Science and Engineering cycles in initializing complex, adaptive systems

Presentation to INCOSE Enchantment Chapter
January 8, 2014

Jack Ring
INCOSE Fellow
Kennen Technologies LLC
OntoPilot LLC
Educe LLC

Educe LLC

You don't know Jack ?

- 1957 – Present. GE 20, Honeywell 10, Edelbrock 3, Ascent Logic 2, IBM OTP 1, Entrepreneur 20. Kennen Technologies LLC, OntoPilot LLC, Educe LLC.
- System Test & Evaluation (Atlas ICBM Radio Guidance System) → System Engineering (State-determined → Stochastic → Non-deterministic System).
- Inaugural chair, 1970, GE-wide workshop on Software Engineering.
- Led SAFE system concept definition for multi-agency federation of intelligence collection, analysis and production.
- Product Manager, Distributed Transaction Processing products suite.
- Corporate Turn-around, Edelbrock Corp., Ascent Logic Corp.
- Projects Director, Object Technology Practice, IBM.
- SME: Autonomous System T&E technologies.
- Tutorials & Papers; ITEA, INCOSE, INCOSE IL, ISSS, IEEE-SMC, IEEE SysCon, ICSEng, NIST.
- Patent co-author, General Purpose Set Theoretic Processor Architecture and Method.

