

A “Get Well” Program for Test & Evaluation of Autonomous Systems

by

Jack Ring

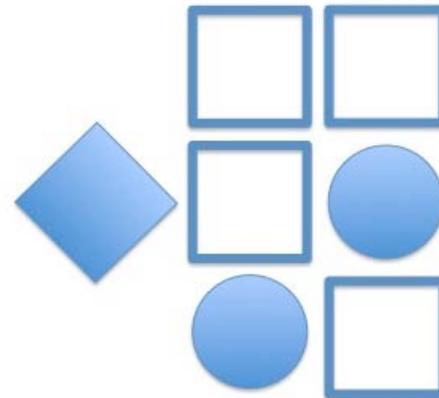
Fellow, INCOSE

Member, Educe LLC

for

San Diego Chapter

Mini-Conference 2010



You don't know Jack?

- Worked 1957-1959. Played 1960–present. Built many systems. Some OK.
- System T&E
 - Atlas Missile Radio Guidance System. Flight Test Conductor verifying operational site readiness. Project Golden Ram.
- System Engineering
 - GE Range Safety and Information System, Sports car instrumentation, Dynamic Automated Retrieval Technique, Test Range Automated Planning and Scheduling System, Intelligence collection, analysis and production system, Computer-integrated manufacturing, Automotive performance systems, General Purpose Set Theoretic Processor, Software engineering, Systems engineering, and Intelligent enterprises.
- Action research and mentoring
 - High Tech startups and turn-arounds
 - Object technology
 - Advancing systemics and systems praxis.
- INCOSE (Fellow), ISSS, IEEE, ACM, etc.
- UAST 'subject matter expert'



Agenda

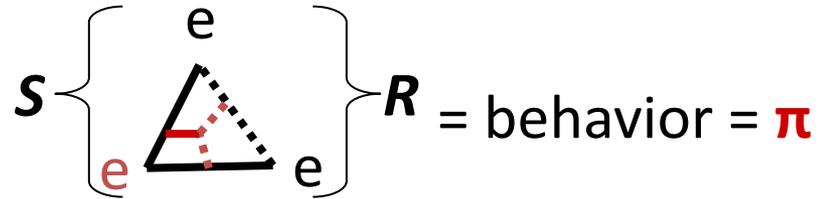
- Problematic Situation: Systems, Autonomous Systems
 - Suitability, Effectiveness, Safety, Survivability, SESS
 - New ways to excel --- or fail.
 - Lack of warfighter-trusted knowledge.
- Reconceptualizing the solution:
 - T&E: What got you here won't get you there.
 - Non-deterministic systems.
 - Knowledge: Acquire, Interpret, Produce, Convey, Utilize, KAIPCU
- Get Well:
 - 1. Soldier systemists driving intelligent evolutionary acquisition.
 - 2. Prototypin.
 - 3. Refurbishing the knowledge workers.
- Questions & Recommendations.

What do we mean by System?

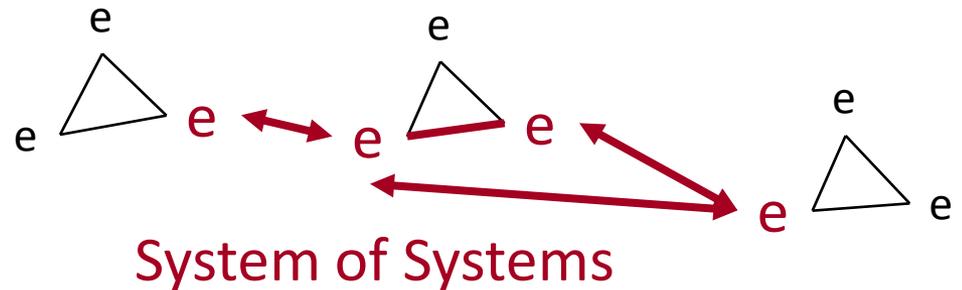
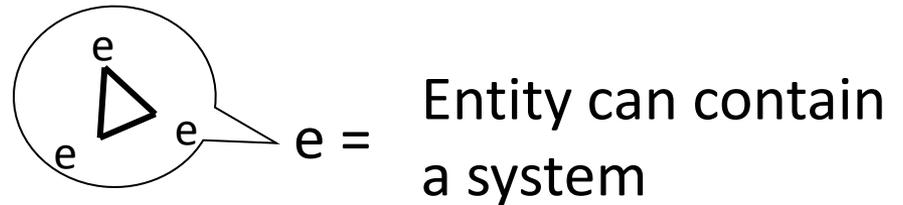
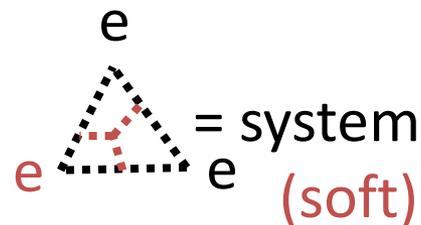
e = entity

