On Principles of Complex Systems Engineering – B. E. White, Ph.D.

Complex Systems Made Simple Tutorial
22 October 2012

Search for the simplicity beyond (or within) the complexity

Proposed Agenda

Begin at 1:00 p.m.
Agenda (2 min)
Video 1: How complexity leads to simplicity (8 min)
Introduction
- What are we going to talk about? (2 min)
- What do you want to get out of today? (5 min)

Terminology (12 min)
Relationships (8 min)
Complex Systems (CS) (10 min)
Systems Engineering (SE) (4 min)
Key Ideas (16 min)
- Enterprise Systems Engineering (ESE) Profiler

What's the Problem? (4 min)
How Might We Do Better? (20 min)
Complex Adaptive Systems Engineering (CASE) (22 min)
Afternoon Break (30 min) 2:45 p.m. – 3:15 p.m.
SE Life Cycle (18 min) (unless there's more time)
- SE Activity (SEA) Profiler

Complexity (42 min)
- CS Behaviors (unless there's more time)

Video 2: How complexity leads to simplicity (8 min)
- Complex SE (CSE) Principles (unless there's more time)

Leadership (14 min)
Decision Making (24 min)
Wrap-Up (5 min)
End at 5:00 p.m.
References
Acronyms

Opening Video

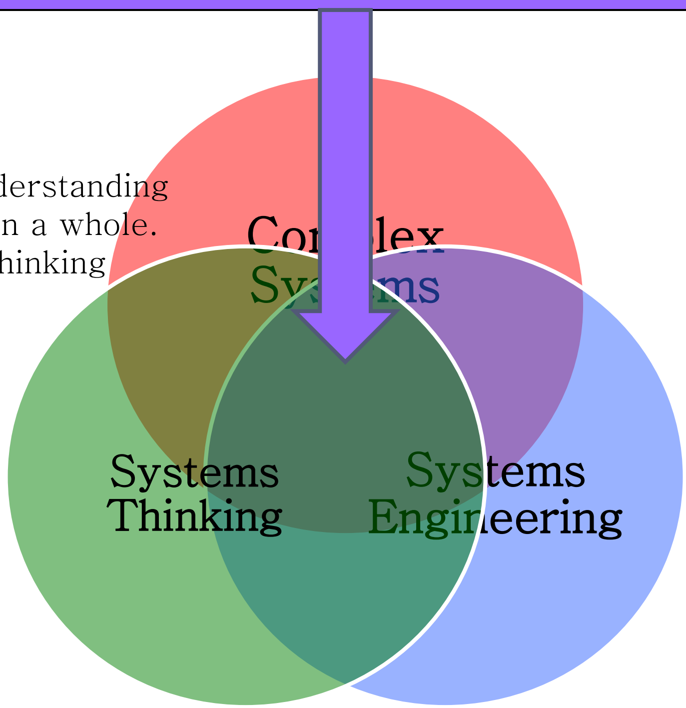
- "Eric Berlow: How complexity leads to simplicity" on YouTube
  - *Start up* from Computer → Desktop → Videos
  - What do you think?
  - http://www.youtube.com/watch?feature=youtube_gdata_player&v=UB2iYzKeej8*
    - Includes blogs of mixed (but mostly negative) reactions of viewers
    - You might wish to watch this again after today's tutorial

* Suggested by Beverly Gay McCarter, 17 Nov 10)

What Are We Going to Talk About?

Complex Systems ∩ **Systems Thinking** ∩ **Systems Engineering** =

Complex Systems Engineering



Systems Thinking is the process of understanding how things influence one another within a whole. http://en.wikipedia.org/wiki/Systems_thinking

(Various authors 2007)

What Do You Want to Get Out of Today?

- *Record* on Flip Chart(s)