Agenda

- Science vs. Engineering
- Complex Adaptive
- You

Main Claim

Science Describes

Engineering Makes

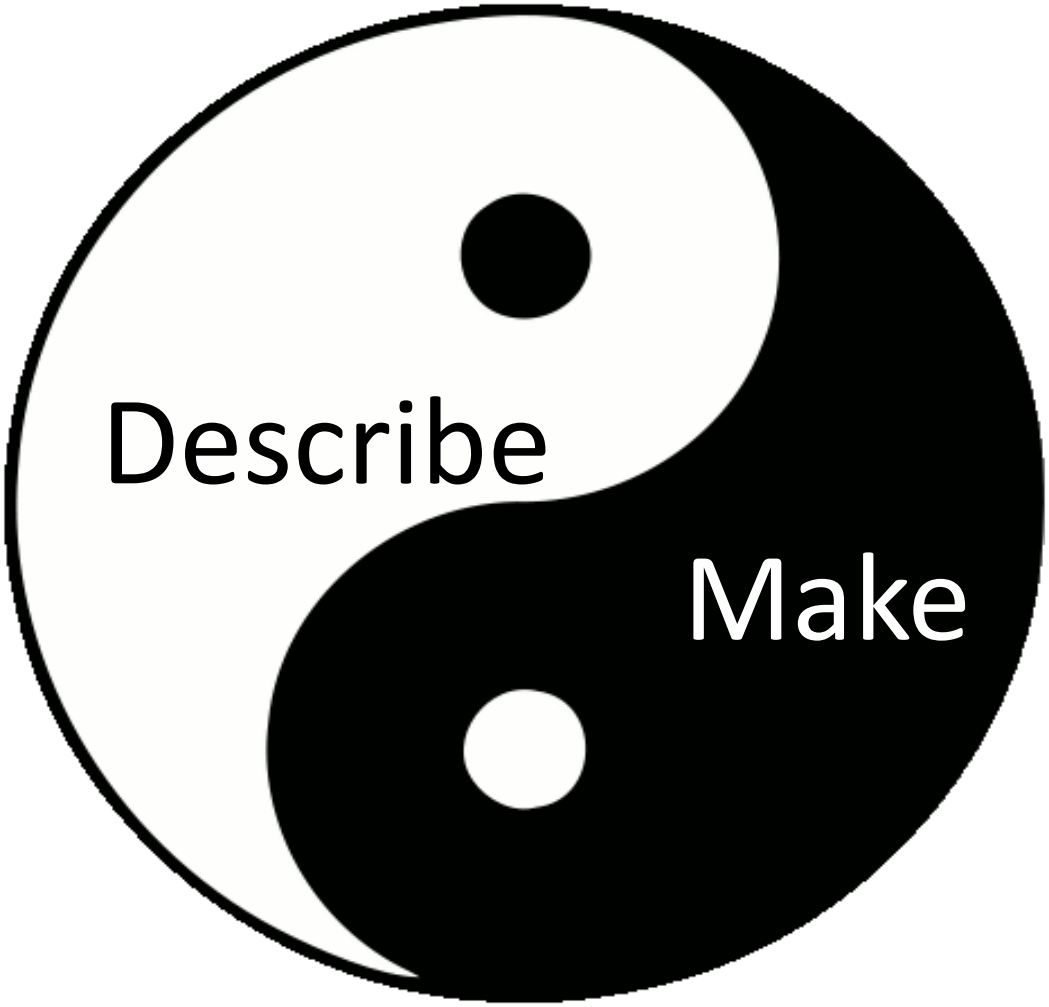
Main Claim

Science Describes

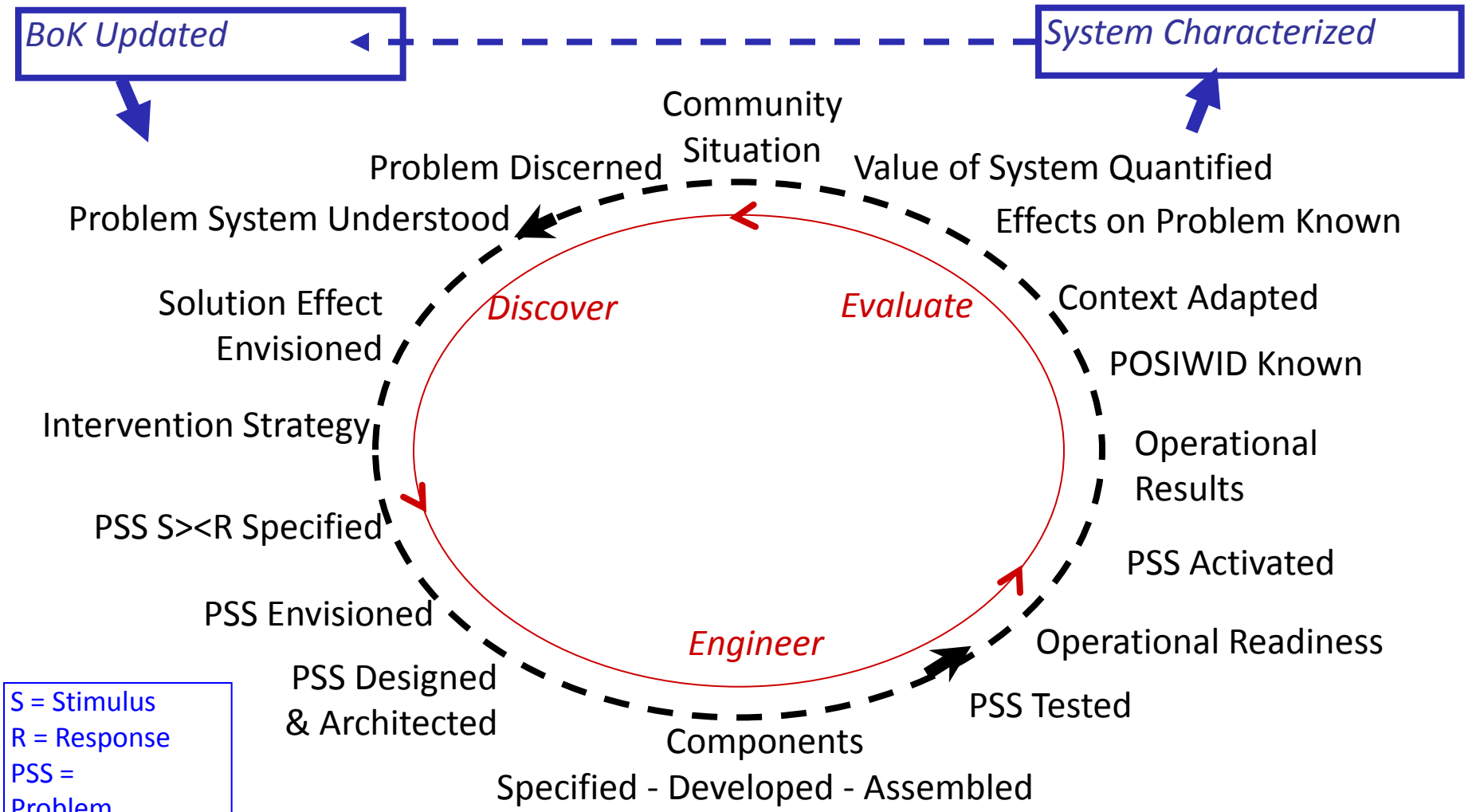
System = Does, Knows, Is

Engineering Makes

The Arrangement of Both is Key



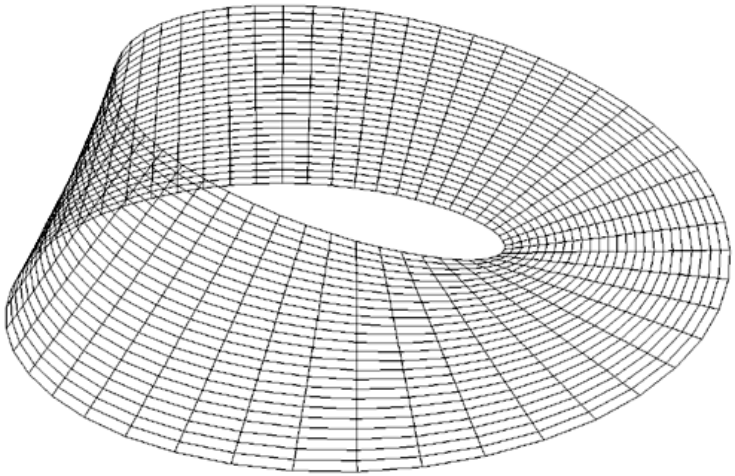
The "Whole System" Scenario Entails Both



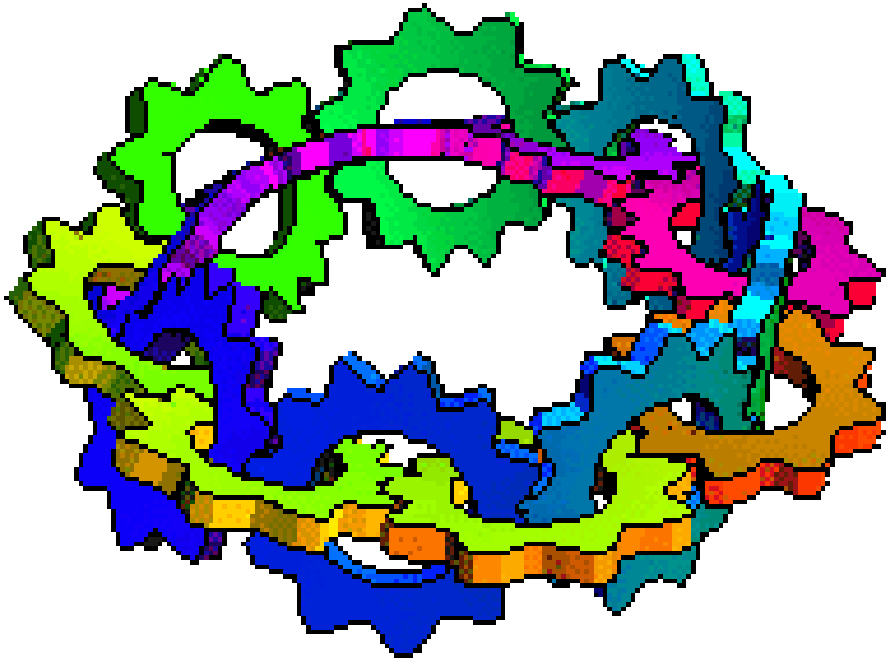
S = Stimulus
R = Response
PSS = Problem Suppression System

