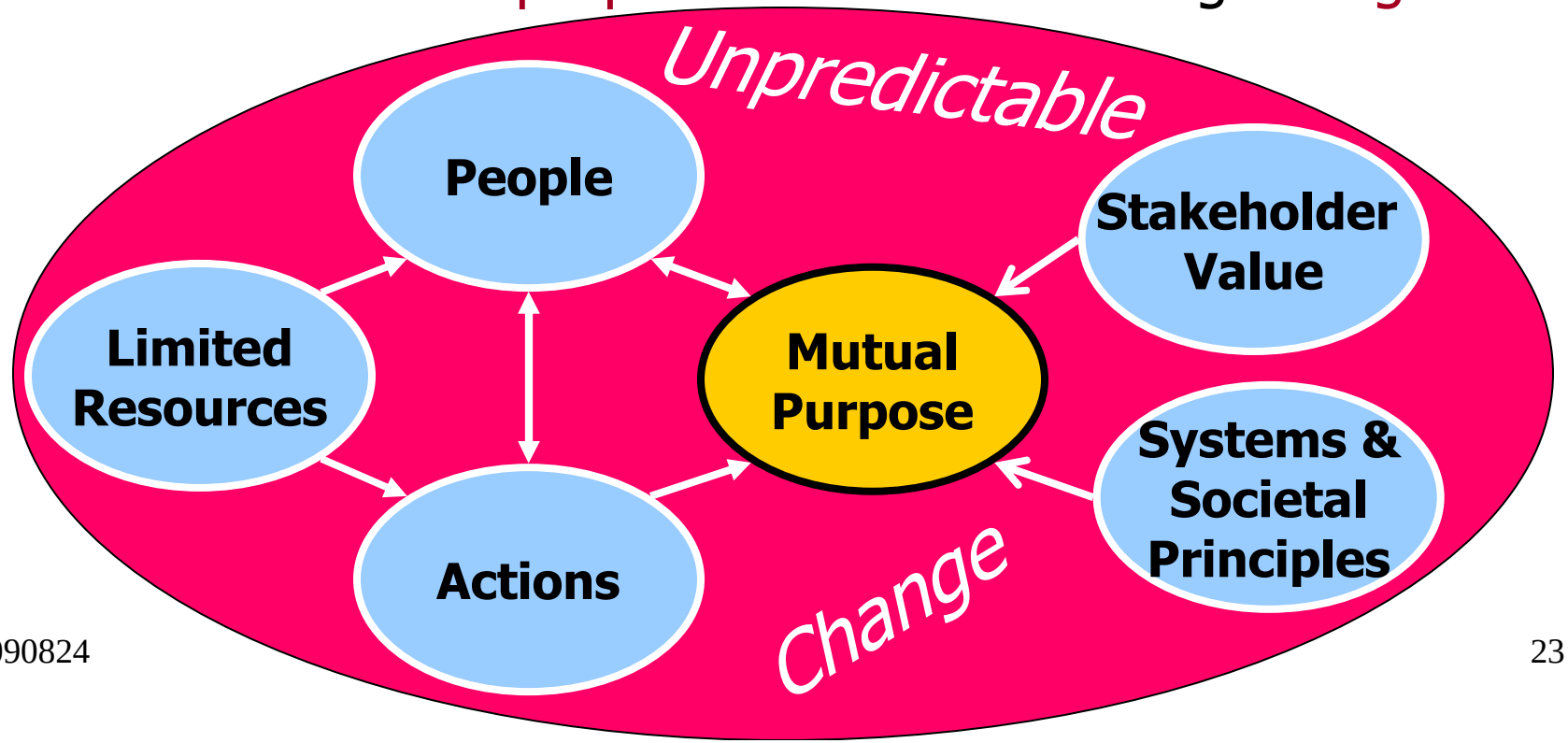
[4] Stakeholder ConOps for ATEE

Enterprise

Two or more persons applying resources through actions to achieve mutual purpose.

Intelligent

Maximizing Stakeholder Value while conforming to principles and surviving change.



ATEE Measures of Effectiveness

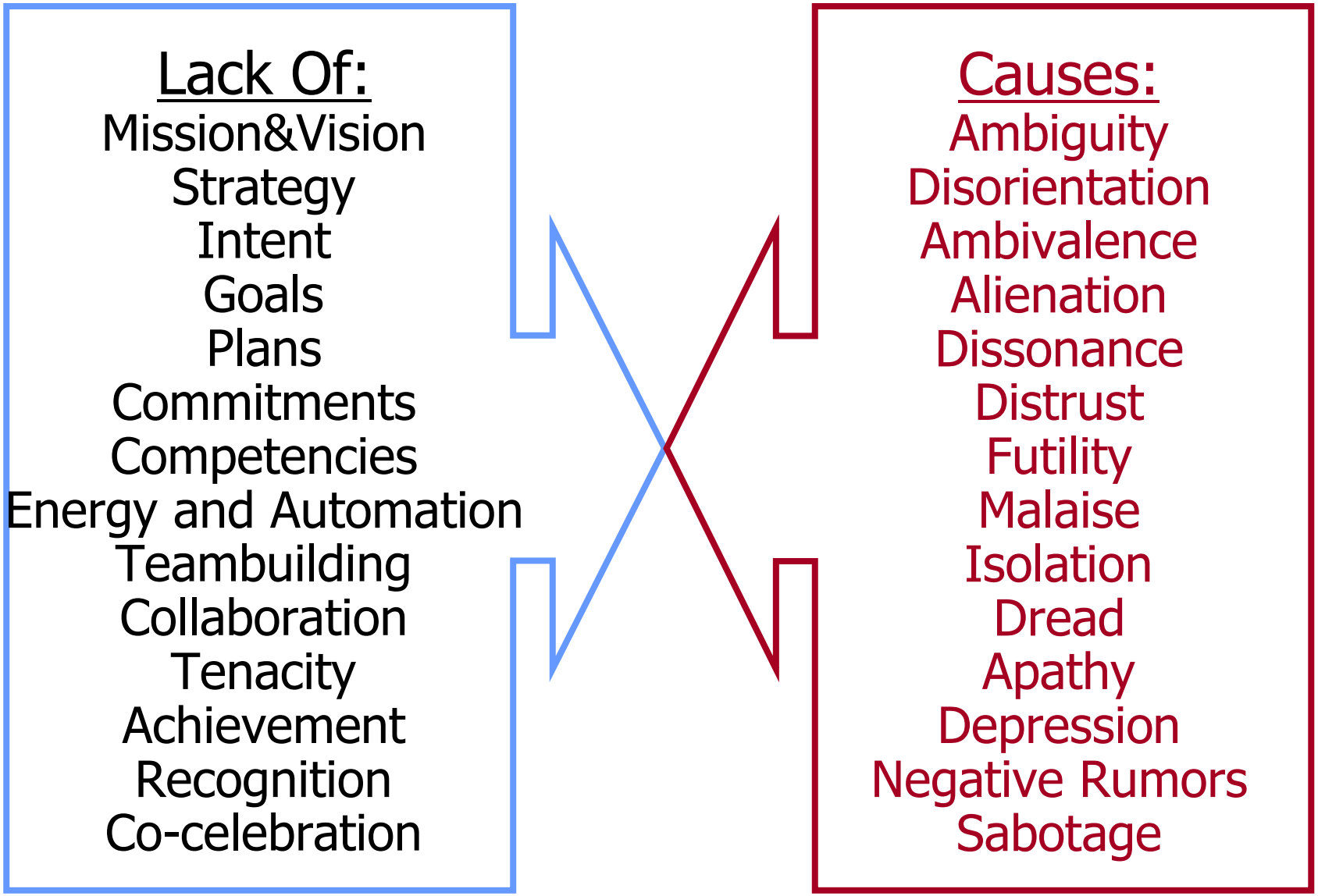
ATEE:
- Market Standing
  - Quality
  - Cycle Time
  - Cost
- Productivity
- Innovation
- Liquidity
- Cost of Quality
- Model Fidelity
- Learning Curve
- Conflicting Goals
- Work Climate Surveys
- Benchmarking

Knowledge:
- Adequacy,
- Accuracy,
- Timeliness

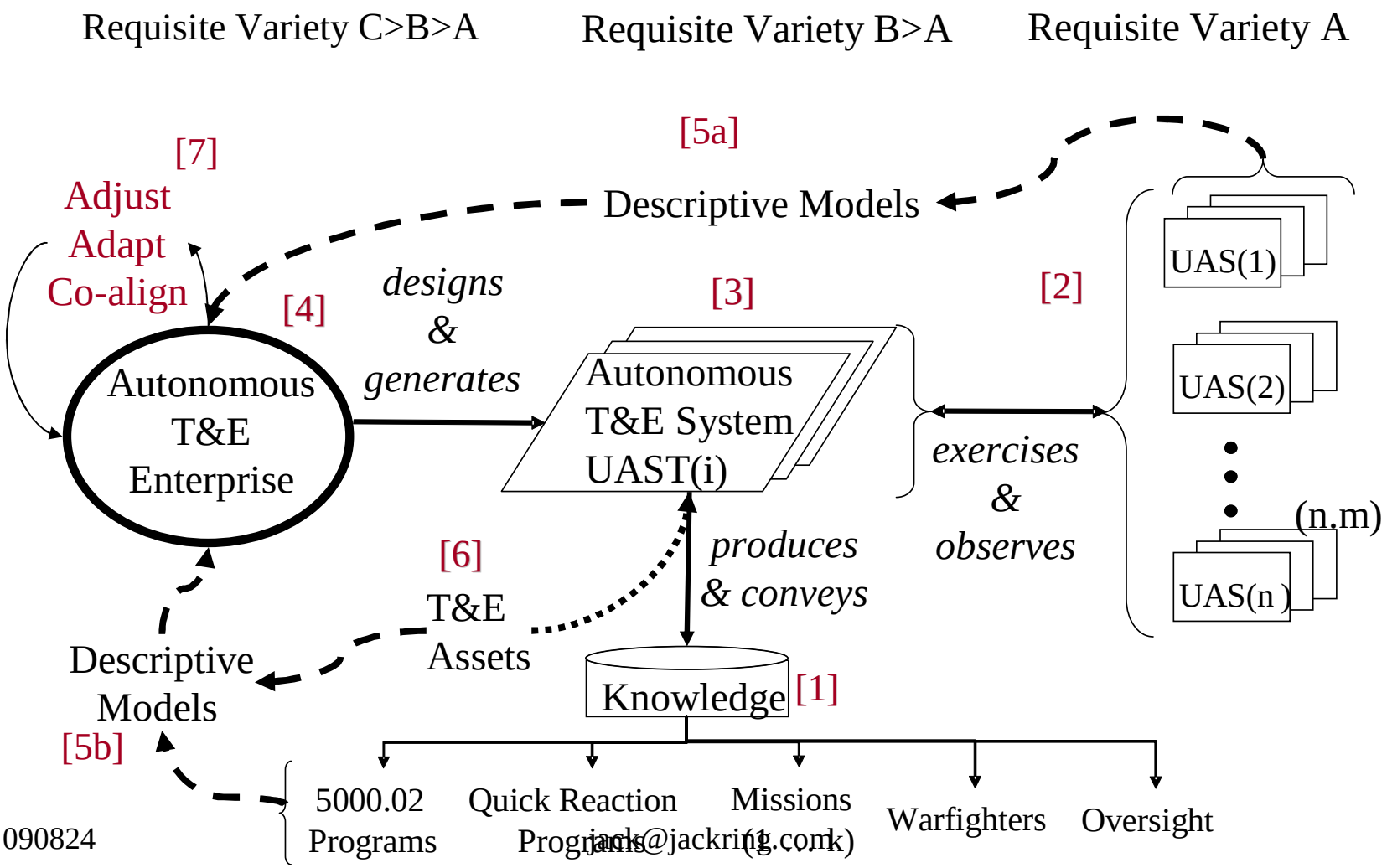
About UAS:
- Safety,
- Suitability,
- System Effectiveness,
  - When Needed
  - Mission Achievement
  - As Member
- Survivability