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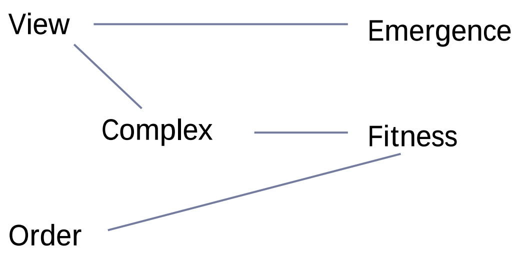
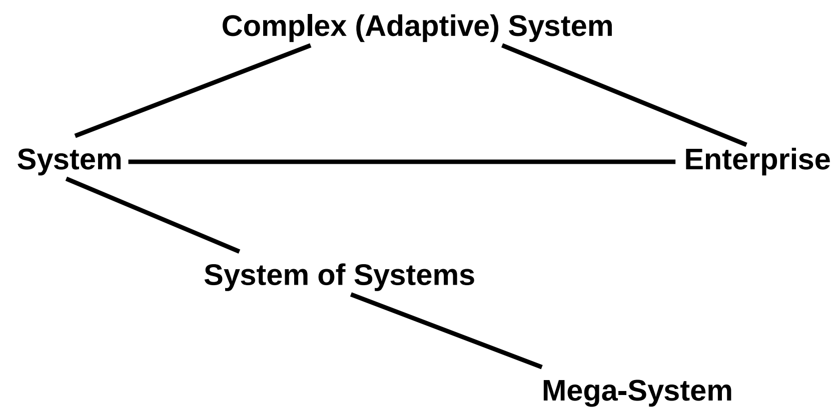
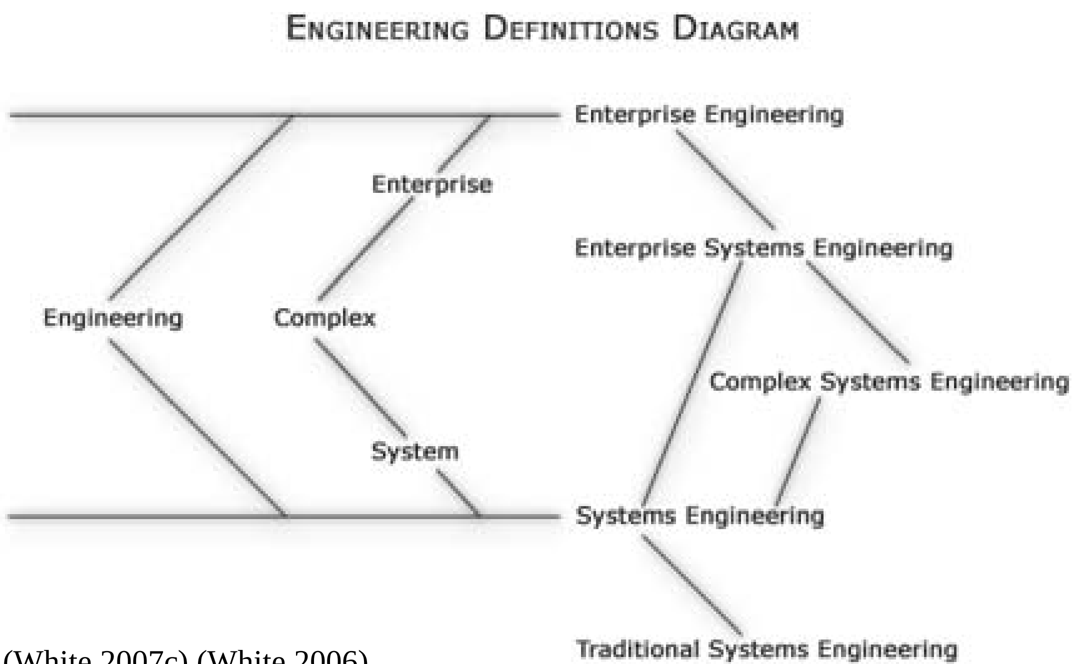
Some Definition Dependencies

Complexity Definitions



System Definitions Diagram





(White 2007c) (White 2006)

See Notes Page

Complexity Terms: View, Complexity, Order, Fitness, and Emergence

- View: A human conceptualization consisting of scope, granularity, mindset, and timeframe
- Complex: Description of the ultimate richness of an entity that
  - Continuously evolves dynamically through self-organization of internal relationships
  - Requires multi-view analysis to perceive different non-repeating patterns of its behavior
  - Defies methods of pre-specification, prediction, and control
    - *Note*: Complexity as really a continuum extending from its lowest degree, complication, say, to its higher degree, intended here.
- Order: A qualitative measure of the instantaneous nature and extent of all specific internal relationships of an entity.
  - *Notes*: If something has only a few relationships, i.e., patterns of attributes defined by values, it has a small order.
- Fitness: The orthogonal combination of complexity and order.
  - *Note*: Both aspects of fitness (order: what currently is; complexity: what could be) are a part of perceiving an entity.
- Emergence: Something *unexpected* in the collective behavior of an entity within its environment, not attributable to any subset of its parts, that is present (and observed) in a given view and not present (or observed) in any other view.
  - *Notes*: Some people employ a broader definition where things that emerge can be *expected* as well as unexpected. Emergence can have benefits *or consequences*.

(White 2007c) (White 2006)

See Notes Page

System Terms: System, SoS and Megasystem

- System: An interacting mix of elements forming an intended whole greater than the sum of its parts.
  - *Features:* These elements may include people, cultures, organizations, policies, services, techniques, technologies, information/data, facilities, products, procedures, processes, and other human-made (or natural) entities. The whole is sufficiently cohesive to have an identity distinct from its environment.
- System of Systems (SoS): A collection of systems that functions to achieve a purpose not generally achievable by the individual systems acting independently.
  - *Features:* Each system can operate independently (in the same environment as the SoS) and is managed primarily to accomplish its own separate purpose.

(White 2006)

- Megasystem [or Mega-System]: A large, man-made, richly interconnected and increasingly

See Notes Page

System Terms (Concluded): Complex System, CAS, and Enterprise

- Complex System: An open system with continually cooperating and competing elements.
  - *Features:* Continually evolves and changes according to its own condition and external environment. Relationships among its elements are difficult to describe, understand, predict, manage, control, design, and/or change.
    - *Notes:* Here "open" means free, unobstructed by artificial means, and with unlimited participation by autonomous agents and interactions with the system's environment.
- Complex Adaptive System (CAS): Identical to a complex system.
- Enterprise: A complex system in a shared human endeavor that can exhibit relatively stable equilibria or behaviors (homeostasis) among many interdependent component systems.
  - *Feature:* An enterprise may be embedded in a more inclusive complex system.