Discovering The Value of Systems Engineering , INCOSE IS2000

YinYang In action: The Möbius Strip



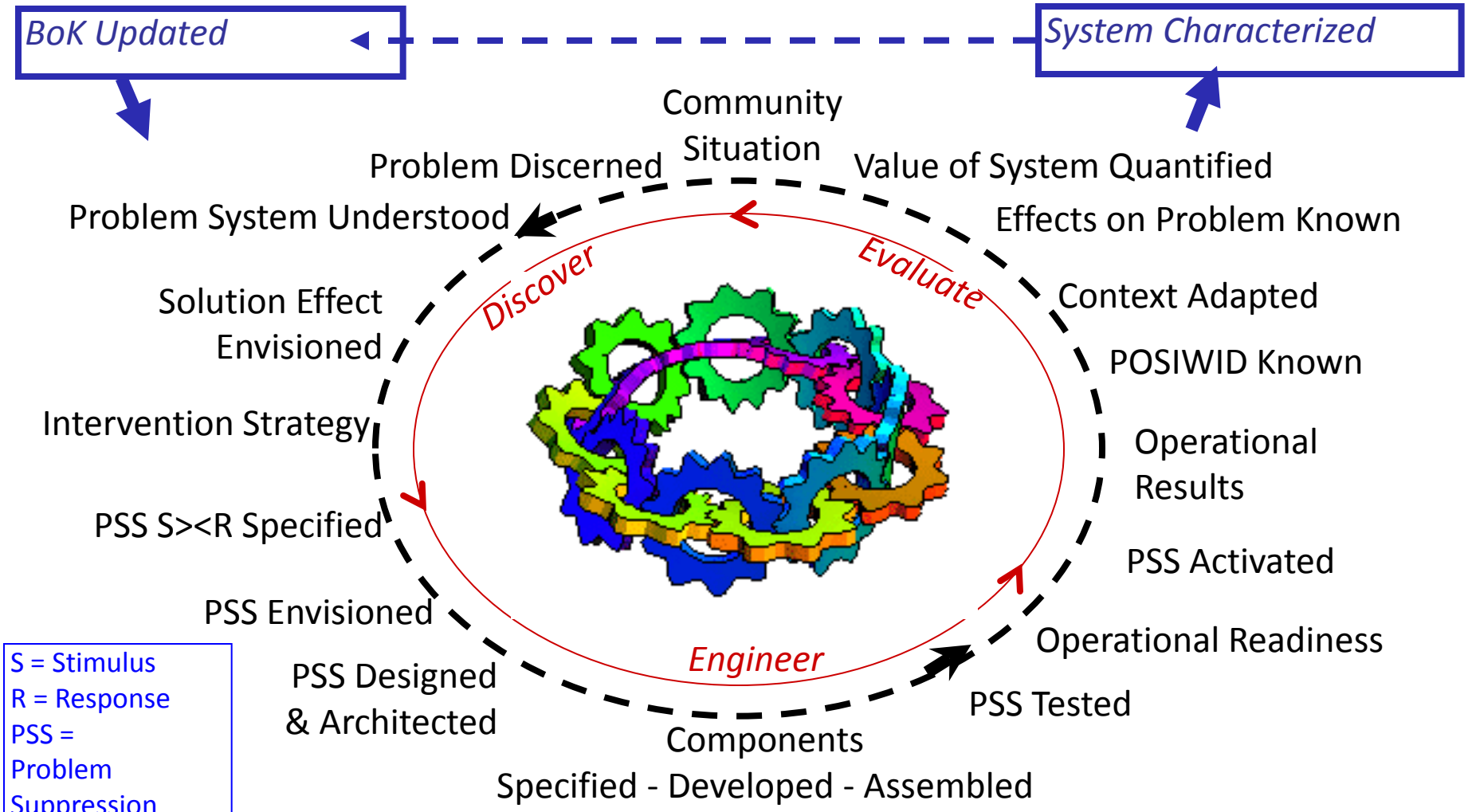
Science



Engineering

http://mathworld.wolfram.com/images/gifs/moebgear.gif

Numerous S-E Cycles in the Systems Process



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The Benefits of E-S Cycles

Science Discovers

- ✓ What was that?
- ✓ Why did It happen?
- ✓ What causes it to happen?
- ✓ How does that work?
- ✓ When will it happen again?
  - – Extent, Variety, Ambiguity.

Engineering Makes

- ✓ What's the problem
- ✓ What effects will be useful
- ✓ What capabilities will generate the effects?
- ➢ Which arrangement of which functions and features will manifest the necessary, sufficient and efficient capabilities?
- ➢ When enabled will/does the system generate the effects?
- ➢ What are its dynamic and integrity limits?

Quality, Parsimony, Beauty!

The Scientific Method

- ➢ What experiment will check your explanation/theory for fallibility?
- ✓ Who independently checked your explanation/theory for fallibility?

The Acclamation Method

- ➢ Form a cohort
- ➢ Make a claim
- ➢ Wait a while
- ➢ Announce that it must be true.

Your Experience?