UAST:
- Coverage,
- Acuity,
  - Contrived context
  - Observations
  - Evaluations
- Availability

Else? Enterprise Etiology



Evolving T&E Enterprise

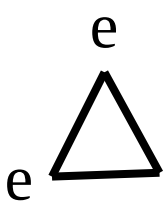


System Concepts and Labels

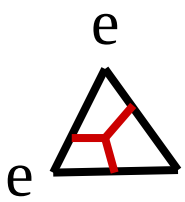
e = entity

— = relation

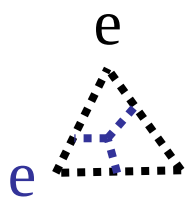
e — e = system



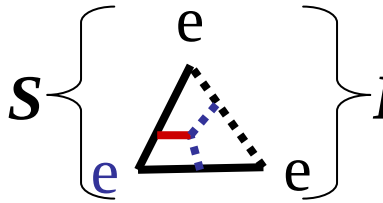
= system (explicit)



= system (implicit)

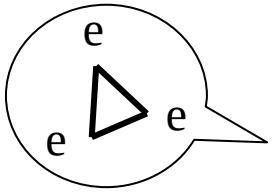


= system (soft)

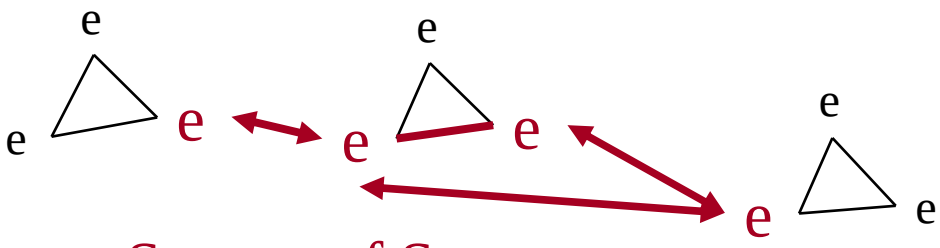


= behavior = Π

S = Stimulus, R = Response



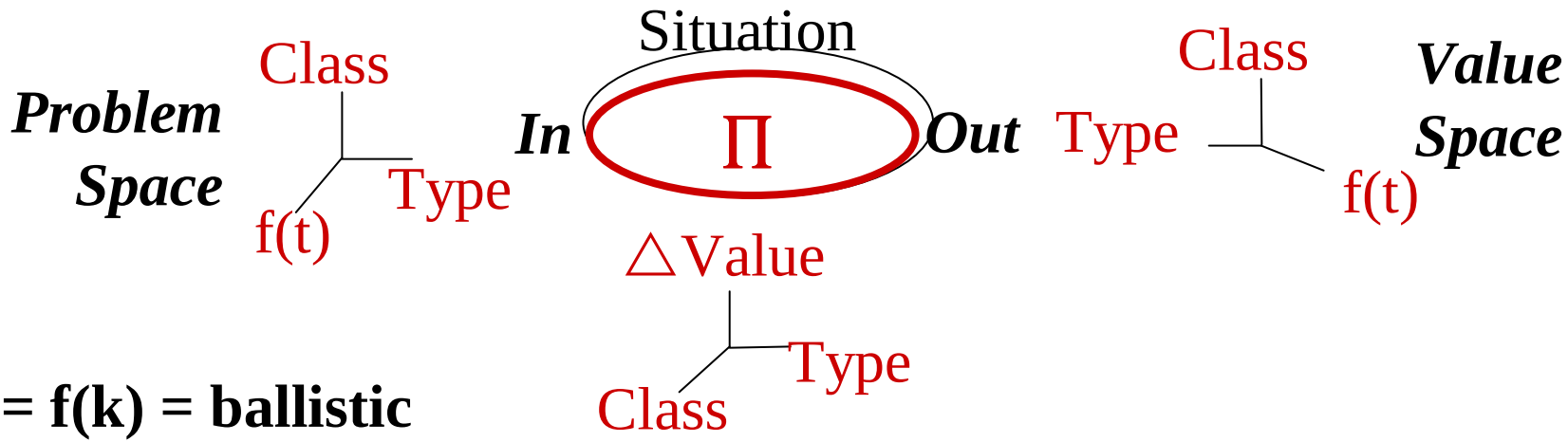
e = Entity can contain a system



System of Systems

(promulgates ambiguity)

A Few System Types



∏ = f(k) = ballistic

∏ = f(O) = governor

∏ = f(I) = anticipatory

∏ = f(Sit, O) = homeostatic

∏ = f(Val) = goal-seeking

∏ = f(Pr) = self-organizing

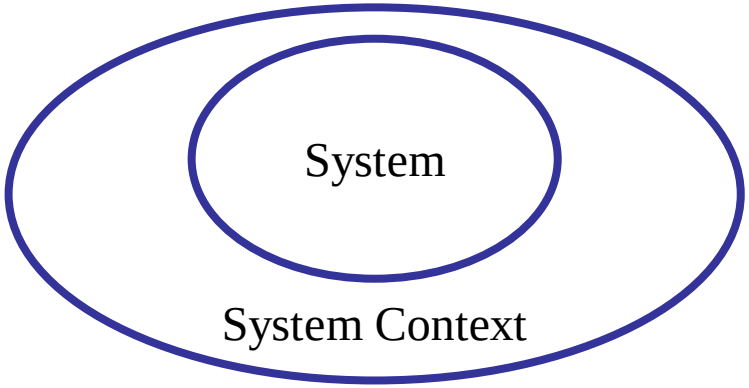
∏ = f(Pr, Val) = autopoietic

∏ = f(all) = autocatalytic

Pr	= Problem Space
Val	= Value Space
S	= Stimulus
R	= Response
Sit	= Situation
Π	= System Transfer Function

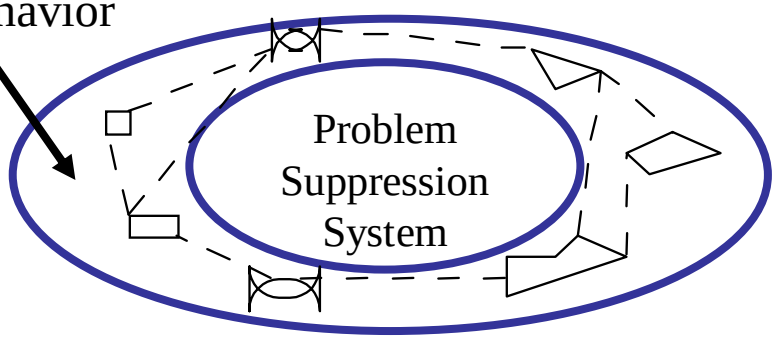
The Essence of Systems Engineering

1.

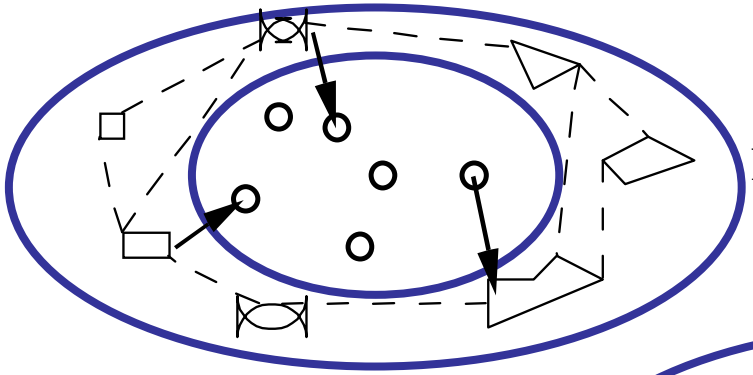


Problem System;
Content, Process,
Behavior

2.

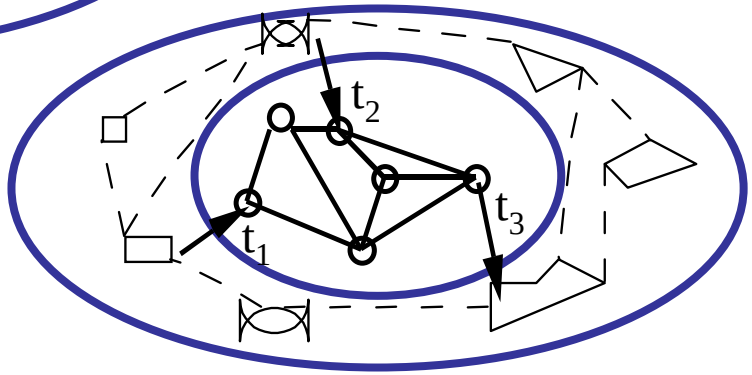


3.



Problem Suppression
System: **Content**

4.

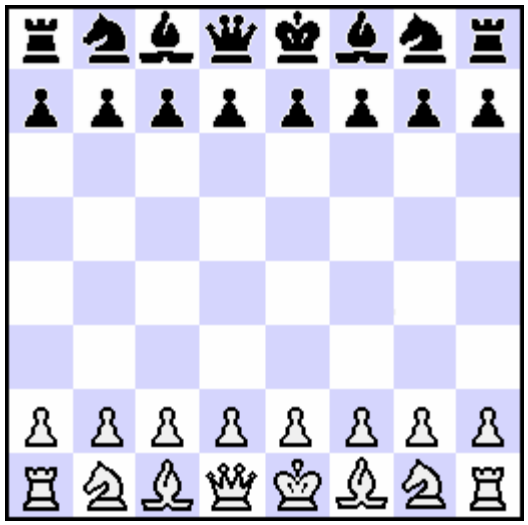


Problem Suppression
System: Content,
Process, Behavior

Adapted from
Science of Generic Design,
John Warfield

Autonomy: Angels vs. Demons Game

- The correctness problem may be reduced to a game between angels and demons where the correct solution is the existence of a winning strategy for our champion: the angel.
- The T&E challenge? Measure whether the angel's strategy wins.



The **demon** may act unpredictably and may react to all the **angelic** moves attempting all possible tricks to defeat the **angel**. That means the angel must be able to counter continuously any **demonic** action: she must change her strategy in response to **demonic** actions

Back, R. and von Wright, J., Refinement Calculus, Springer Verlag, 2008

The Rest of ISO/OSI

Context > Wisdom < Context

Knowledge

e.g., semiotic web

Stakeholders

About ATEE

About UAST

UAS

Session

Ontology

Meaning

e.g., semantic web

Version

Presentation

Data Dictionary

Algorithm ↔ Application ↔ Data

Files

Transport

Network

Link

Physical

Model-based System Engineering of ATEE

The truth,
the whole truth,
and nothing
but the truth.