— = relation

e — e = system



S = Stimulus, R = Response

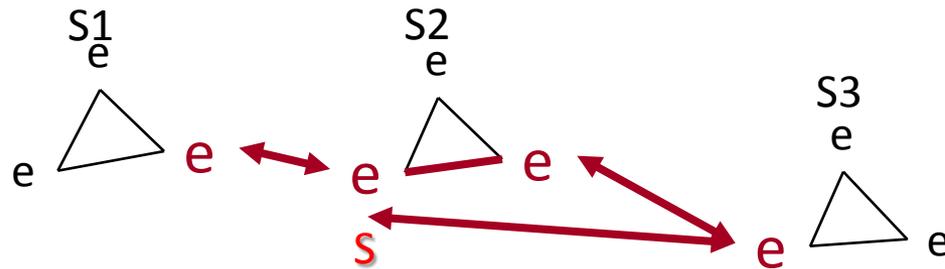


Three kinds of System of Systems

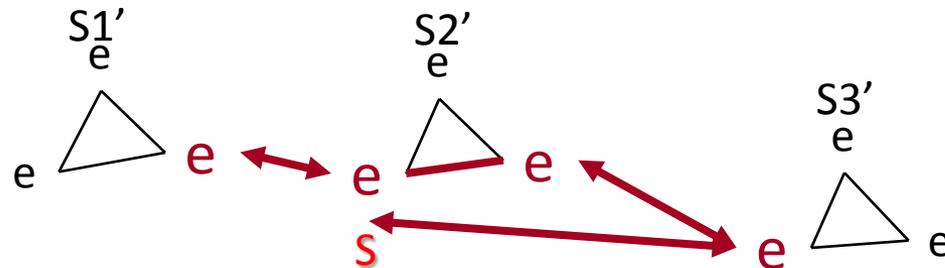
Dedicated



Shared



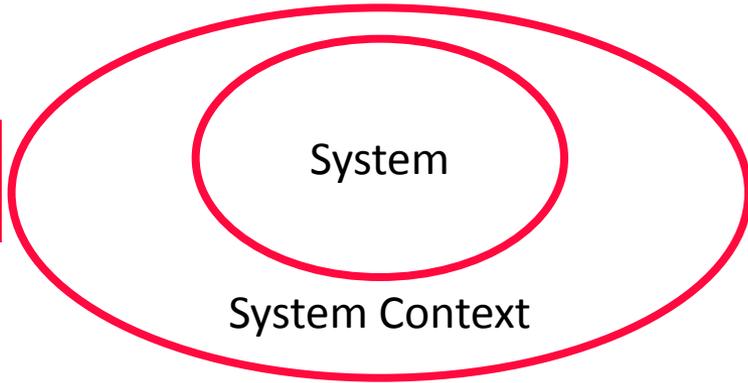
Concurrent



POSIWID: The purpose of a system is what it does, regardless of the intent of sponsor, designer, user or operator.

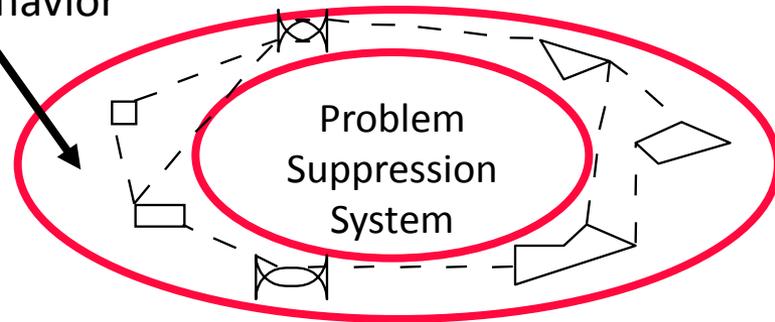
Systems Praxis

1.

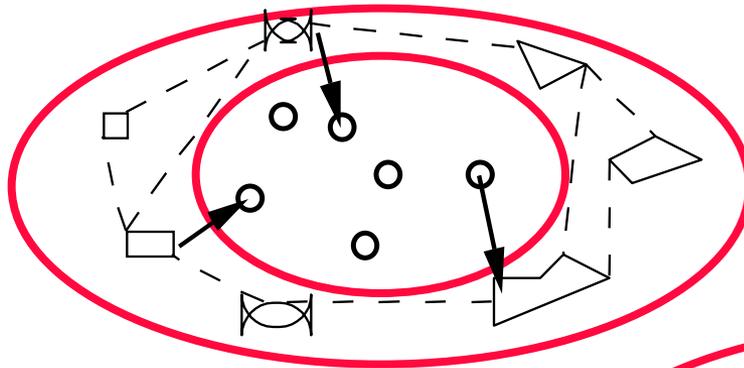


2.

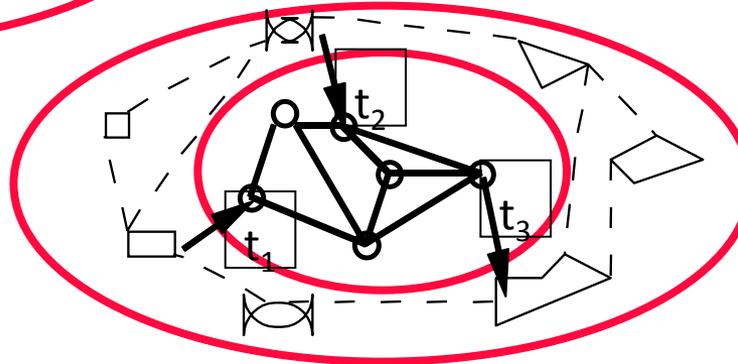
Problem System;
Content, Process,
Behavior



3.