Continuum, National Air and Space Museum

Agenda

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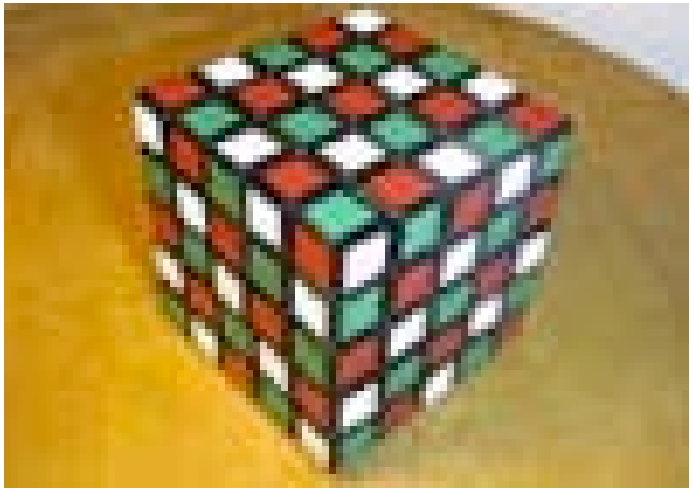


stAGES of coping with Complexness

- Age ≈10 we learned about simple, compound and complex sentences and the underlying rules of grammar.
  - John saw Sally. John saw Sally and Sally saw Jane.
  - When John saw Sally he smiled then she smiled back.
  - Throw the horse over the fence some hay.
  - If I were you I would not have done that until tomorrow.
- Ruleset:
  - Independent clause; subject+verb = complete thought → Simple
  - > 1 Independent clauses joined by coordinator → Compound
  - Independent clause + dependent clause + punctuation → Complex
  - Independent, subordinator, dependent + punctuation → Complex
  - Independent, delimiter, dependent + punctuation → Complex

stAGES of coping with Complexness, con't.

- Age ≈12 simultaneous equations.
  - ✓ 2X = 4Y, X+Y = 3
- Technique: Isolate a variable in one of the equations then substitute in the other equations.
  - ✓ X = 3-Y, 6-2Y=4Y, 6=6Y, Y=1, X=2
- Key: Which variable and equation simplifies the whole set of equations.

Feynman's CPU
circa 1940

stAGES of coping with Complexness, con't.

- Age ≈13 algebra (complex expressions) taught us about transforms. Viewing a problem set from a different perspective often made the discovery of a solution much easier --- if you could do the inverse transform at the end.
- In the 1960's System Dynamics highlighted a) influences or causalities between variables, b) patterns of such relationships and c) the effect of time delays on the relationships.

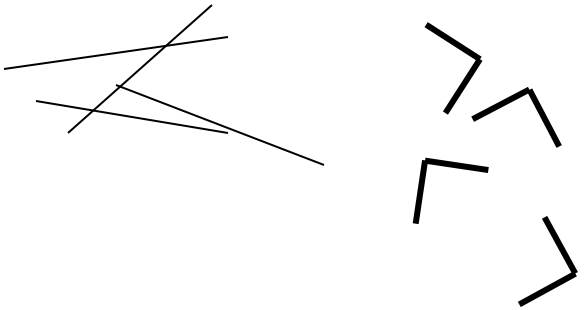
stAGES of coping with Complexness, con't.

- Second order implicit differential equations help deal with the rate of change of stimuli, resources, system gradients and system structure.
- Bayesian Belief Networks aided by genetic algorithms as goal-seeking agents.
- Category theory in the field of mathematics?
- Constraint theory and calculus of sets?
- How to characterize the degree of complexity of any given set of equations?

What clues do these give for devising complex adaptive systems for intervention of non-deterministic problematic situations?

We Do Not Recognize Patterns, We Use Rulesets to Qualify Meaningful Compositions

We Perceive Elements



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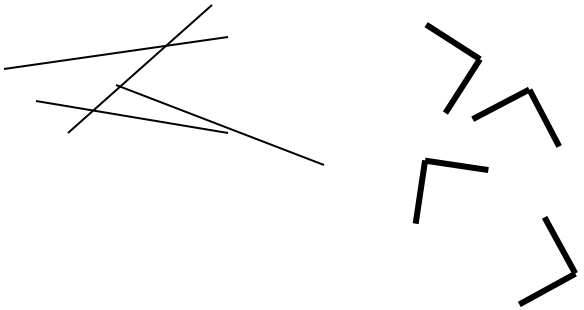
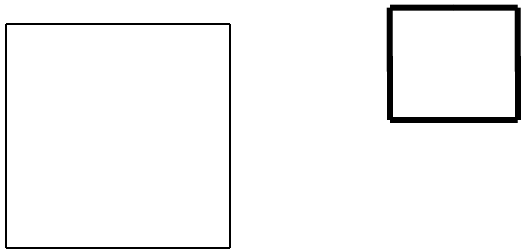


We find which *a priori* rule set they fulfill



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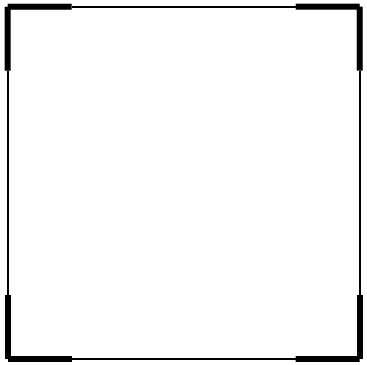

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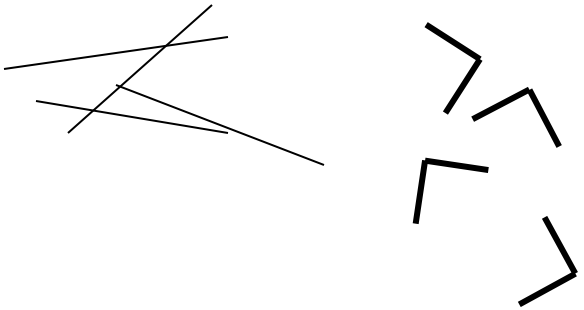

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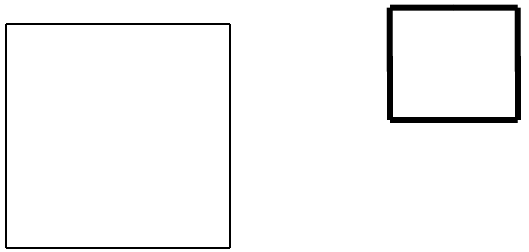