Informatics
Thermodynamics
Biomatics
Teleonomics
Social Dynamics
Economics
Ecologics

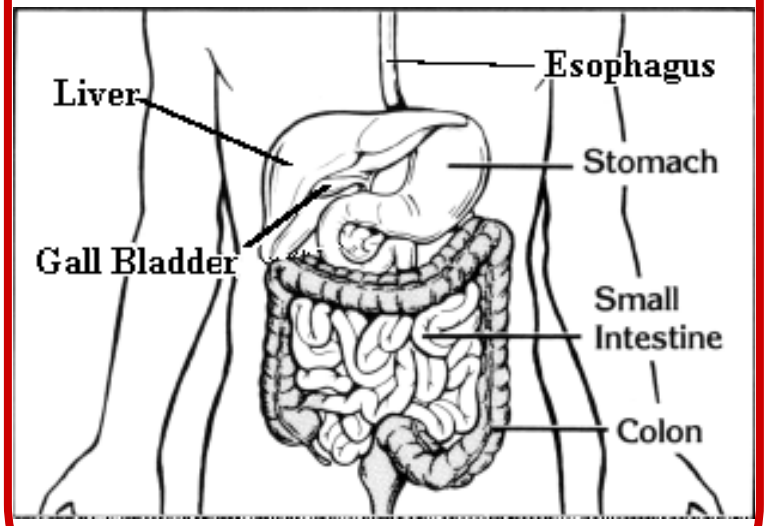
Minimal Implicate Order

Relevant Emergence

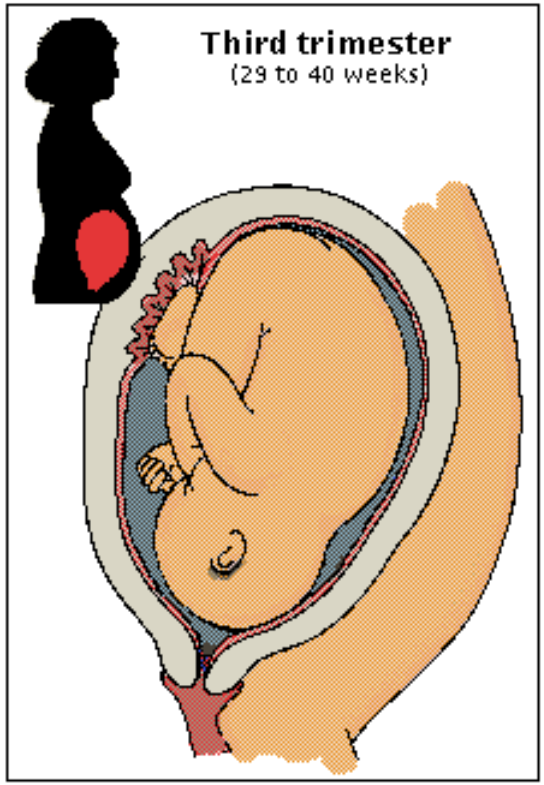
SysML

Input-Process-Output vs. Gestation

Input – Process - Output System

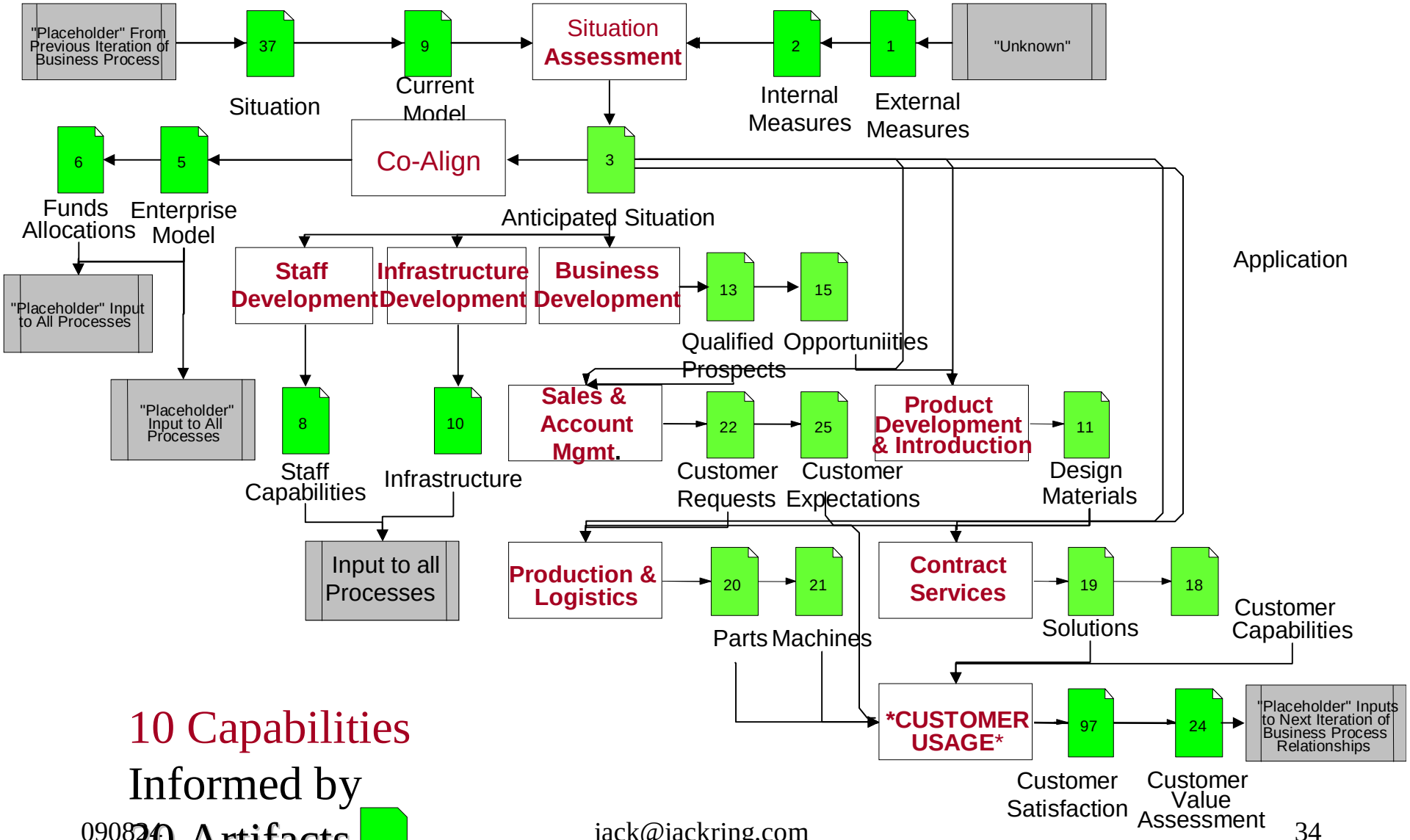


Generative System



jack@jackring.com

ATEE Capabilities & Relationships



10 Capabilities

Informed by

20 Artifacts

Enterprise Capabilities Purposes and Measures

Situation Assessment (SA):

Purpose: Ensures enterprise awareness of conflict and change, both external and internal.

Measures: No Big Surprises. Sufficient SA Model fidelity.

Co-Alignment (CA):

Purpose: Directs ProMetal evolution.

Measures: Funds are sufficient. Plan is achieved. Goals are sufficient and non-conflicting. Competitors are outpaced. Sufficient CA Model fidelity.

Business Development (BD):

Purpose: Gains sufficient business opportunities and associates to achieve plan.

Measures: Market standing. Image. Sufficient BD Model fidelity.

Enterprise Capabilities Purposes and Measures

Product Development & Introduction (PI):

Purpose: Generates a stream of new product designs that can add value to each customer.

Measures: Value perceived by customer. New Opportunities. Cycle Time to Production Release, Quality. Return on development resources. Sufficient PI Model fidelity.

Sales & Account Management (SM):

Purpose: Gains customers and grows their satisfaction and loyalty.

Measures; Follow-through. Sufficient customers, margins and sales productivity. Sufficient SM Model fidelity.

Production and Logistics (PL):

Purpose: Responds to customer orders and PI test requests..

Measures: Quality. Return on production resources. Sufficient PL Model fidelity.

Enterprise Capabilities Purposes and Measures

Customer Contract Services (CS):

Purpose: Helps customer realize inherent value.
Measures: Value perceived by customer. Image. Customer-funded selling. Sufficient CS Model fidelity.

Infrastructure Development (ID):

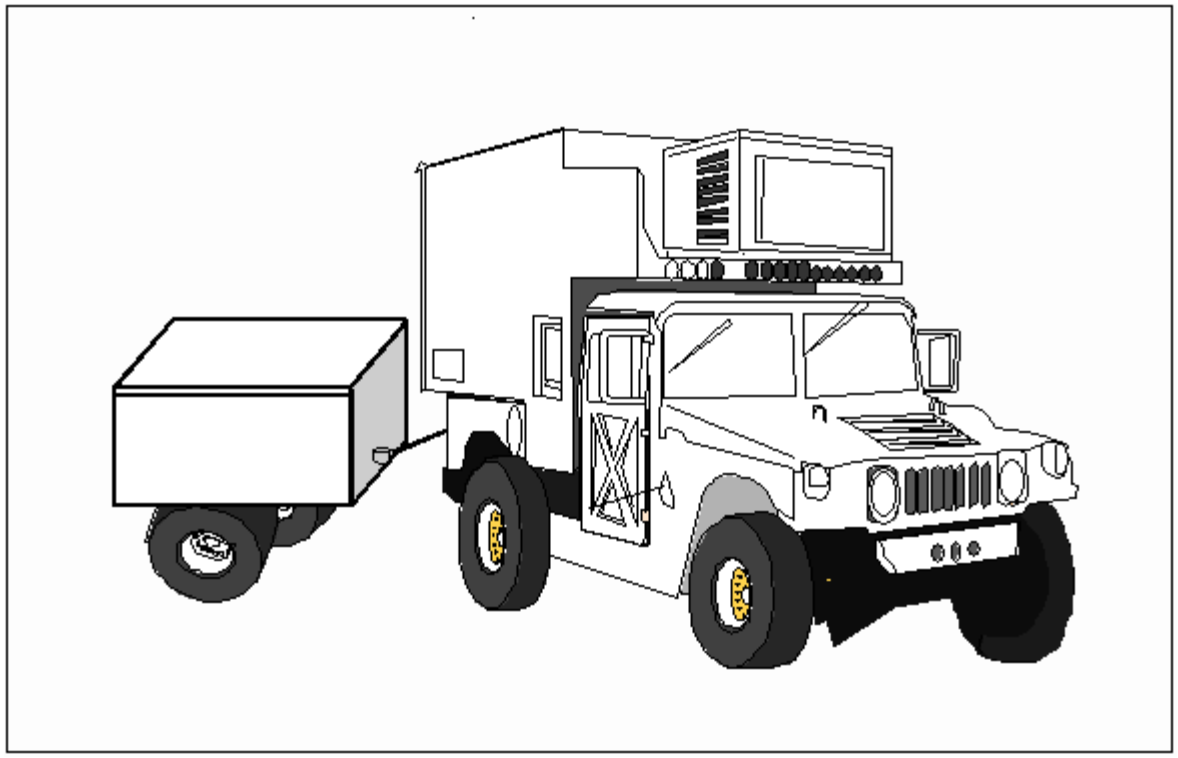
Purpose: Provides an agile framework for ProMetal activities and decisions -- extendable to associates and customers.
Measures: Reach and span.. Liquidity. Sufficient ID Model fidelity.

Staff Capability Development (CD):

Purpose: Evolves staff capability to execute plans.
Measures: Cost of quality. ROI of Training. Work Climate. Enterprise learning curve. Sufficient CD Model fidelity.