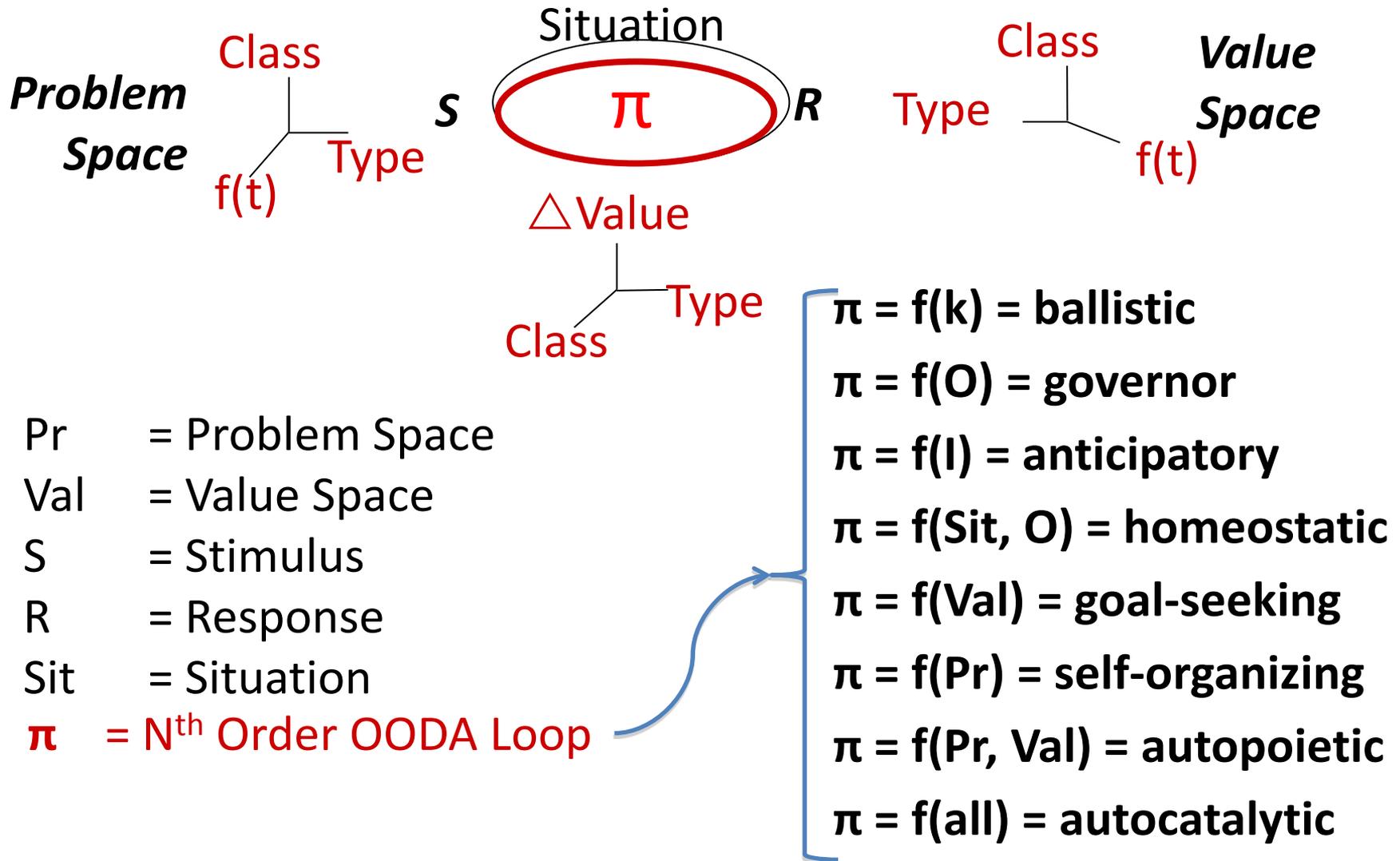


4.



Adapted from
Science of Generic Design,
John Warfield

Some Categories of Systems

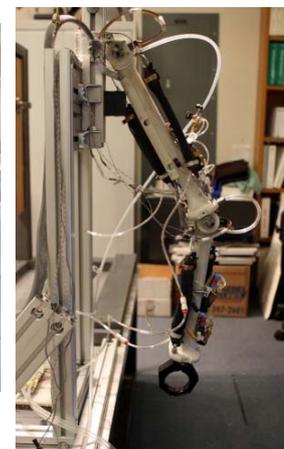


Autonomous Systems

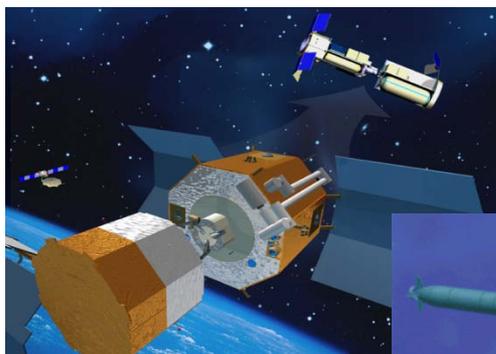
- An autonomous system is characterized by its ability to:
 - **Perceive** the environment and itself
 - **Reason** based on perception, to achieve goals within constraints
 - **Act** to achieve goals within constraints