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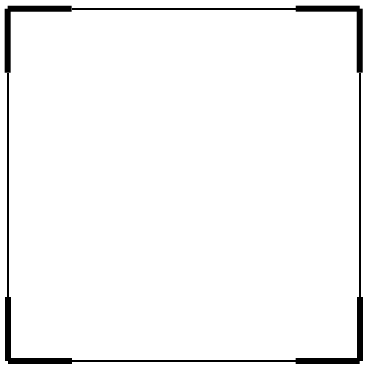
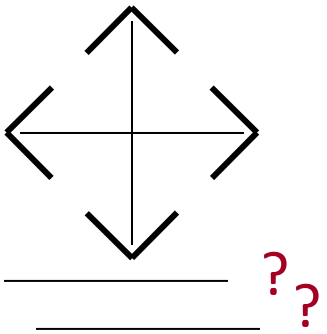
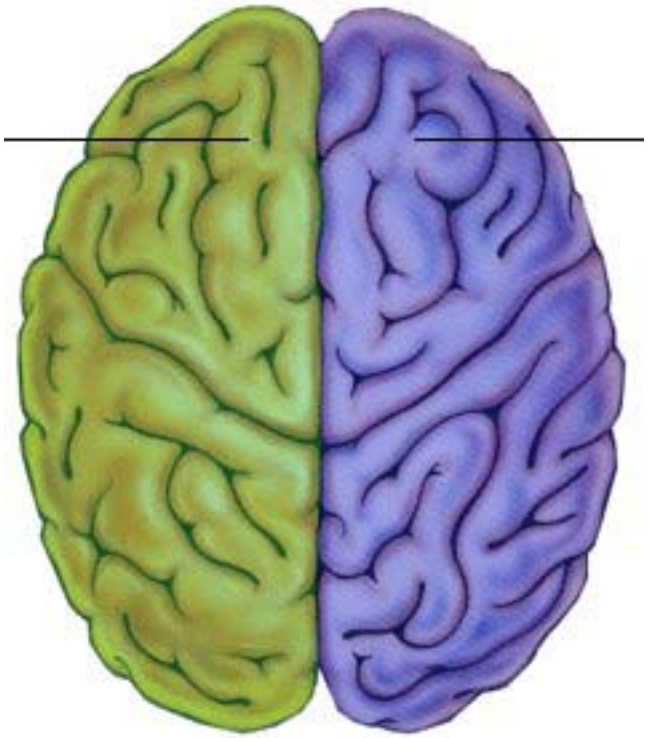


And we reject some



Unless 6 of 8 is sufficient.

Got Rule Sets?



Operands
Vocabulary

An apparently
Infinite stack

Operators
Rules

An apparently
Infinite web of
relations

Language and Human Behavior, 1995, Bickerton Derek, U. of Washington Press

The coming era of Computer-aided ~~Design~~ Discovery

- Mankind is capable of multiple kinds of thinking.
- To date our digital aids have encouraged mostly linear, hierarchical mental models.
- New devices are revolutionizing the design process.

Deterministic → Nondeterministic → Autonomous

Making sense of a variety of symbols

Addressing the Critical Need for "New Ways of Thinking" in Managing Complex Issues in a Socially Responsible Way
Prof. Ockie Bosch, et al, 2013

Social Networks, Values Networks, Wisdom of Crowds, Prediction Markets.

Agenda

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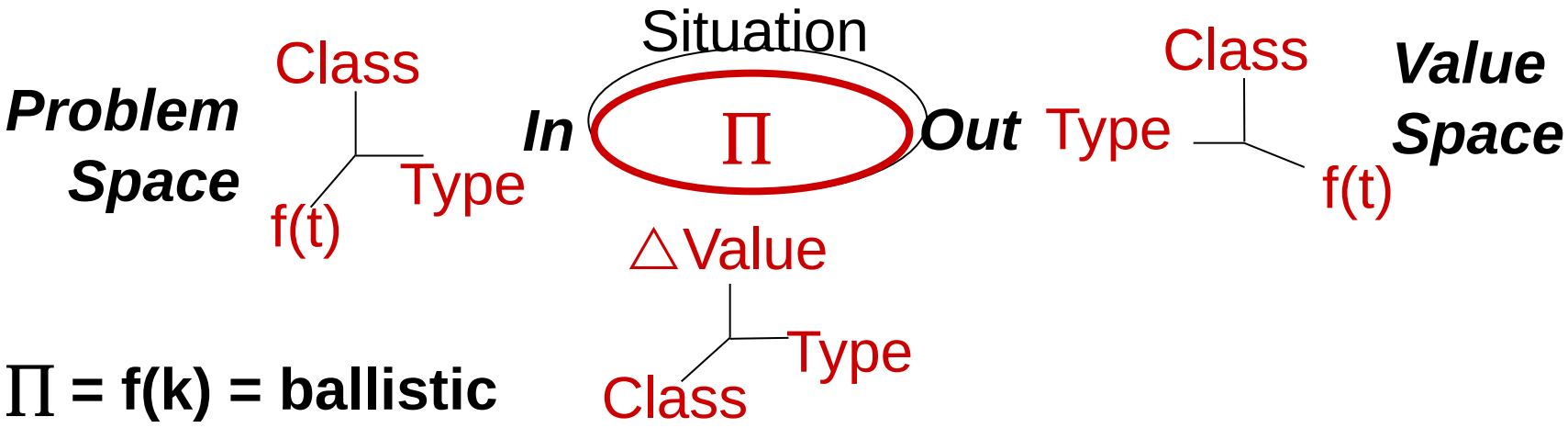
Categories of Adaptive