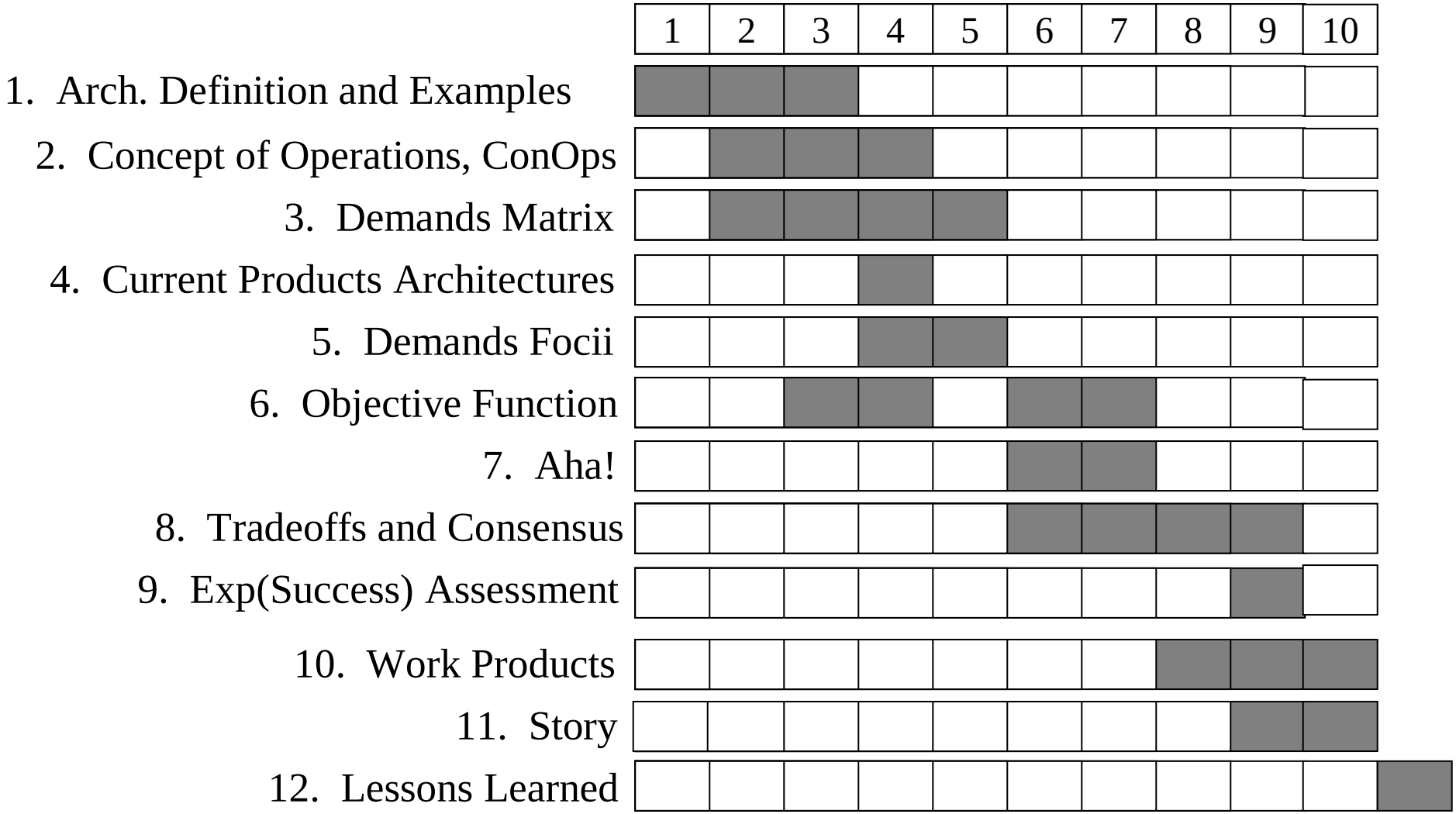
[4 next?] Test Range on Wheels?

Whatever



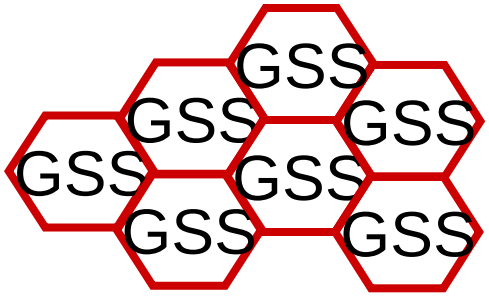
Whenever Wherever

Architecture Discovery Process



Enterprise Architecture Choices

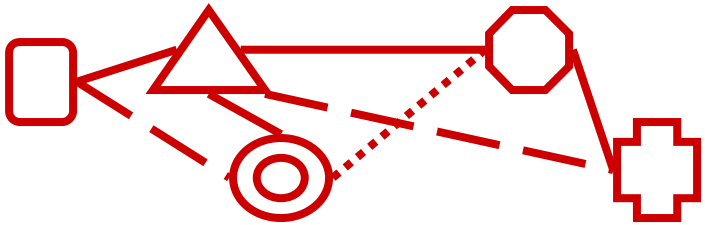
Chaordic Form
~10 instances



Goal
Seeking
System

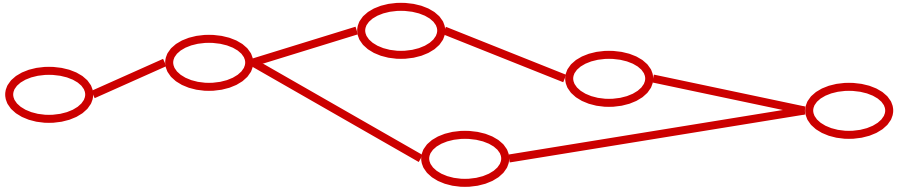
≈ 8-32X

Object Form
~10^2



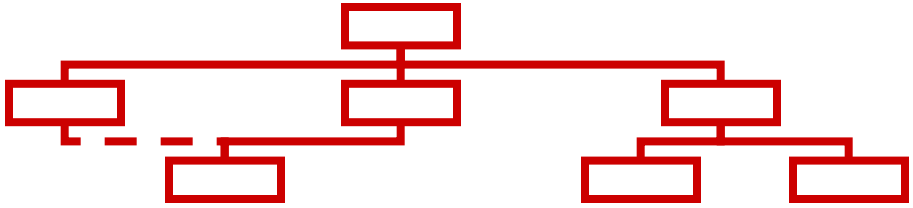
≈4X

Process Form
~10^4



≈ 2X

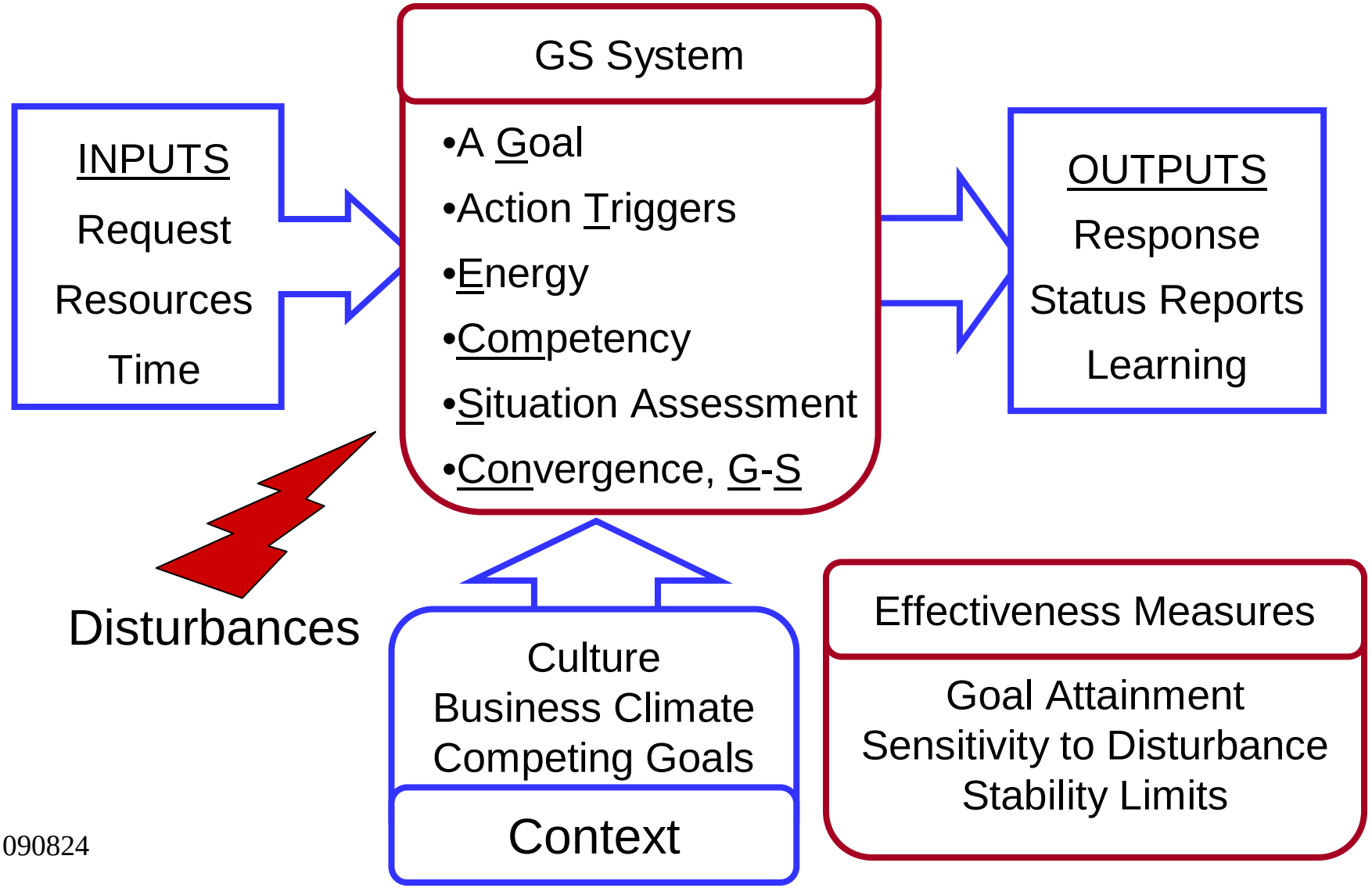
Structural Form
~10^8



1X

Functional > Product > Market > Matrix > ?