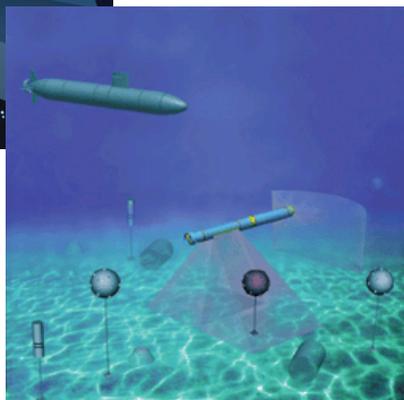
ISS control room



Stanford Robotics Lab



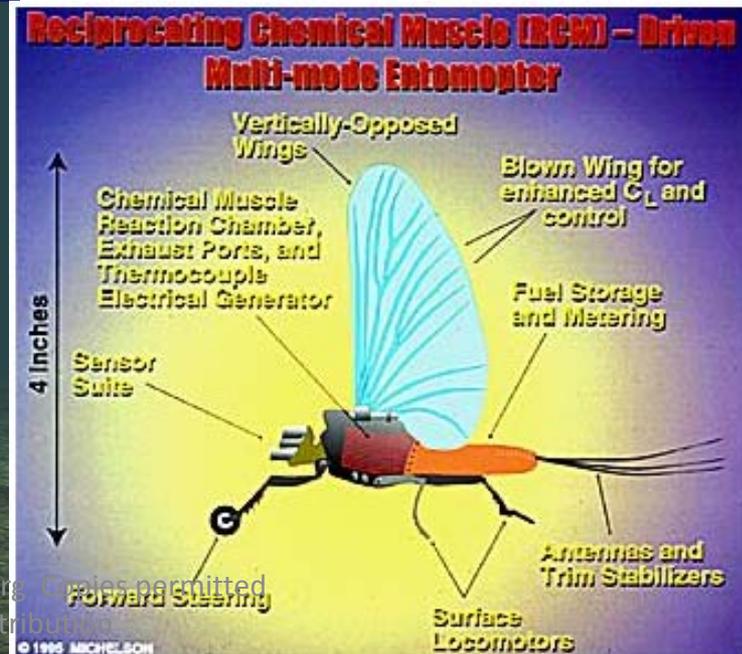
Orbital Express System



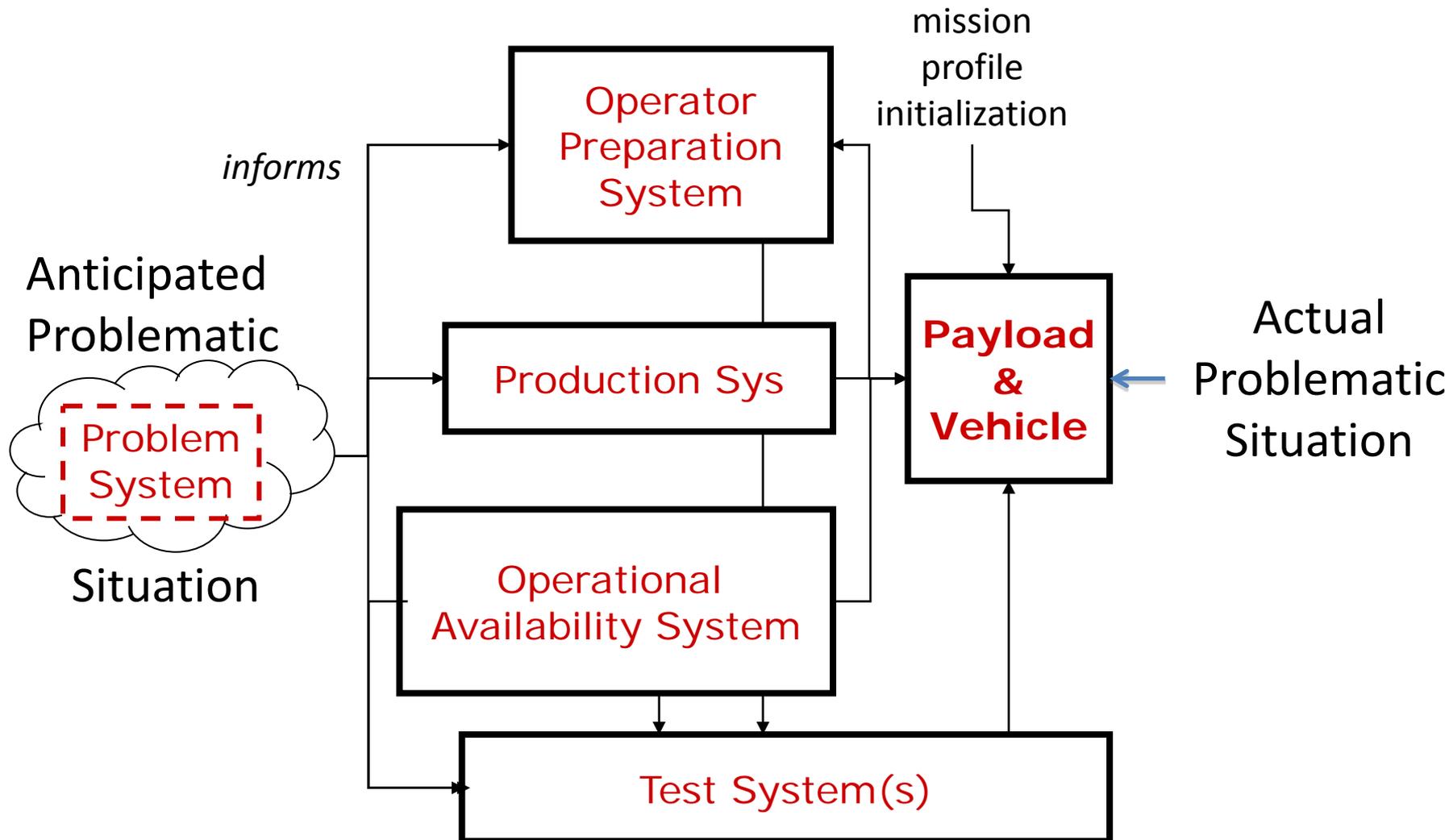
MCM

- Autonomous systems are created through the integration of various disciplines ...
 - Mission planning, guidance & control algorithms, human-system collaboration, communications, etc.
- ...and can be anywhere along the mobility spectrum
 - Vehicle -> articulated robotic arm -> habitat management system