(White 2006)

Engineering Terms: Engineering, Enterprise Engineering, and SE

- Engineering: Methodically conceiving and implementing viable solutions to existing problems.
- Enterprise Engineering: Application of engineering efforts to an enterprise with emphasis on enhancing capabilities of the whole while attempting to better understand the relationships and interactive effects among the components of the enterprise and with its environment.
- Systems Engineering: An iterative and interdisciplinary management and development process that defines and transforms requirements into an operational system.
  - *Features:* Typically, this process involves environmental, economic, political, social, and other non-technological aspects. Activities include conceiving, researching, architecting, utilizing, designing, developing, fabricating, producing, integrating, testing, deploying, operating, sustaining, and retiring system elements.

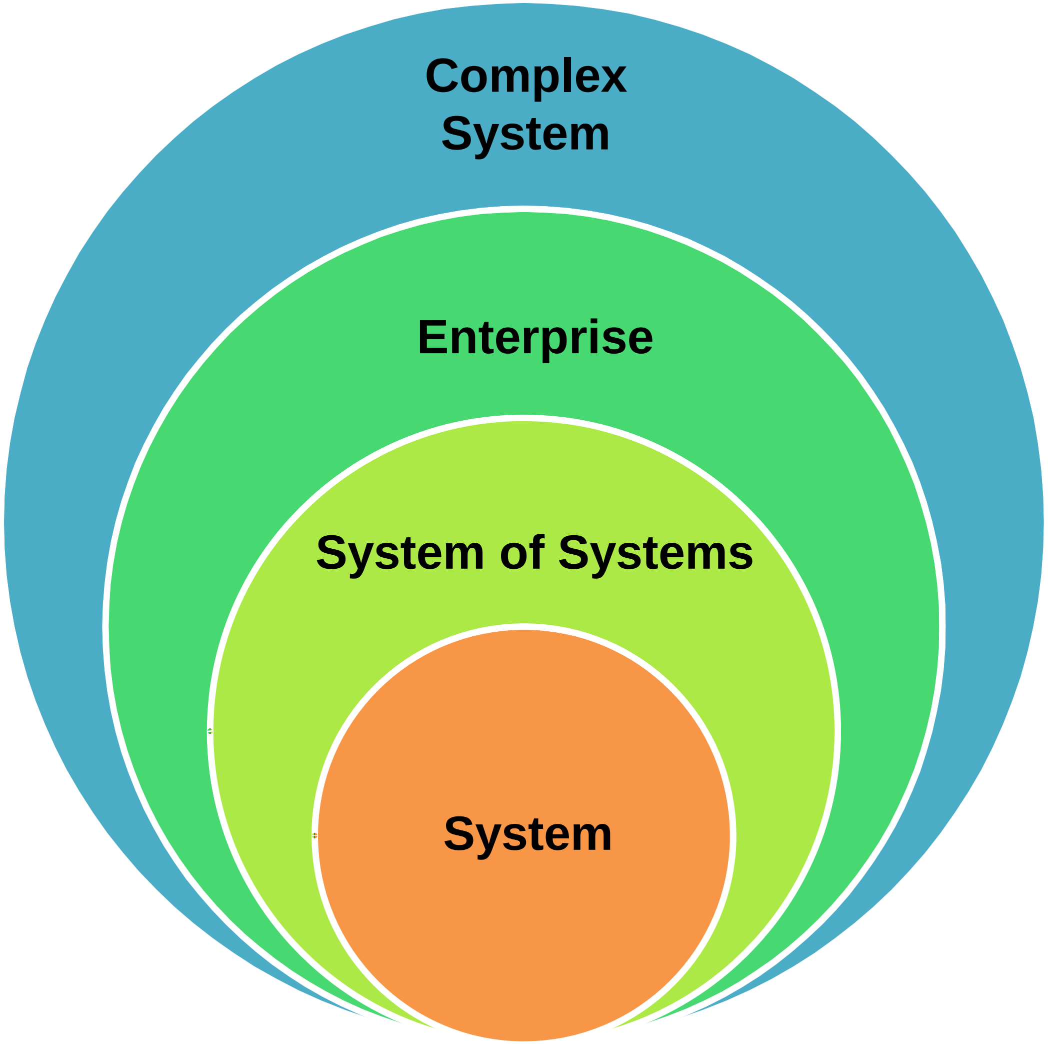
(White 2006)

Engineering Terms (Concluded): TSE, ESE, and CSE

- Traditional Systems Engineering (TSE): Systems engineering but with limited attention to the non-technological and/or complex system aspects of the system.
  - *Feature:* In TSE there is emphasis on the process of selecting and synthesizing the application of the appropriate scientific and technical knowledge in order to translate system requirements into a system design.
- Enterprise Systems Engineering (ESE): A regimen for engineering "successful" enterprises.
  - *Feature:* Rather than focusing on parts of the enterprise, the enterprise systems engineer concentrates on the enterprise as a whole and how its design, as applied, interacts with its environment.
- Complex Systems Engineering (CSE): ESE that includes additional conscious attempts to further open an enterprise to create a less stable equilibrium among its interdependent component systems.
  - *Feature:* The deliberate and accelerated management of the natural processes that shape the development of complex

(White 2006)

A Nested View of System Classes



5 Ways to Describe TSE - ESE Relationships

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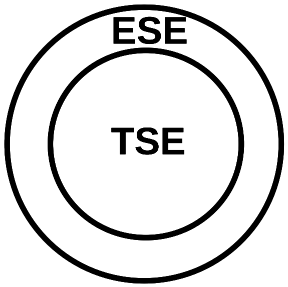
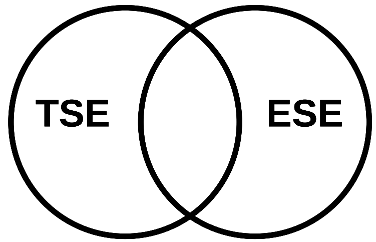