The Goal Seeking System (GSS) Archetype



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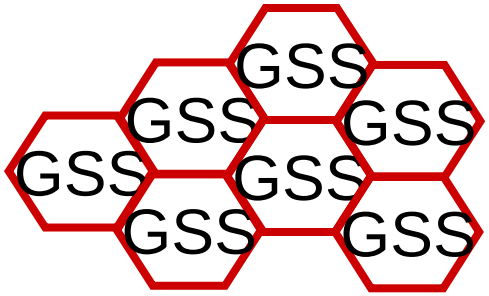
Enterprise Architecture Choices

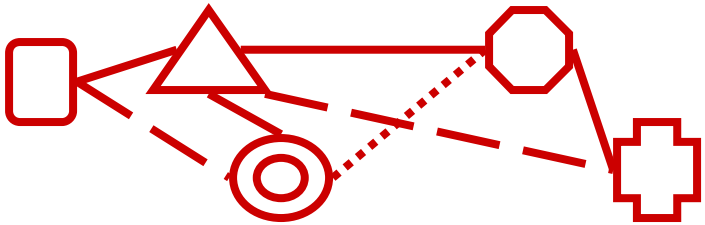
Chaordic Form
~10 instances



Goal
Seeking
System

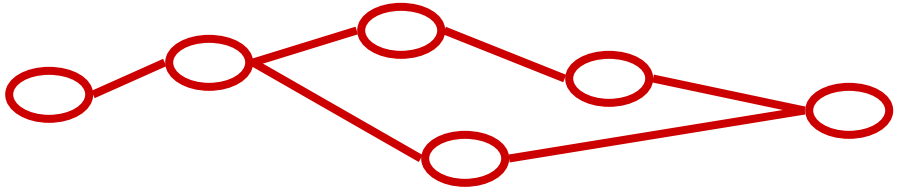
≈ 8-32X

Object Form
~10^2



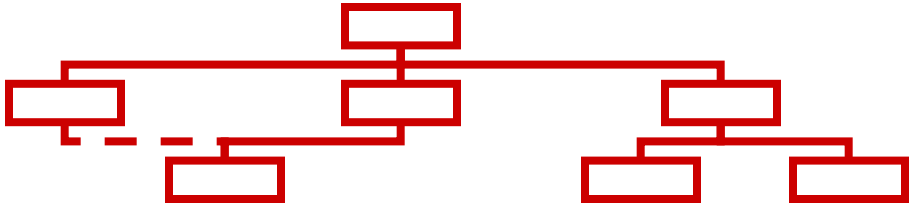
≈4X

Process Form
~10^4



≈ 2X

Structural Form
~10^8



1X

Functional > Product > Market > Matrix > ?

Comparison of Key Success Factors

Factors	Structure	Process	Object	Chaordic
Complexity	High	High	Medium	**Minimal**
Latency	Very High	High	Medium	**Low**
Agility	Low	Low	Medium	**High**
Trust building	Low	Medium	Medium	**High**
Productivity	Low	Medium	**High**	**High**
Learning	Low	Medium	Medium	**High**
Accountability	Low	Medium	**High**	**High**

Technology < Process < **Interpersonal Style**

Agile Thinkers

Problem System

Problem Symptoms

The Stakeholders value ---

The Problematique and SCI is ---

The Necessary and Sufficient SDR is:

Measures of Effectiveness
Standards of Acceptance

MOE's SOA's

System acceptable IFF --

KSF's Goals

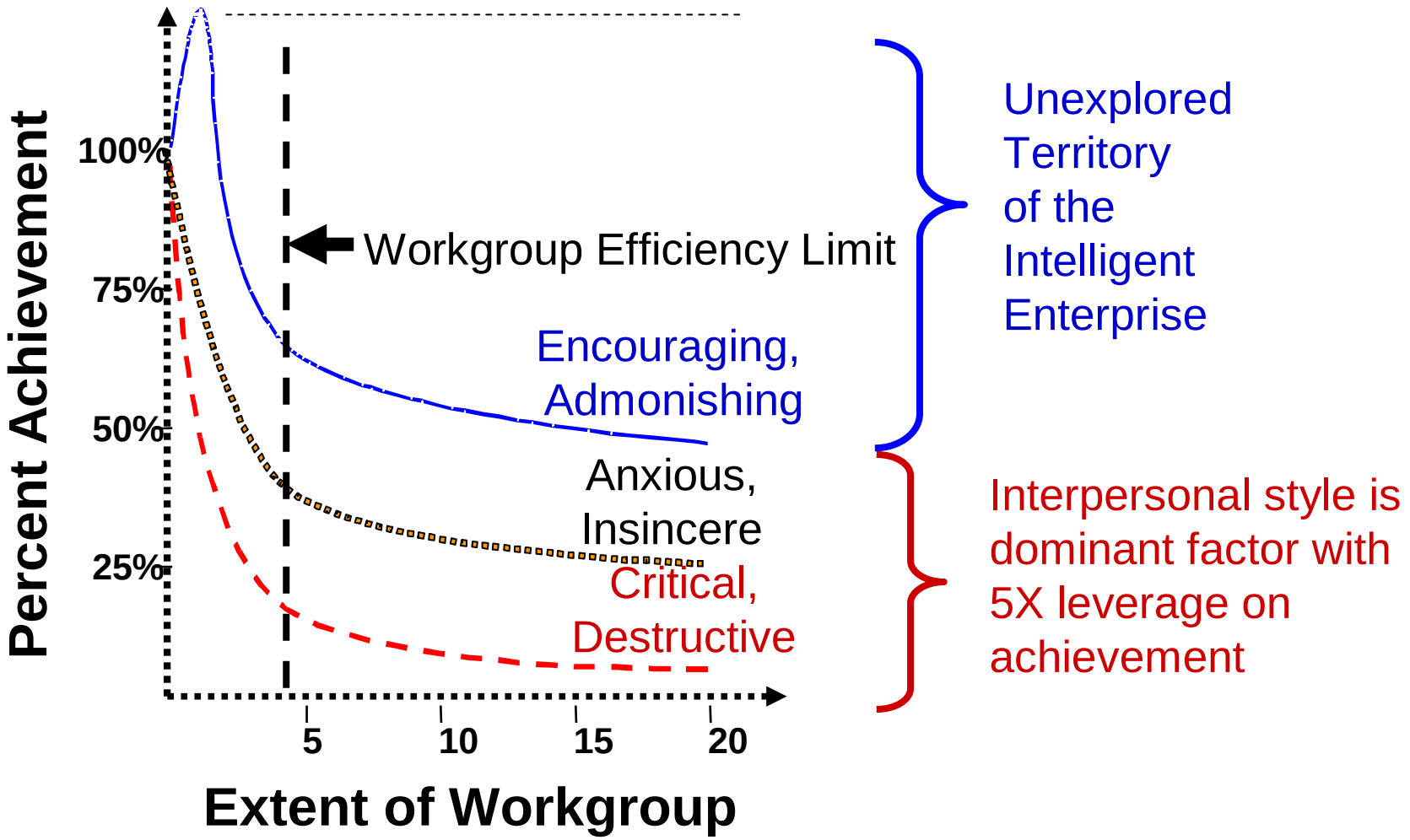
SEMP acceptable IFF --

System Model

Levels of Human Synergy

Relationship	Meaning	Mediators
Co-evolve	Tri-coherent morphing	Joy-enabled Level of Consciousness
Co-facilitate	Value Out/Value In ≈ e^N	Stewardship by N participants
Co-learn	Meaningful reflection	Shared knowledge claims
Collaborate	Help one another	Desire to serve
Co-celebrate	En-joying one another	Time & Space, F2F
Cooperate	Compatible Actions	Willing to wait
Commit	Principled relationship	Courage to plan
Converge	Common compelling purpose	Shared self-respect
Communicate	Share interests and values	Common language
Connect	Two discover one another	Accessible attributes