Autonomous Vehicles

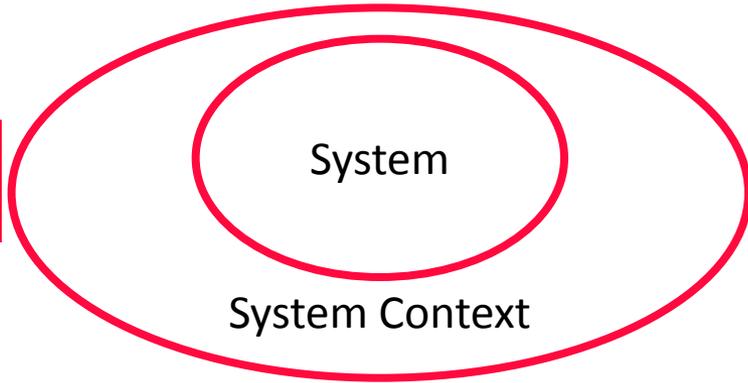


The Warfighter's Whole System Context



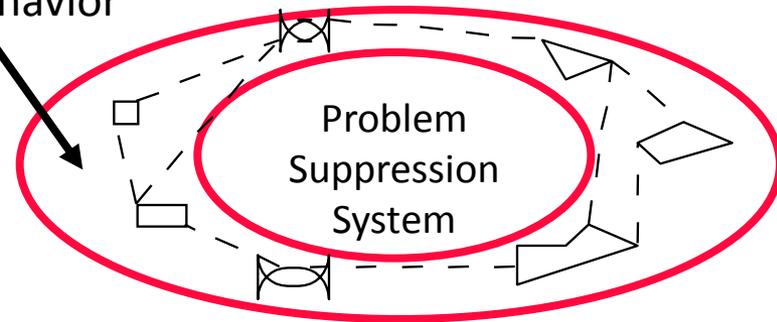
Systems Praxis

1.

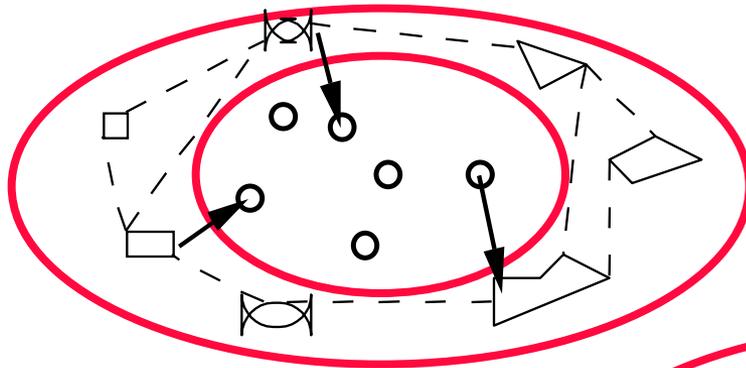


2.

Problem System;
Content, Process,
Behavior

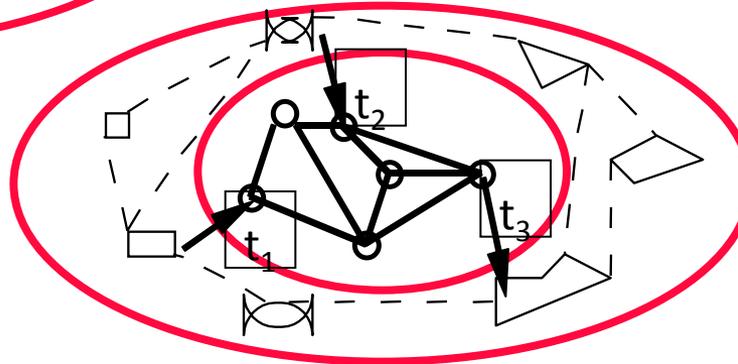


3.



Problem Suppression System: **Content**

4.



Problem Suppression System: **Content, Process, Behavior**

*Adapted from
Science of Generic Design,
John Warfield*



Autonomic Actions

Adjust: Gradients on relationships

Arrange: Pattern of relationships

Co-align: Content of system with context and resources.

Within Dynamic and Integrity Limits

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

- **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:** Waste, Fads, Unintended Consequences

Autonomous Engagement Categories

Non-deterministic



Probabilistic

Deterministic

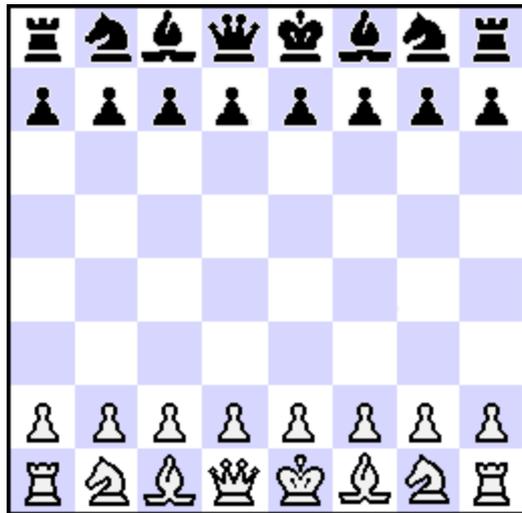
Behavior is predictable from knowing past trajectory of states and current inputs.

Locus of behaviors is predictable from knowing content, relationships and envelope of inputs.

Limits of integrity and stability are estimatable from knowing whether ruleset and resources can always achieve requisite variety.

Anticipating SESS?

- SESS may be treated as the outcome of a **game** between an **angel** and **demons**. Ideally our champion: **the angel**, can marshal, allocate and schedule resources to prevail.