Π = f(k) = ballistic

Π = f(Out) = governor

Π = f(In) = anticipatory

Π = f(Sit, Out) = homeostatic

Π = f(Value Space) = goal-seeking

Π = f(Problem Space) = self-organizing

Π = f(Problem, Value) = autopoietic

Π = f(all) = autocatalytic

Π = System Transfer Function

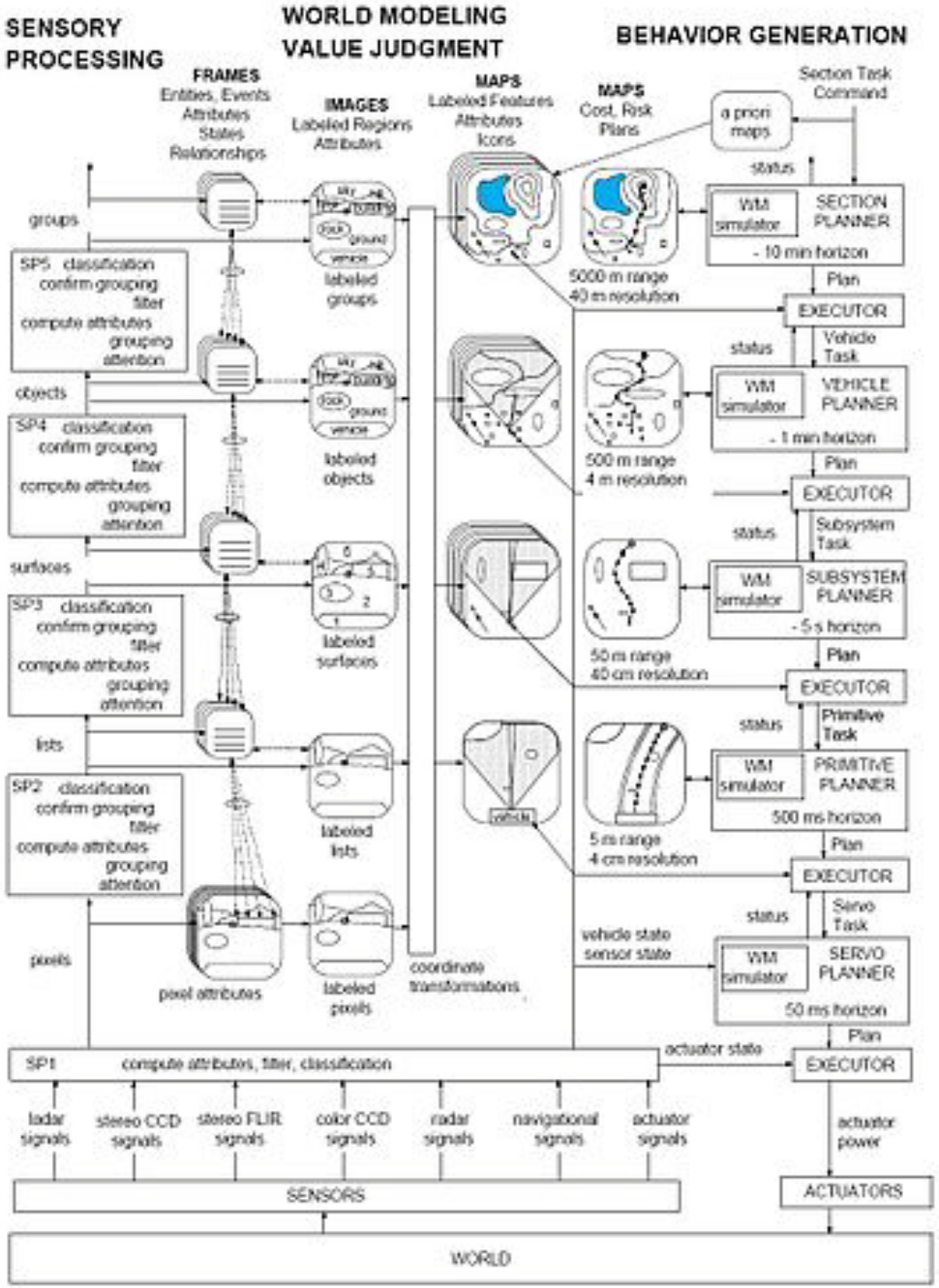
Autonomy Levels for Unmanned Systems Framework, ALFUS

Mission Complexity

Unmanned System

Environmental Complexity

Human Independence (Autonomy Level)