Primary Constraint



People Interact 2nd Order, Implicit Systems

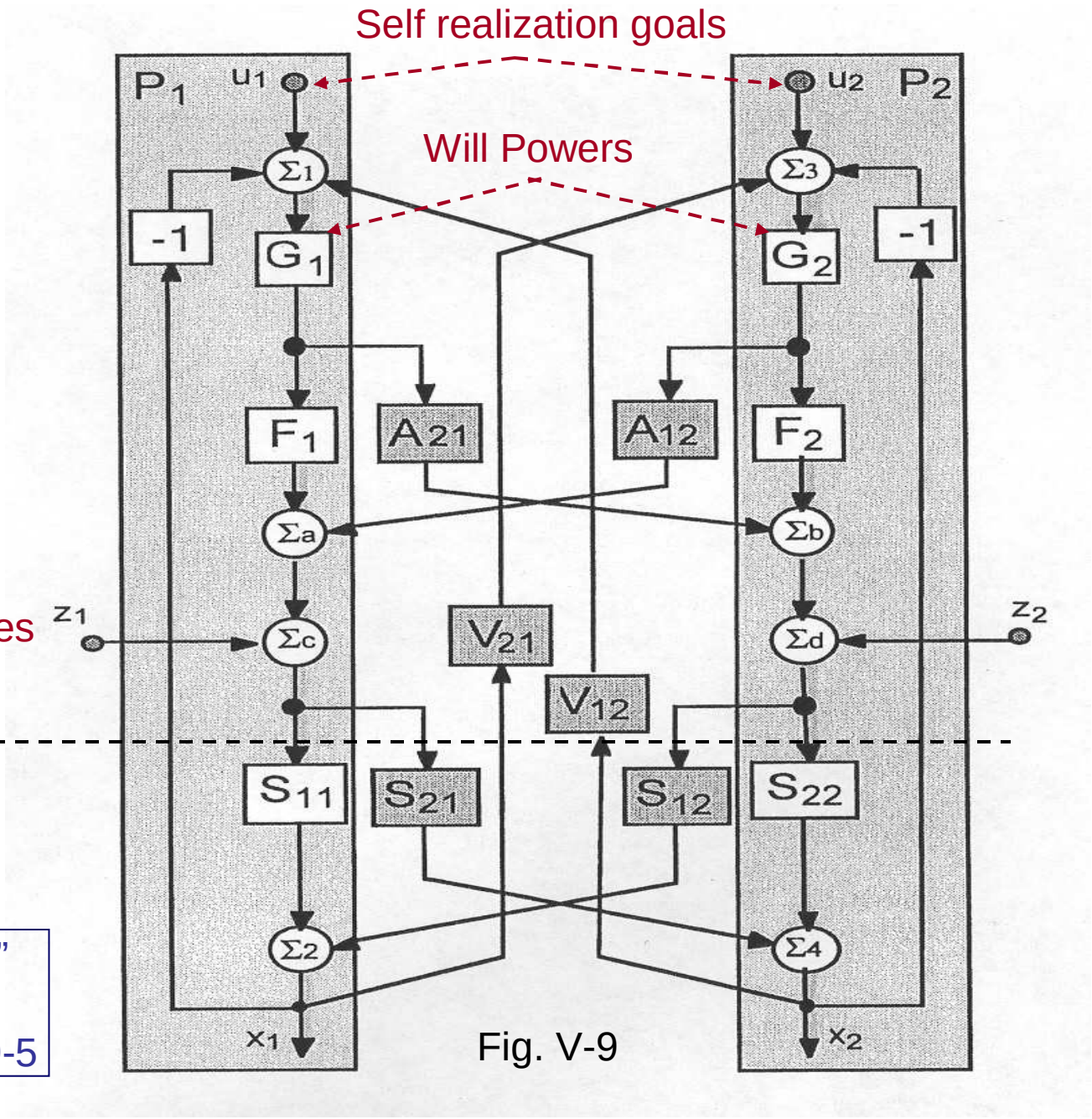


Fig. V-9

"Amity and Enmity"
by R. Starkerman
ISBN 3-908730-29-5

090824

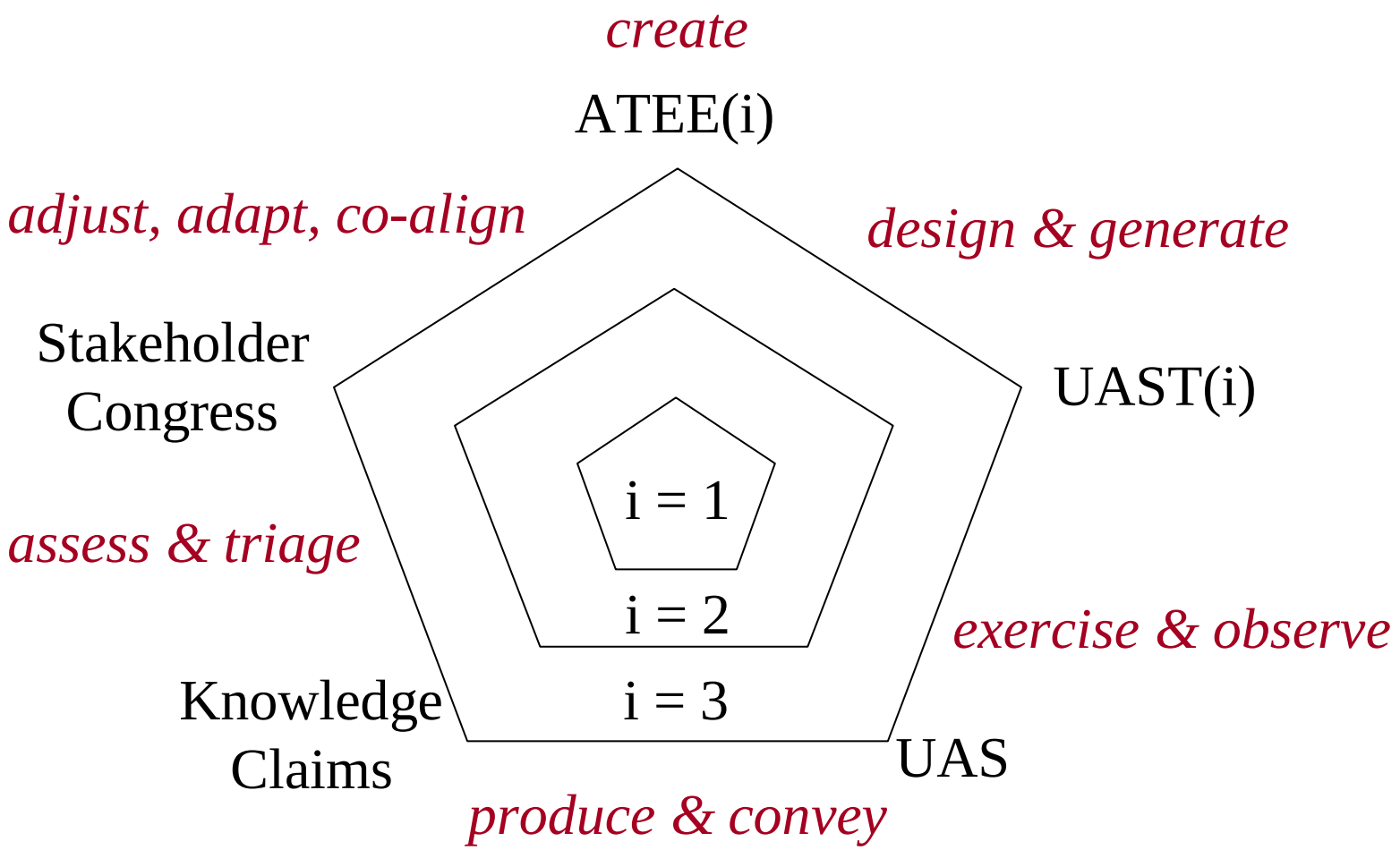
Herzberg on Motivation

Motivation Factors
Direct Feedback
Client Relationship
Psychological Growth
Scheduling One's Own Work
Unique Expertise
Responsibility For Costs
Authority For Direct Communication
Personal Accountability

Hygiene Factors
Pleasant work environment
Good cafeteria
Pleasant co-workers
Company policy and admin; especially communication