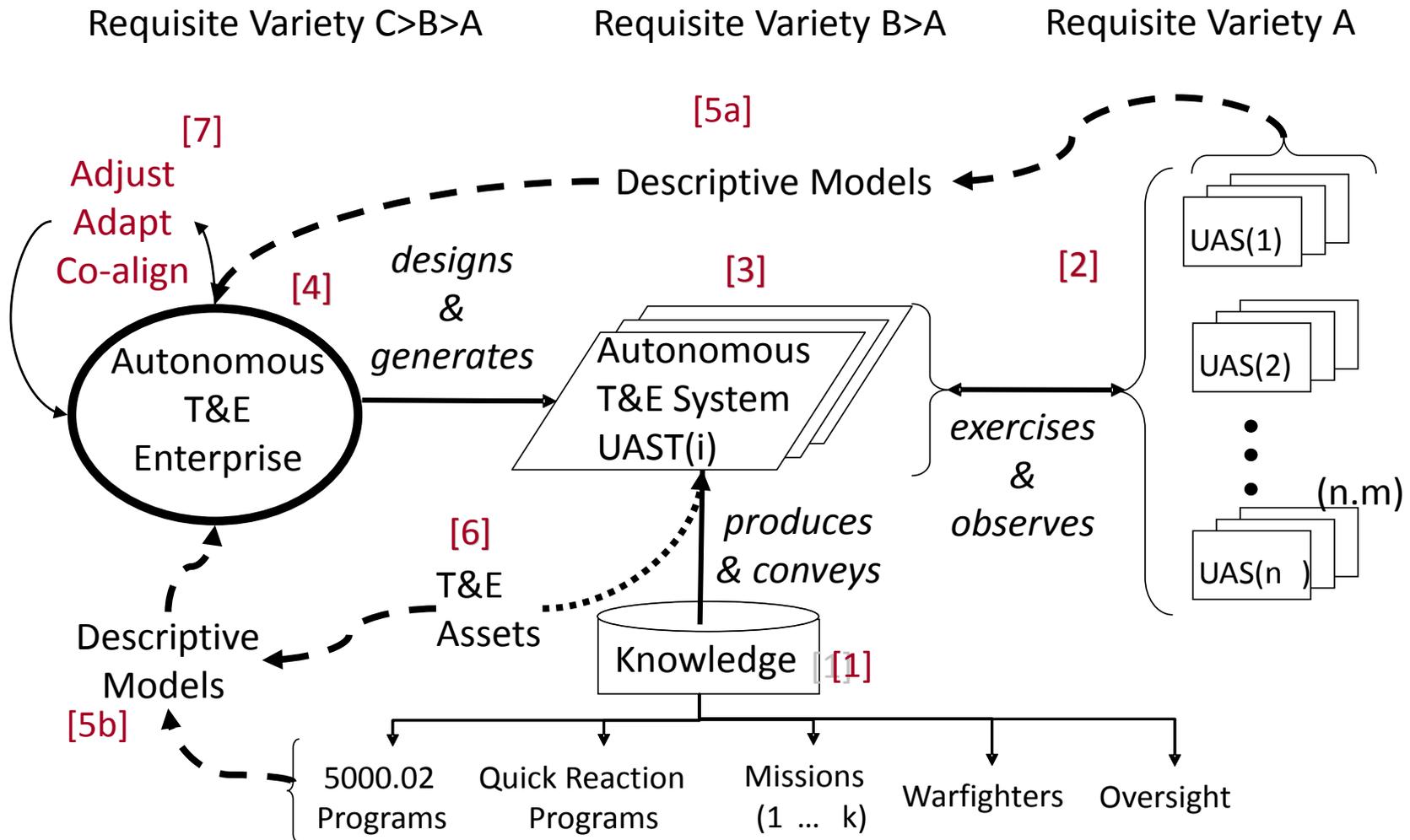
The **demon** may react to all the **angelic** moves attempting all possible tricks to defeat the **angel**. That means the **angel** must be able to counter continuously any new **demonic** action change her strategy and behavior in response to **demonic** actions

Angel Requisite Variety

- The angel is supposed to be able to exhibit requisite variety for duration of the engagement.
- If the environment is **finite** (*the number of potential interactions with the angel is chosen from a finite set although they may occur erratically*) it is possible to reach a **Nash equilibrium** wherein angel and demon use their respective best strategy thus no strategy change is needed.
- If the environment is **unbounded** the game **cannot** reach a Nash equilibrium, therefore the angel may be defeated.
- A System of systems contains a web of angels and a web of demons.
- Our job is the discover the weak angel w/r warfighter situations.