Each Person A Mobius: Janusian Thinking

Domain Distinctions = MOE's

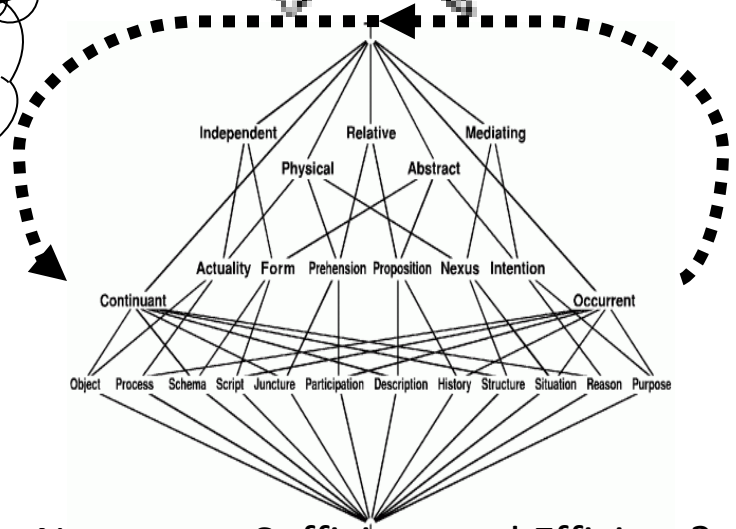
The Problem Is ---

The System will be acceptable when ---

Problem Symptoms

Problem System

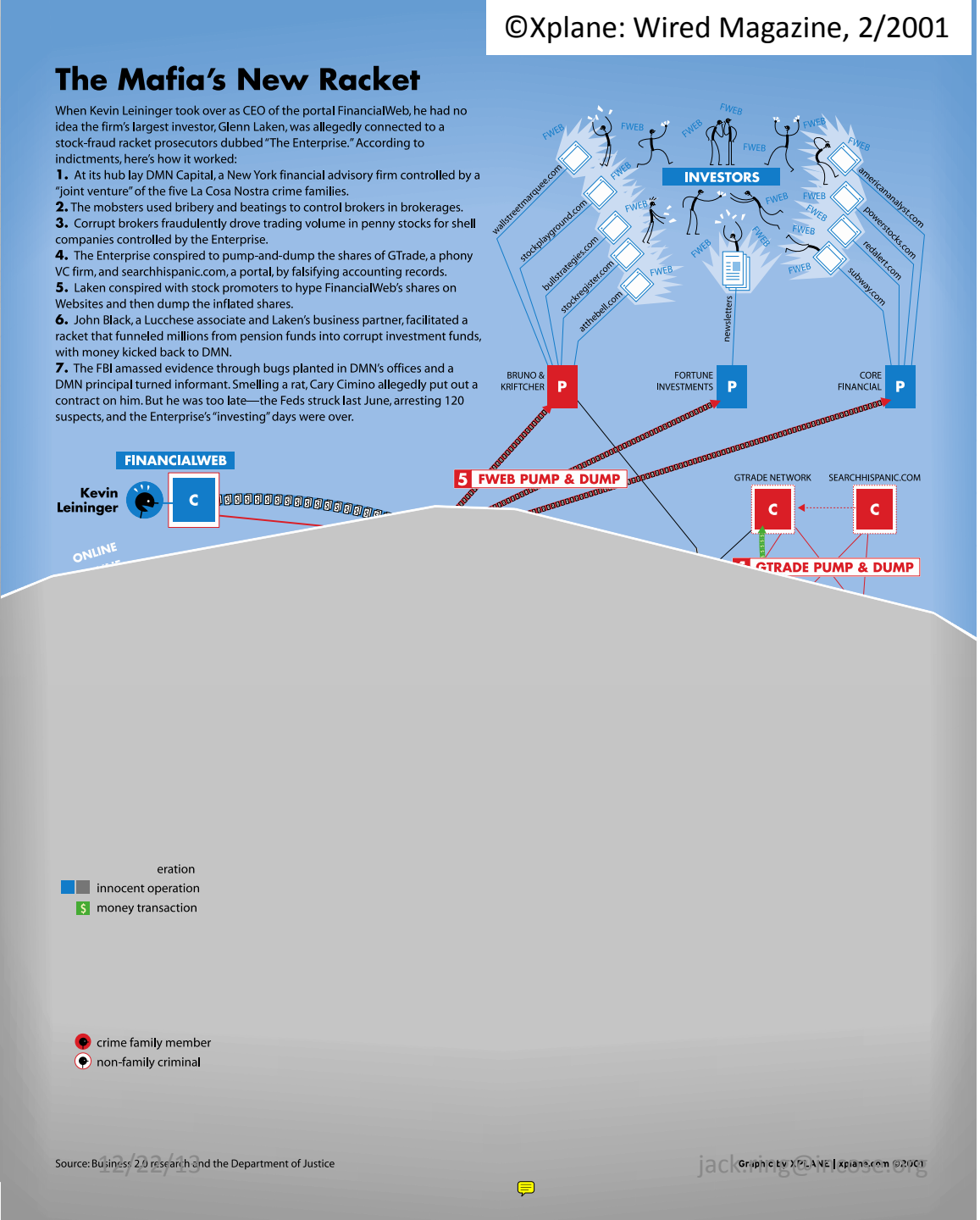
Solution Concept



Necessary, Sufficient and Efficient?

Self-Aware Systemists

©Xplane: Wired Magazine, 2/2001



Start with the end in mind.

As Is (see graphic)
May become, grow
May become, morph

State-determined
Ergodic
Non-deterministic

Stakeholder Perspective
- Significance
- Urgency
- Intent
- Concerns

Oh, Really? Then what?

- A system is marked by what it DOES, KNOWS and IS.
- One or more of these change with every stimulus:response transaction.
- We must design an Intervention system not only for the Problem system that prompted it but also for the next version of the Problem system that the Intervention system will cause when it is activated.
- And we must design the intervention system to coherently evolve after each operation.

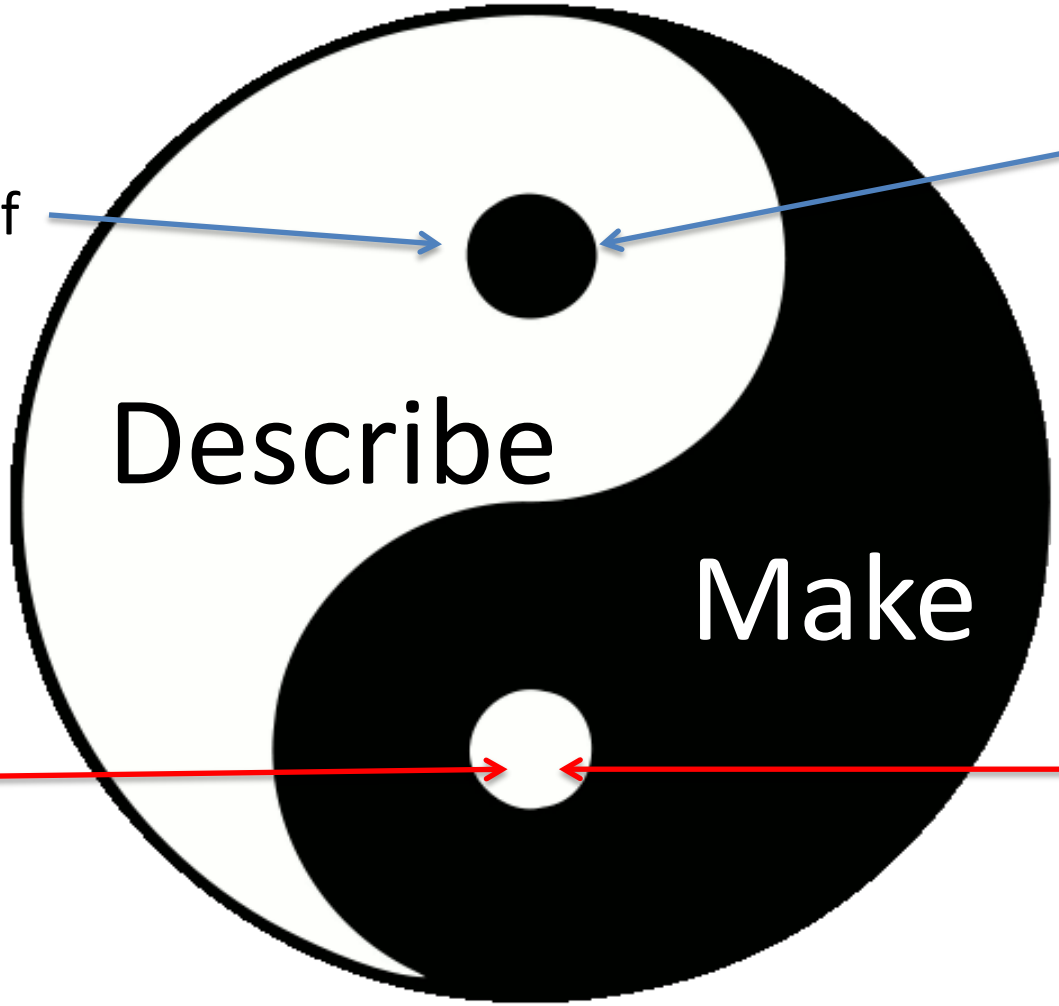
Design, Develop, V&V and T&E THAT!