ESE extends TSE

One can extend TSE methods to achieve ESE

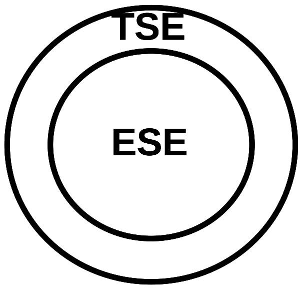
Case I



ESE is complementary to TSE

ESE involves something in addition to TSE, and some TSE methods do not apply

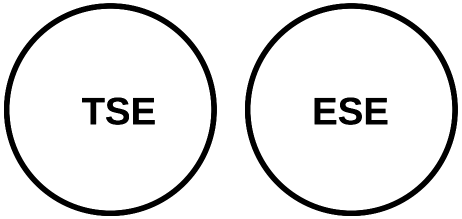
Case II



TSE includes ESE

ESE is nothing really new

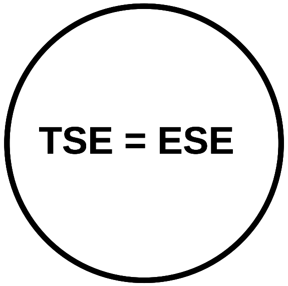
Case III



ESE and TSE are disjoint

ESE is completely different than TSE

Case IV



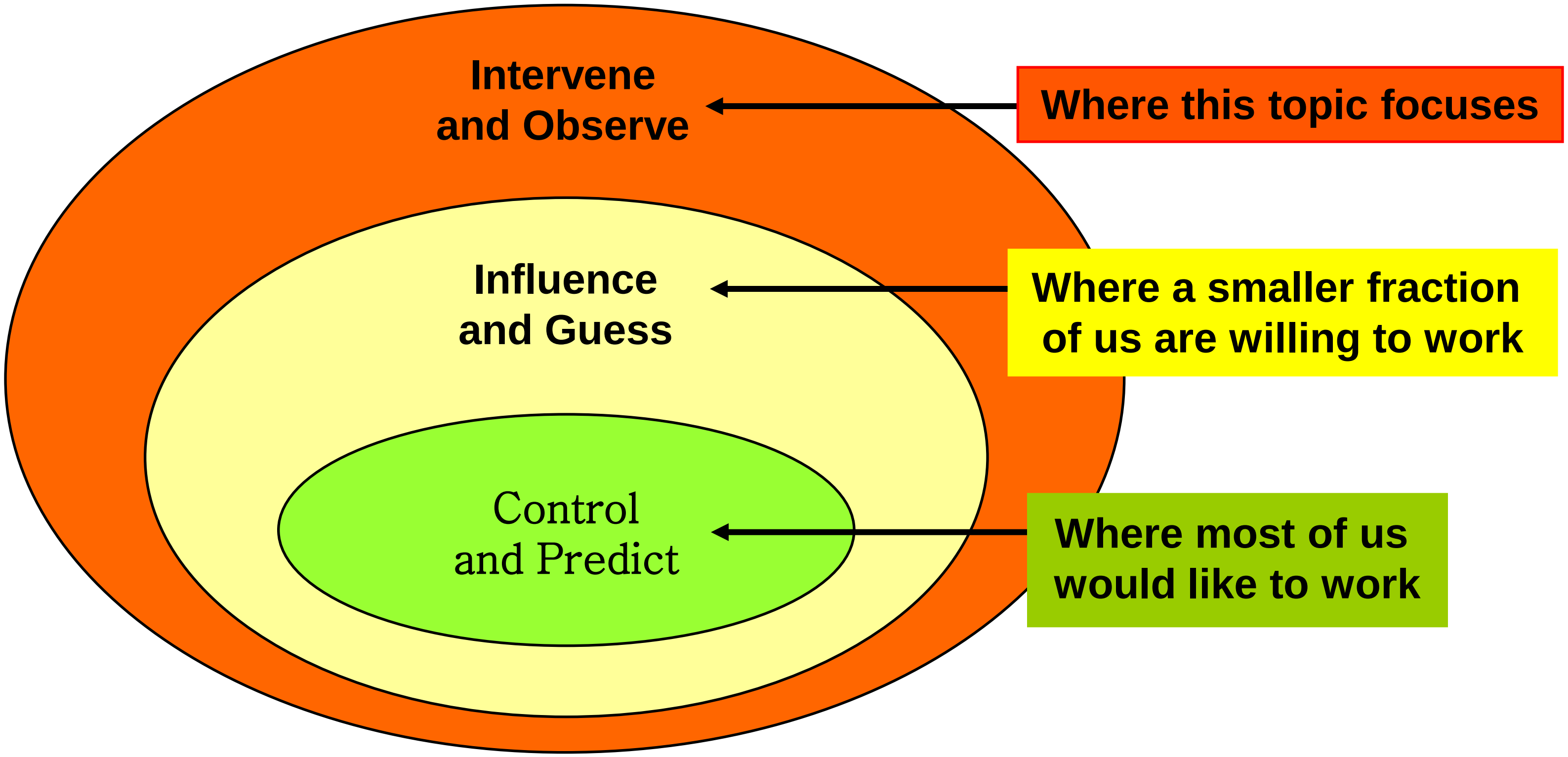
ESE is identical to TSE

Systems Engineering is SE

Case V

(White 2006b)