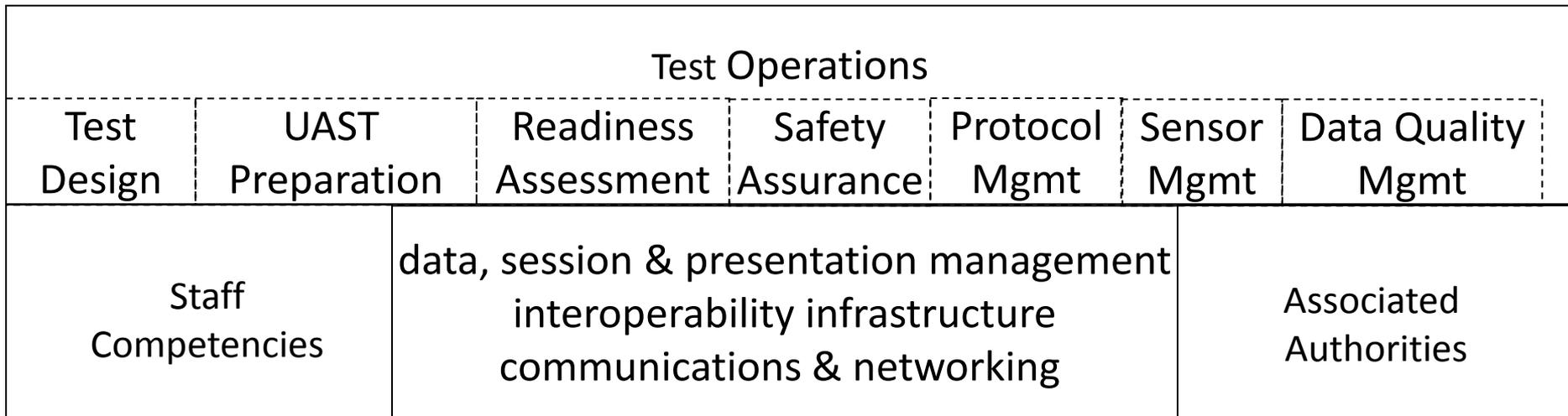
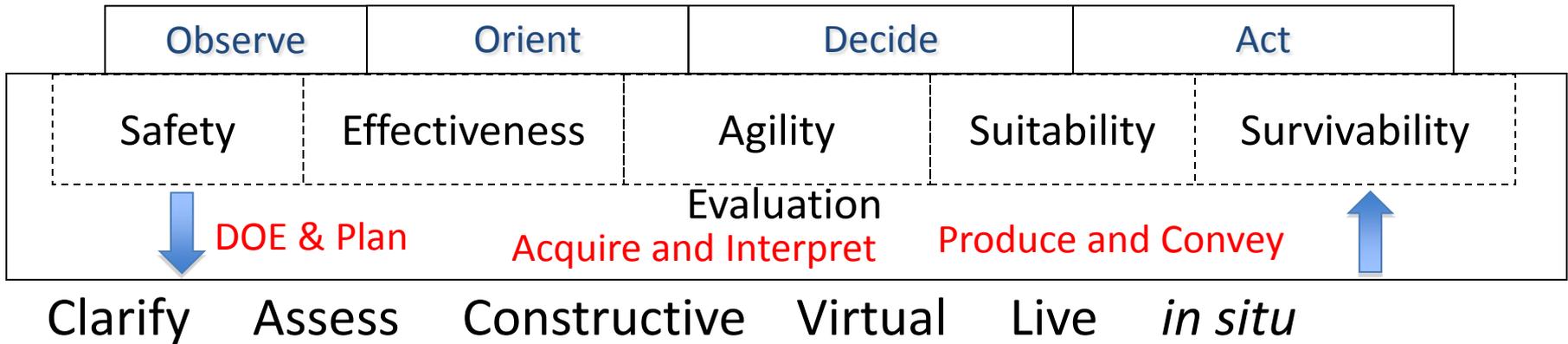
Reconceptualizing The Solution



Generic "T&E" Capabilities

Blue Force Environment Red Force

Knowledge Needs



It's the LIMITS, Stupid

Strategy

The allocation and scheduling of resources sufficient to overcome impediments to objectives

- Dynamic Limits – pursuit
- Dynamic Limits – morph
- Integrity Limits – recoverable
- Integrity Limits -- unrecoverable