Systems of the Third Kind, INCOSE INSIGHT Vol. 15, Issue 2, July 12, 2012

The Arrangement of Both that Excels

Methods and tools for assessment of intervention concepts.

Is the theory consistent with realization capabilities?



Quality, Parsimony, Beauty!

>

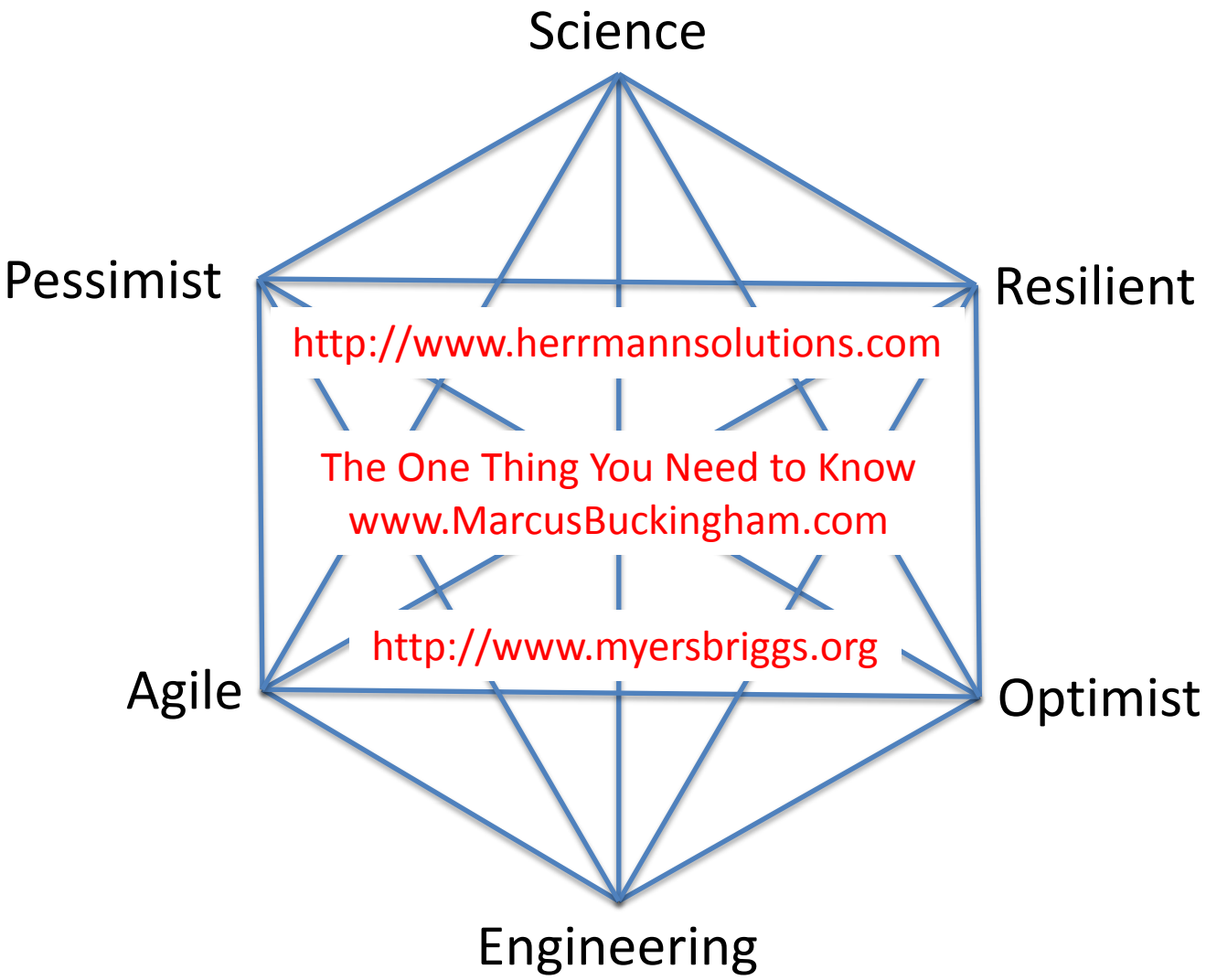
Extent, Variety, Ambiguity?

IV&V/T&E

Oh, Really!

Then what?

Navigating Toward Your Personal Best



Questions? Comments?