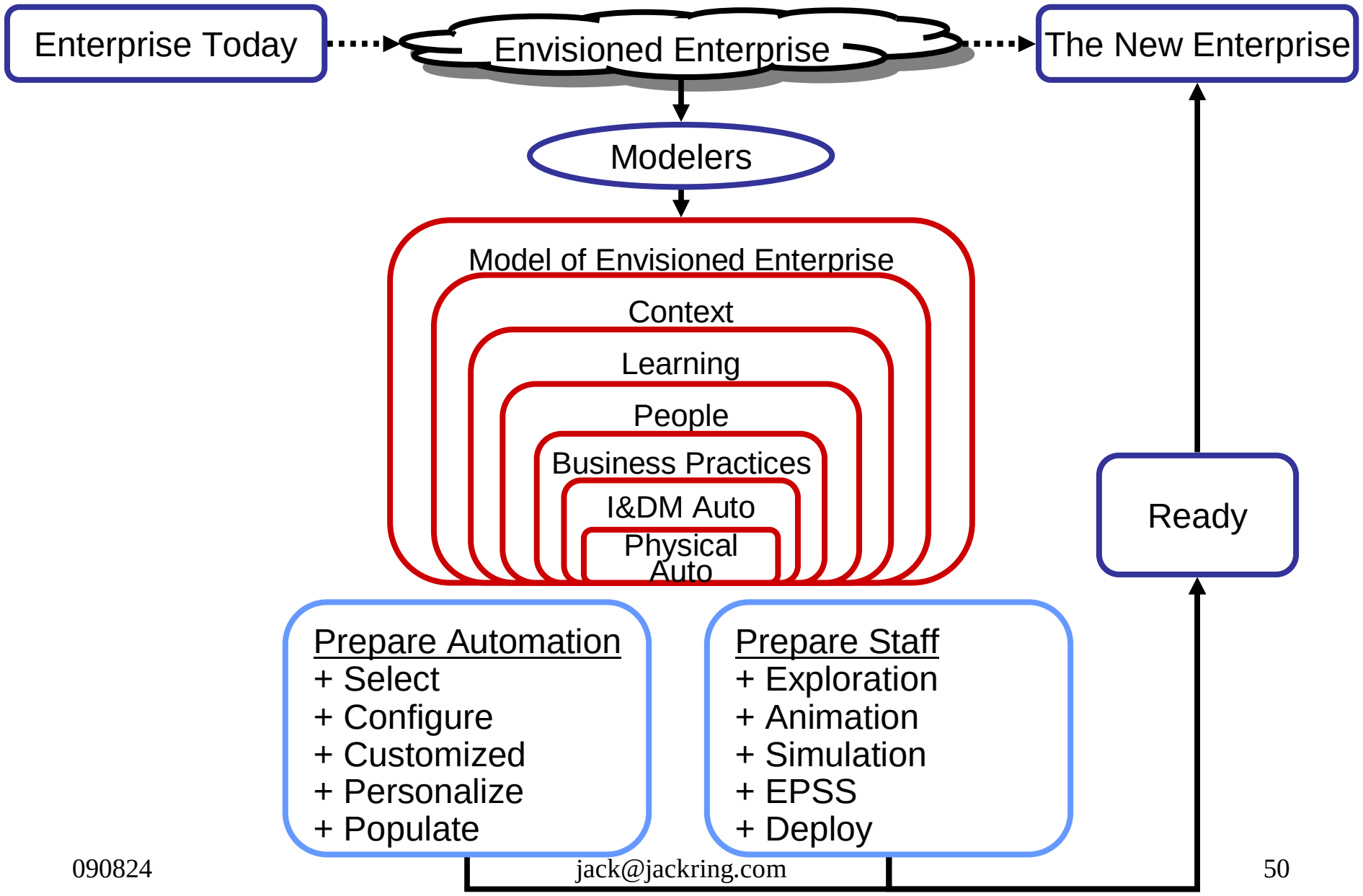
Prof. Fredrick Herzberg, U. of Utah

Initializing the ATEE



3 cycles of 100 workdays each

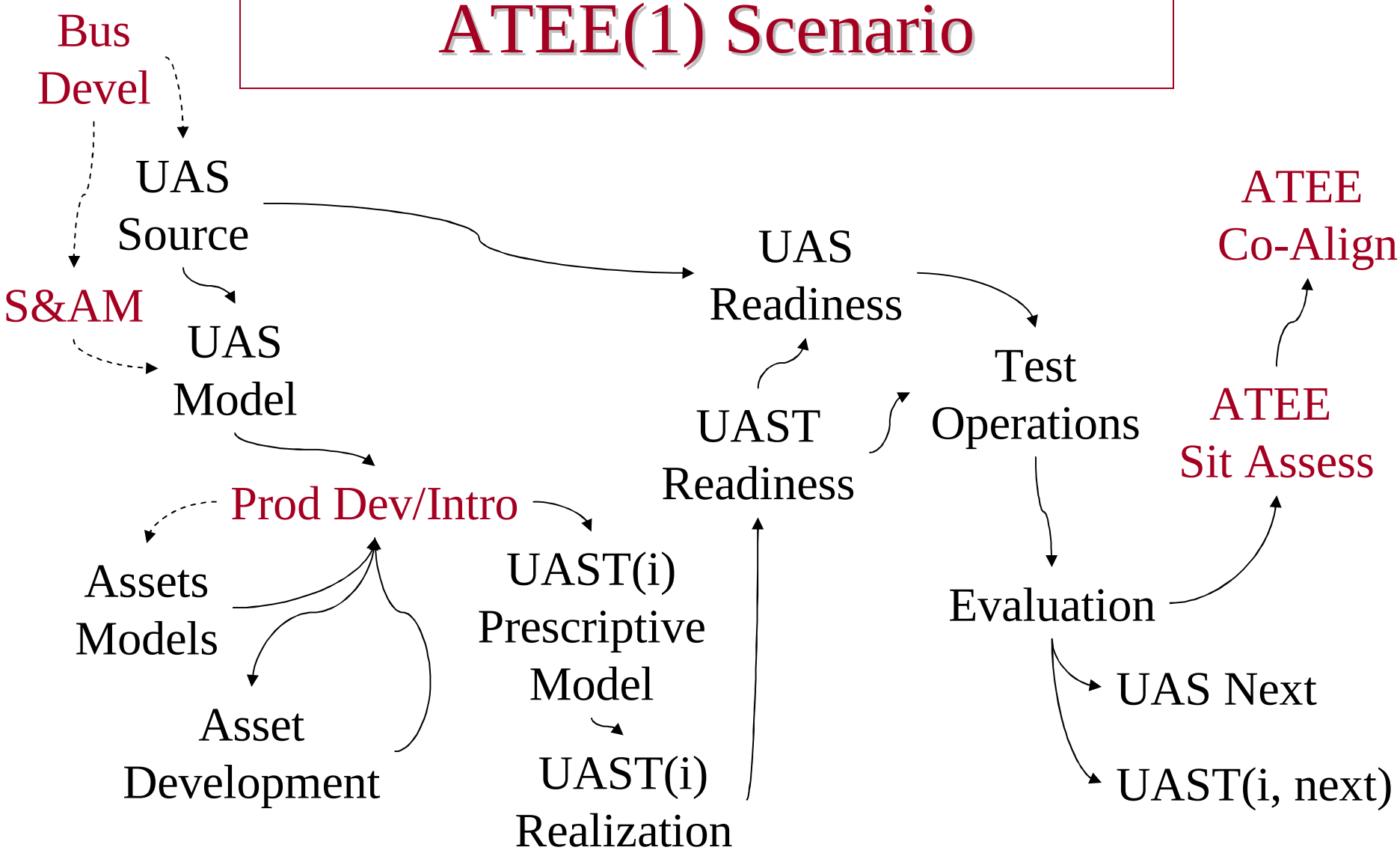
An Enterprise Evolution Pattern



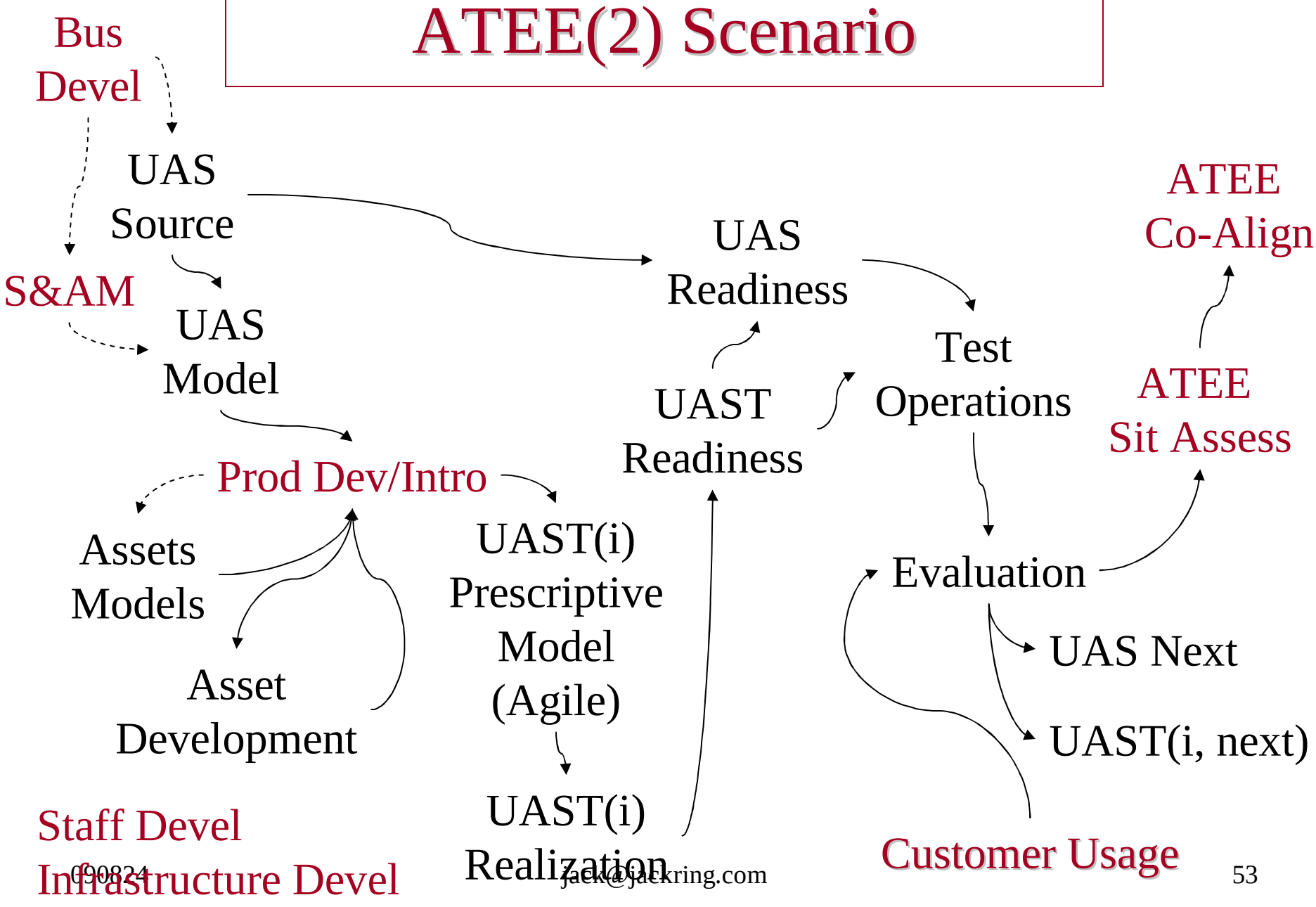
ATEE Evolution Scenario

Aspect of System	ATEE(1)	ATEE(2)	ATEE(3)
Situation Assessment	Post Test	Pre-Post	Anticipatory
Co-alignment	Storm/Norm	Max UAST	Max ATEE
Business Development	Single	Multiple	Joint
Product Dev & Intro	90% Civ/10% DoD	50/50	10/90
Sales & Account Mgmt	Single	Multiple	Joint
Production & Logistics	N/A	IOC	FOC
Contract Services	Yes	Yes	Yes
Staff Development	Selection	UAST focus	ATEE focus
Infrastructure Devel	Minor	Info & Select	Holon Assets
UAST	Local	Networked	Composable
UAS	Single	Hetero	Swarm

ATEE(1) Scenario



ATEE(2) Scenario



UAST Evolution Constraints

$X, d(X)/dt, d^2(X)/dt^2$

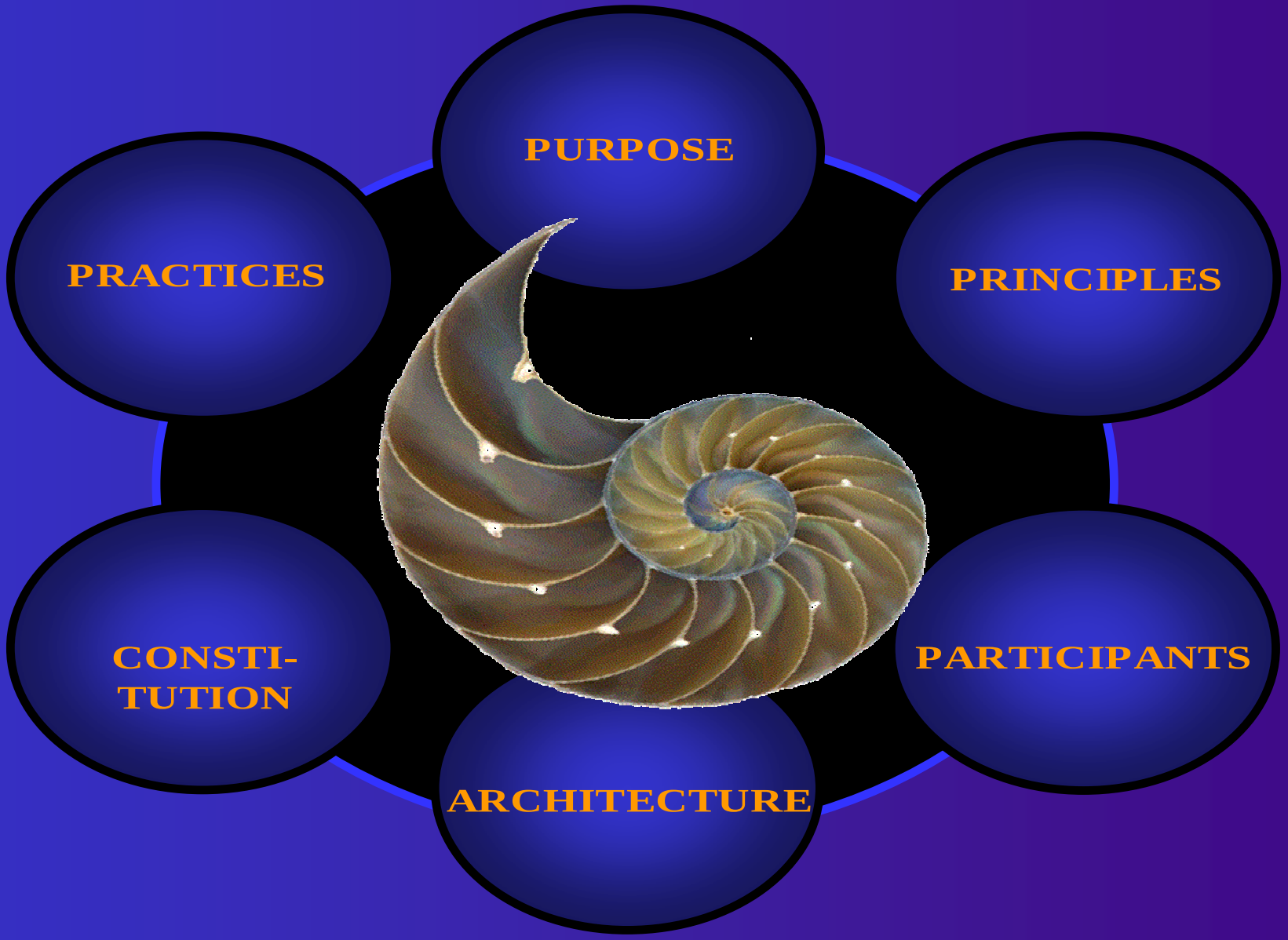
Viable options for morphing UAST will be constrained by conservation laws, e.g.,

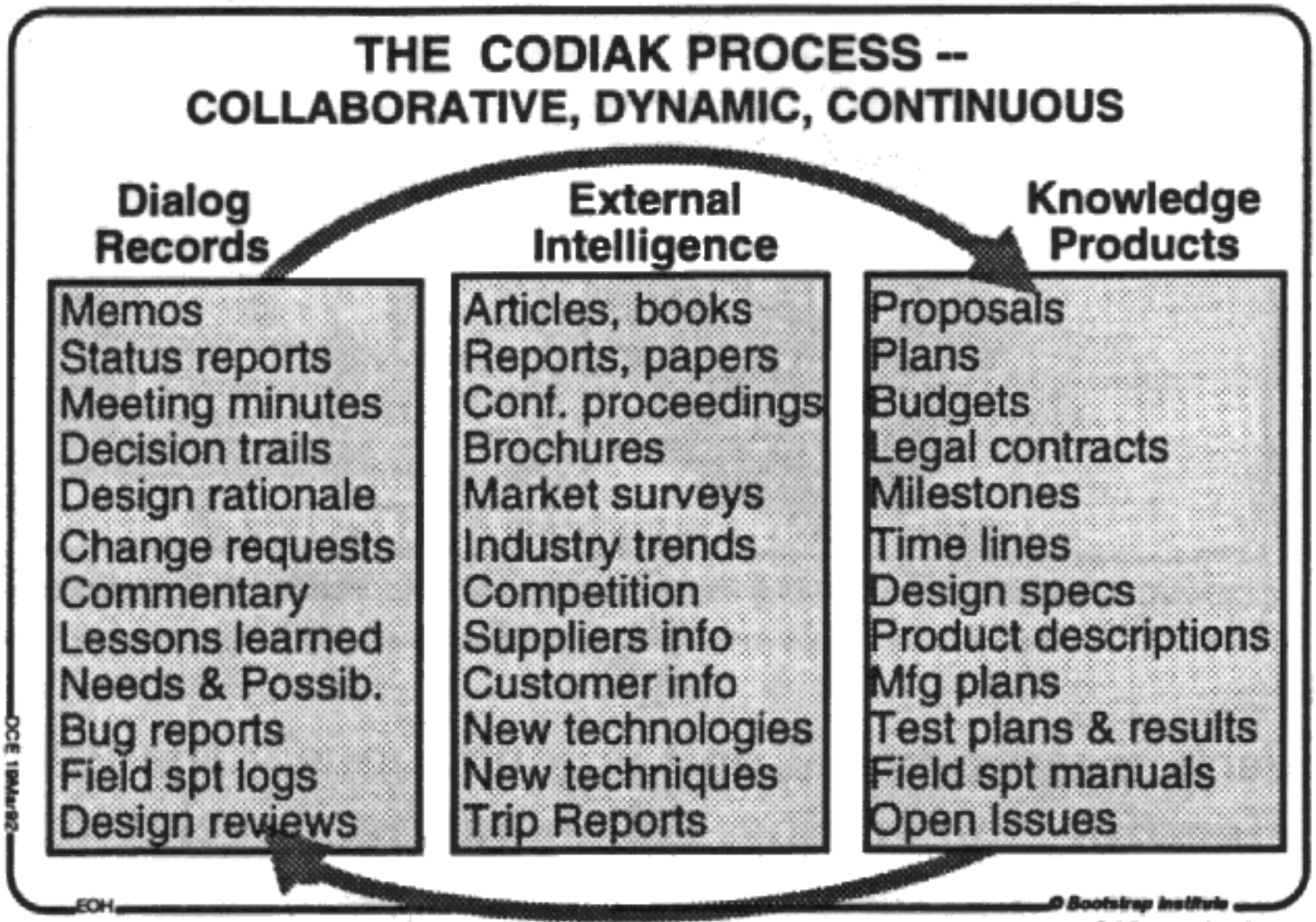
- Thermodynamics: mass, momentum and energy
- Informatics: data, information and knowledge
- Teleonomics: skills, rate of learning, and rate of invention
- Human social dynamics: trust, enthusiasm, co-evolution
- Economic: Investment, ROI, Liquidity
- Ecology: ???