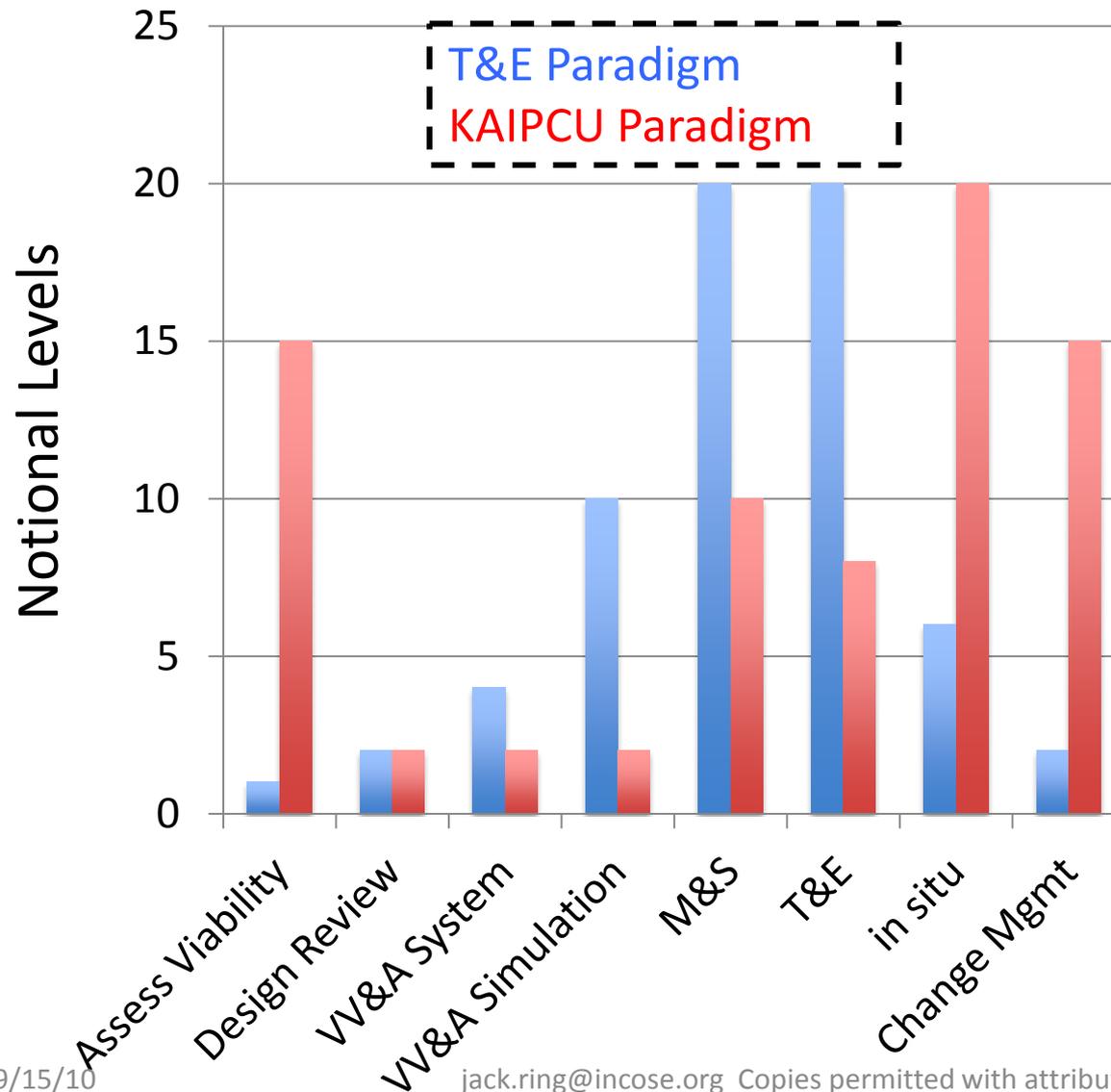


The warfighter needs to know, and trust, the Suitability, Effectiveness, Safety, Survivability limits of each autonomous system.

Design for Prevention Precludes Unintended Consequences



The “get well” paradigm shift



Shift Your Paradigm!

1. Personnel
2. Prototyping
3. Parsimony



Get Well 1: Personnel

Objective: Bring a 12 person DOD cadre up to systemist level of competency for each kind of UAS (Space, Air, Ground, Marine, Undersea). Will lead prototyping. Will become exemplars for expanded cadre.

Action: a) Interactive Management session to identify and stratify the UAS problematic situation, formulate a variety-sufficient response, and compose a scenario of systems architecting, engineering, and learning.

b) Perspective session: SDOE 678 and 683 courses by Stevens Institute of Technology, School of Systems and Enterprises, or equivalent.

c) Perspective session: Design for Prevention paradigm



Get Well 1: Personnel – MOE's

- Systemists acknowledge that the challenges are not about test and evaluation but about discovering the expected SESS of unmanned autonomous systems of systems in anticipated, albeit ambiguous situations.
- Systemists understand how to implement knowledge acquisition, interpretation, production, conveyance and utilization, KAIPCU, for warfighters and their support organizations (including in-service engineering or equivalent).
- Systemists know that SESS expectations must be generated throughout development, integration, initial deployment and operational life, **whenever, wherever**.
- Systemists know how to qualify not only a whole autonomous system but also diverse systems that coordinate, cooperate, collaborate, or co-learn.

Ten C's of Human Synergy

Relationship	Meaning	Mediators
Co-evolve	Coherent morphing	Change proficiency
Co-facilitate	Value Out/Value In >	Tri-win situations
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 motivations
Communicate	Share interests and values	Common language
Connect	Two discover one another	Accessible attributes

Get Well 2: Build Prototypes

- Proto 1: qualifying SESS of a whole autonomous system
 - Assess viability,
 - Continuously Anticipate MOE's
 - Measure Behaviors CVL,
- Proto 2: generating a 'family of KAIPCU systems' responsive to each mission situation.
- Proto 3 evaluating whole system SESS wherever and whenever needed (not just at Test Ranges).
- In each Proto 1, 2, 3 ---
 - Proto X.1: Top three challenges in the problem space
 - Proto X.2: 80% solution to a meaningful mission situation
 - Proto X.3: Proof of value to stakeholders



Get Well 2: Prototypes MOE's

MOE's:

- Knowledge conveyed is deemed trustworthy by all stakeholders.
- Knowledge is produced from Day 2 of development phase to autonomous system end of life
- Capability minimizes False positives and False negatives
- Applies across all viable Joint configurations
- Demonstrates cycle time inside Development phase OODA loop
- Lean, e.g. integrated with warfighter and support staff training.

Get Well 3: Parsimony

- De-duplication
 - UAS self-test.
 - Descriptive models of engagements, missions and environments.
 - Model-based SE of UAS's (executable models).
- National Autonomous Systems Information Clearinghouse.
- Harmonization, e.g. Stds, Regs, Guides to provide for non-deterministic angels.

Get Well 3: Stage the Evolution

- Measures of Effectiveness and Standards of Acceptance as THE primary "requirements."
- Sufficient UAS self-test of operational readiness and in-operation malfunction detection.
- Update guides and handbooks for systems engineering and system of systems engineering to include "design for prevention" of nth-order implicit systems.



Beware Re-use?



Take Aways

- What do we mean by autonomy? A gaggle of arbitrarily changing systems. POSIWID
- What do we need to know? Do your angels have sufficient requisite variety? What are the limiting factors to SESS?
- Anticipating Suitability, Effectiveness, Safety, and Survivability? Less by contrived exercises at test ranges and more by KAIPCU *in situ*, whenever, wherever, continuously.
- How do we “get well?” Shifting our paradigm from contrived T&E. Responding in proportion to opportunity and urgency. Initiative and leadership.

Questions – Recommendations?



Thank You!