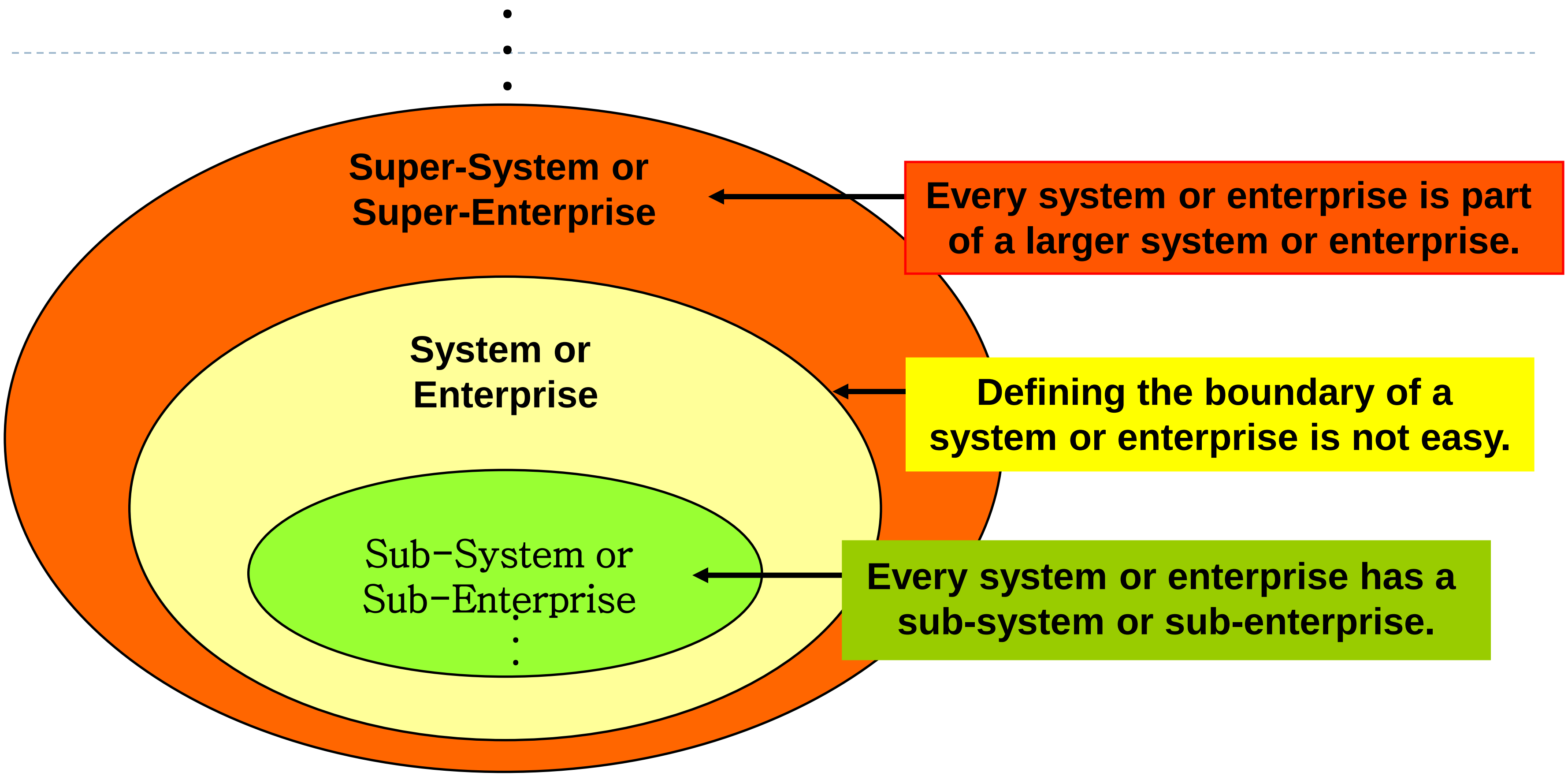
Context of This Discussion



After (Gharajedaghi 2005, p. 31)

(White 2005)

Systems and Enterprises Can Be Nested – and Changing Their Boundaries Can Be Illuminating



Some feel that no matter at what scale one is, in this nested structure, the same known SE techniques can be applied to effect good results.
Others say, no, depending on the scale in question, some radically different SE techniques may be needed.

(White 2005)