Principles

Einstein	Problems cannot be solved at the same level of consciousness that created them.
Lesson	The new consciousness is: Problem System, PS, and Problem Suppression System, PSS.
Livingston	Complex problems are rarely solved, just controlled to a tolerable degree.
Lesson	Second-order, implicit systems.
Warfield	Design Context, Content, Structure. Behavior emerges.
Lesson	Enterprise Context presents a jumble of stochastic shocks.
Weinberg	Behavior is in the Relationships.
Lesson	The Big Trade Off is Stability vs. Maneuverability
Wymore	Model-driven SE cuts through complexity and confusion.
Lesson	Model the Six Facets then the Requirements become obvious.
Blanchard	Modeling is a process of Languaging the participants.
Lesson	Establish a semantic framework on which to hang the knowns and unknowns.
Ashby	The PSS must have greater "agility" than the PS.
Lesson	When the PSS becomes operational, new problems appear elsewhere in the PS, some more severe than the original problem.
Livingston	Design PSS for the current PS and the PS that will be caused.
Lesson	A system that includes people is inadequately modeled as a state-determined system.
Starkerman	PSS Effectiveness is >80% people relationships.
Lesson	POSIWID, The Purpose Of a System Is What It Does --regardless of what was intended.
Lesson	Once the PSS becomes operational the **other half** of the SE's work can begin.
Taylor	It is all easier if done with intelligent objects.
Lesson	Model a PSS that is self-documenting, adjusting, repairing, and morphing.
Hahn	EVOP must be faster than Mean Time To Demand for Change.
Lesson	The System Adaptation Protocol is key.
Roe	A fool with a tool is still a fool.
Lesson	There is no substitute for thinking.

Chaordic Design: Six Lenses





CODIAK: COncurrent Development, Integration, & Application of Knowledge.

http://www.dougengelbart.org/

plic, as in complicated
or plex, as in complex?

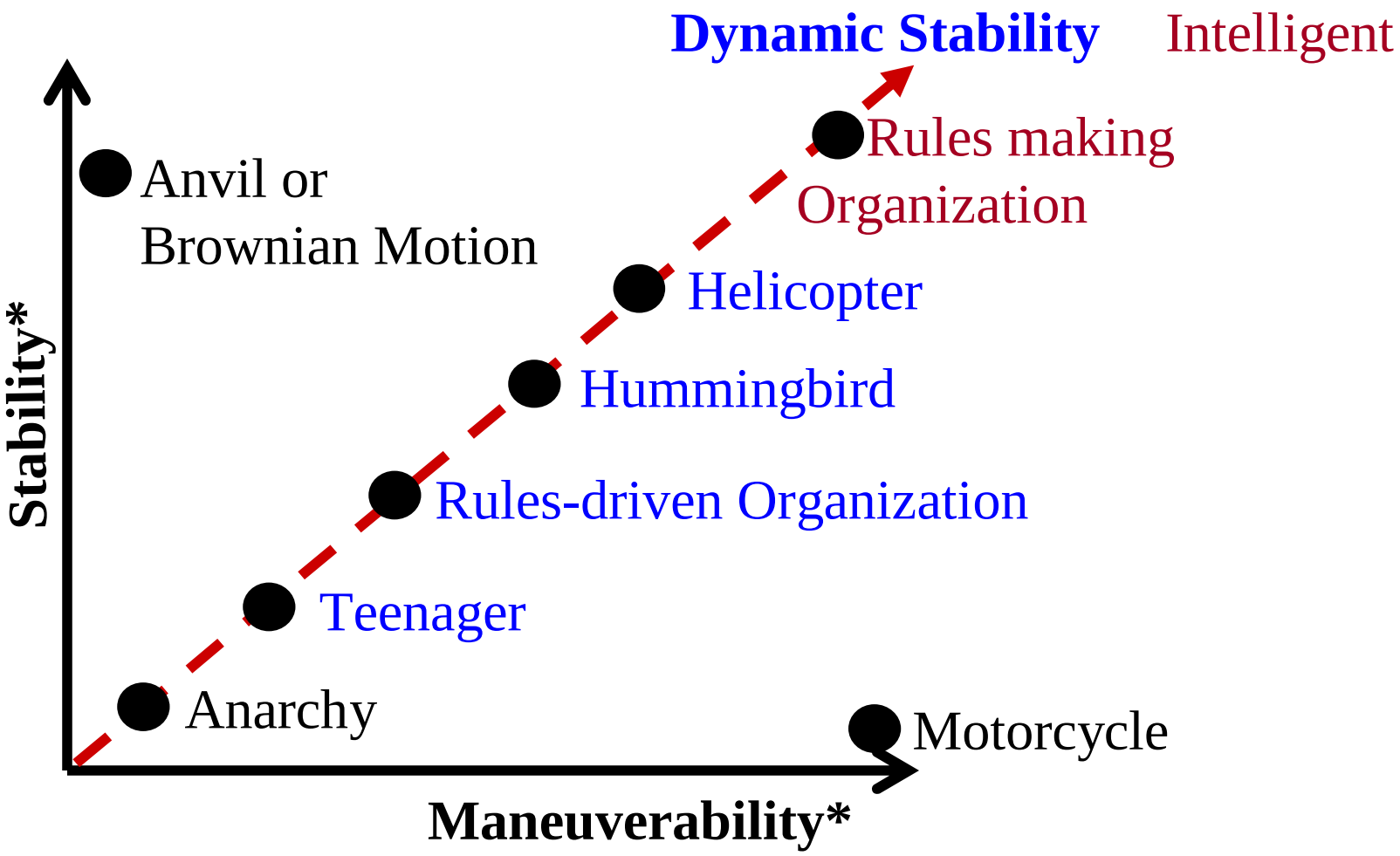
Complexity: The nature of the relationship between observed and observer.

Evolving an Autonomous T&E Enterprise?

Initialize it properly
and let it evolve itself.

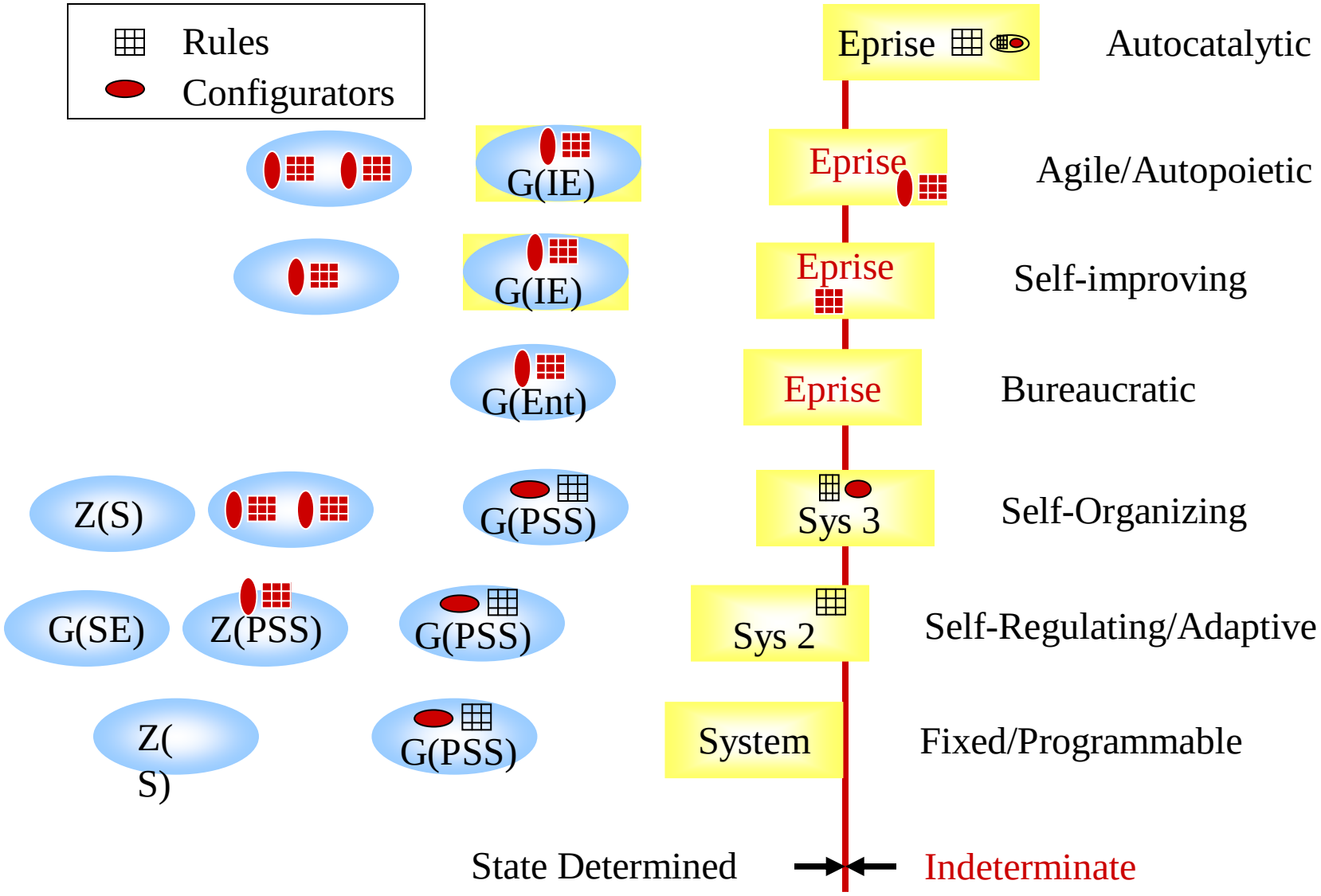
Questions?

A Basic Behavioral Tradeoff



* Also, Gain vs. Bandwidth, Efficient vs. Innovative, Lean vs. Agile,

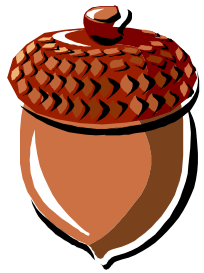
Locus of SE --- Folded Systems



Example G(S)
Continuous Innovation Systems

When you crack open an acorn you do not find a tiny oak tree.

You find a nut -- that “knows” how to become an oak tree -- and will, IFF it gets the right environment and nourishment.



Enterprise Measures

Enterprise Four

Market Standing =
unknown → dominant

Productivity =
1.1 X Competitors

Innovation =
outpace competition
pace customers

Liquidity =
negative → ++

Management Seven

Cost of Quality

Model Fidelity

Learning Curve

Conflicting Goals

Work Climate Surveys

Benchmarking

Personnel Fifteen

Ambiguity
Disorientation
Ambivalence
Alienation
Dissonance
Distrust
Futility
Malaise
Isolation
Dread
Apathy
Depression
Negative
Rumors
Sabotage