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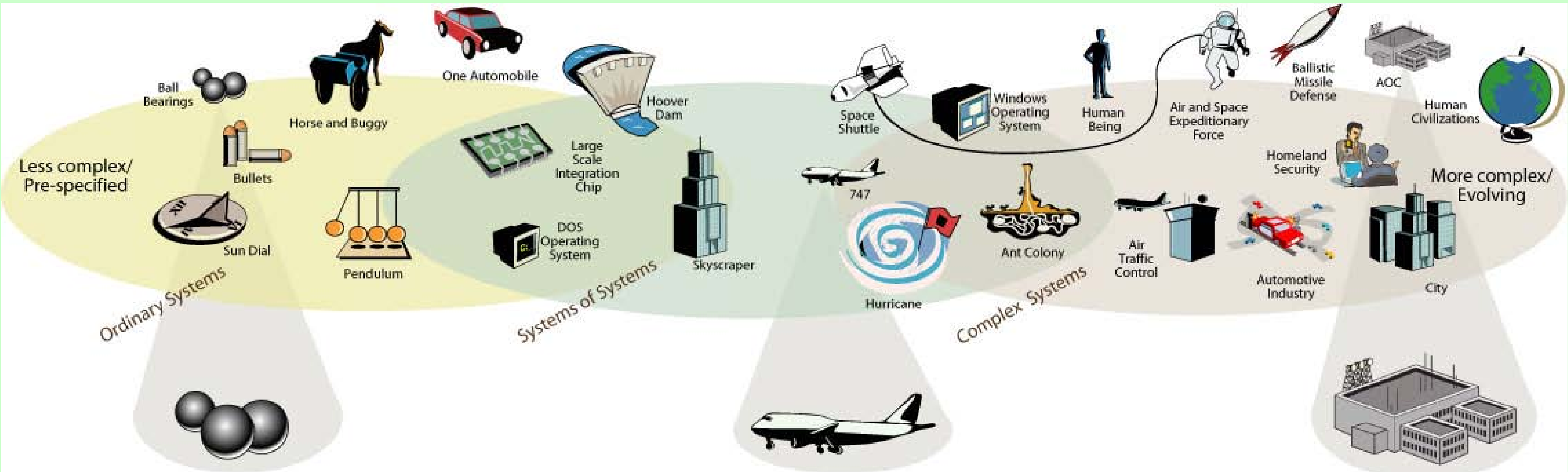
A Spectrum of Systems

System: An instance of a set of degrees of freedom* having relationships with one another sufficiently cohesive to distinguish the system from its environment.**

*Normally grouped into subsets or elements **This cohesion is also called system identity



Less complex Pre-specified ◄·····► ***More complex Evolving***

(Kuras-White 2005)

(White 2005)

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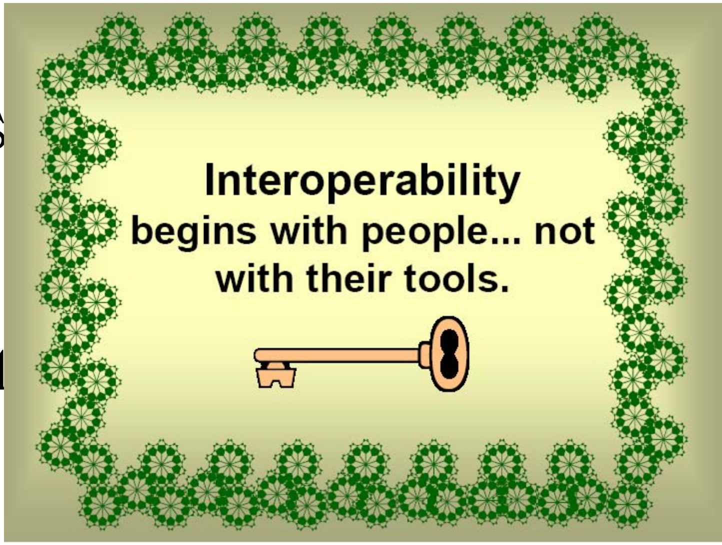
Complex Systems

- Complex systems is a well established and highly interdisciplinary field of study. It includes
the following sub-disciplines
  - Agent-Based Modeling
  - Evolutionary computation
  - Mathematical tools and techniq
    Game theory, Power-laws, Highly Optimized Tolerance (HOT), Chaos theory, Multi-Scale analysis, …
  - Scientific and industrial applications
- Complex systems have been studied primarily in academia—although there are increasingly many real-life applications.



(Various authors 2007)

Distinguishing Attributes of Two Classes of Systems

Complex-systems	Non-complex systems
Unique	Identical and reproducible
Development and operation concurrent and continuous	Development and operations are separate and distinct
Emergence: development and operation at multiple scales	One predominant scale amenable to reductionist analysis and synthesis
Stochastic, unpredictable	Predictable at its predominant scale
Always open	Treatable as closed or with completely specified inputs
Learning and memory of prior history alters behavior	Repeatable transients
Requires both cooperation and competition to function effectively	Competition (for resources), friction and so forth reduce effectiveness

(White 2005)

Source: Mike Kuras 2005

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Distinguishing Attributes of Two Classes of Systems (Concluded)

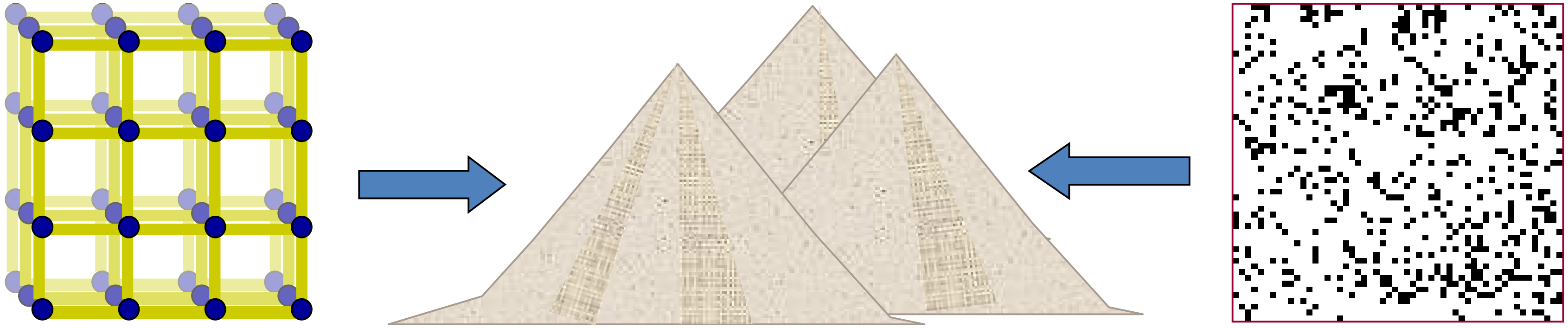
Complex-systems	Non-complex systems
Robust and broadly inefficient	Can be optimized and made efficient
Ambiguous and shifting boundaries	Well-defined, distinct boundaries at its predominant
Exp[illegible] possibilities	[illegible]vely removes *unwanted* possibilities
Self-integrating and re-integrating	Integrated by external agents in one or more configurations
Dominated by transient and short-range relationships	Dominated by uniform and permanent relationships
Can exhibit relational networks at O(n), O(n^2), and O($\sim 2^n$)	Can exhibit relational networks at O(n) and O(n^2)
Hierarchies are partial and transient	Hierarchies are important, extensive, and durable

Assertion: Complex-systems can only be engineered by intervention, not by specification and then development.

(White 2005)

Source: Mike Kuras 2005

Complex adaptive systems adapt toward edge of chaos



Order	Complexity	Chaos
Mechanical systems	Biological systems	Many domains
Newtonian laws	Fractals	Laws of chaos
Bell curves	Power Laws	Strange Attractors
Plans	Priorities	Reactions
Environment stays same	Environment Evolves	Environment unusable
Predictability	Adaptation	Flexibility
Control	Leverage	Variety
High overhead	Agility	Low overhead
Little communication	Critical Point	Instability

Source: Sarah A. Sheard, Principal, 3rd Millennium Systems LLC. 2008; used with her permission

Systems Engineering

- Systems engineering, understood broadly, plays a role in
  - Policy analysis and planning
  - Capability assessment and needs determination
  - Requirements, architecture, design, development, deployment, operational insertion
  - Operation, maintenance, enhancement, evolution, re-purposing, and end-of-life transitioning.
- Systems engineering has been primarily a practitioner/program-manager discipline, consisting mainly of best practices—although it has begun to establish itself academically.

(Various authors 2007)

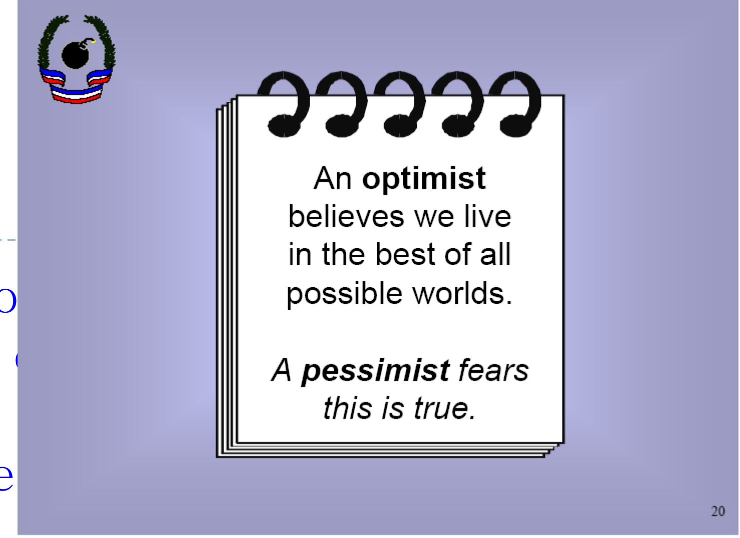
The Communities Are Still Distinct

- So far, most work in the intersection of complex systems (CS) and systems engineering (SE) has been at the application level.
- A formal coupling between the fields has not yet been formally and clearly established.*
- However, BKCASE, SEBOK, and GRCSE ("Gracie") are changing that (http://www.bkcase.org/)
- CS and SE have a lot to offer each other and are coming together.
  - Academic: MIT's Engineering Systems Division (ESD), Stevens Institute of Technology, USC, Old Dominion University, Johns Hopkins, Universities of Illinois, Vermont, and Virginia, …
  - FFRDCs: MITRE, RAND, Aerospace, …
  - Conferences: CAS, CSER, SoSE, IEEE Systems, INCOSE, Australia, Europe, …

* INCOSE has been struggling with defining and relating complexity, systems science, and complex and enterprise systems engineering for years, e.g., engage with the following Working Groups: Complex Systems www.incose.org/practice/techactivities/wg/complex/; Systems Science www.incose.org/practice/techactivities/wg/syssciwg/

(Various authors 2007)

Big Ideas



- Complex systems abound
  - Mega-projects in transportation, the enviro
    U.S. DoD's Global Information Grid (GIG),
  - Internet culture—
    massive connectivity and interdependence
- Complexity theory applies
  - Much activity in complexity science across many fields
  - University interest in developing ideas for engineering (MIT, Johns Hopkins, UCSD, USC, Stevens, UVM, U of I, Old Dominion)
- Complexity is embedded in everyday knowledge
  - The Gardener metaphor (vs. The Watchmaker)
  - Biology and natural evolutionary processes
  - The way we think, our language/semantics
  - Markets (viz., *The Wisdom of Crowds, The Black Swan*)
- Traditional Systems Engineering (TSE) methods may not help
  - But temptation is strong to keep trying them
- One can dependably, but not predictably, build complex systems
  - Using systems thinking and Complex Systems Engineering (CSE)

(DeRosa 2006)

(White 2008a)

Enterprise Systems Engineering (ESE) Profiler

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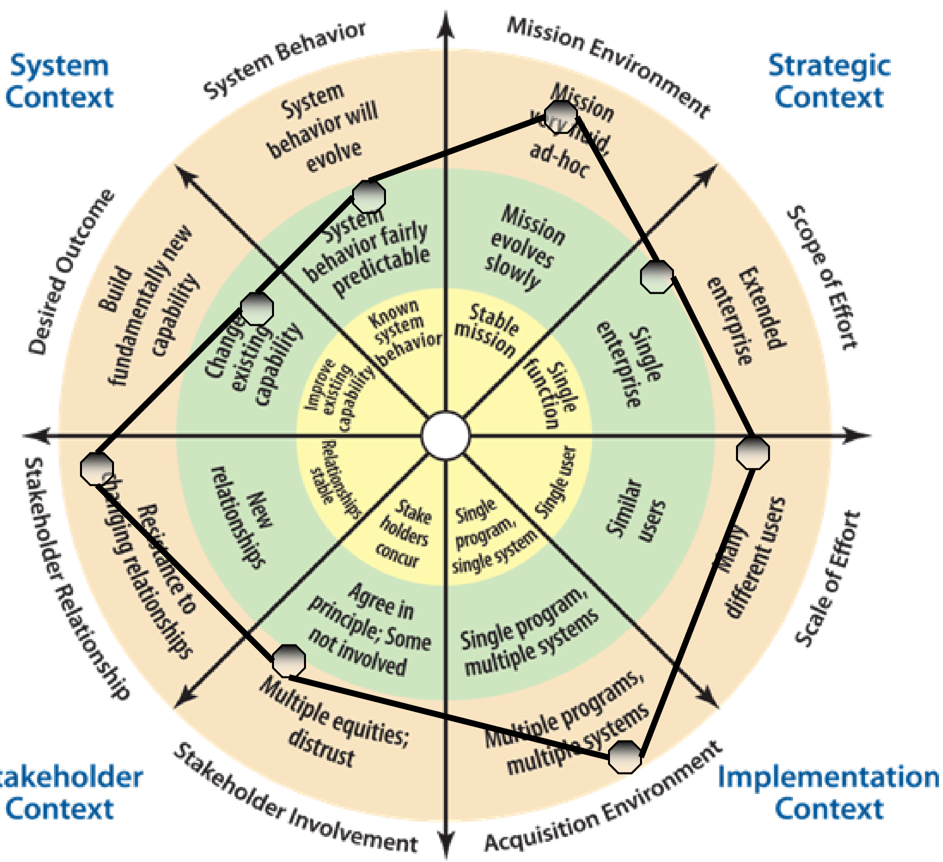


- Traditional program domain
  - *Well-bounded problem*
  - *Predictable behavior*
  - *Stable environment*
- Transitional domain
  - *Systems engineering across boundaries*
  - *Influence vs. authority*
- Messy frontier
  - *Political engineering (power, control…)*
  - *High risk, potentially high reward*
  - *Foster cooperative behavior*

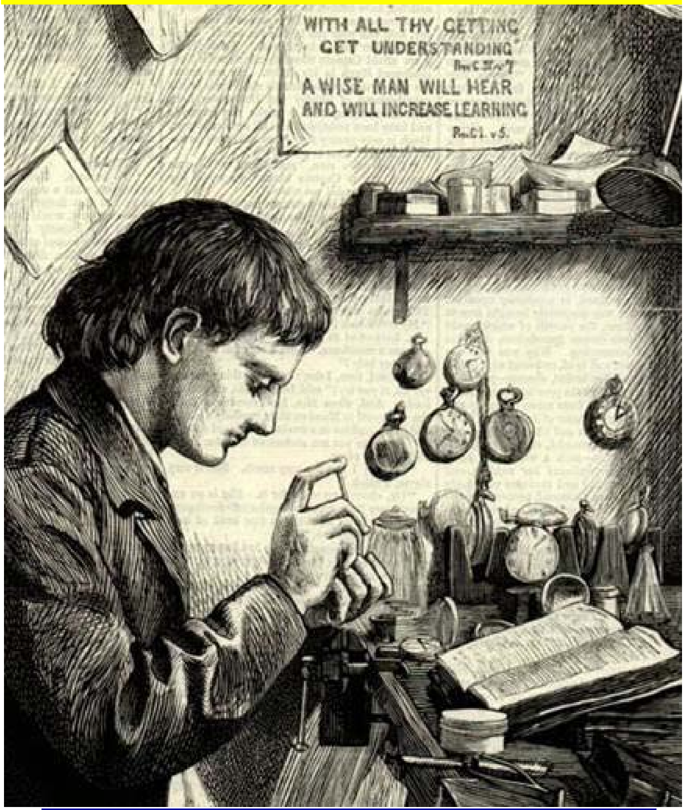
(Stevens 2008)

(White 2008a)

From Control to Intervention

Traditional Systems Engineering | Enterprise Systems Engineering

The Watchmaker: Everything has its place.



Static: As Is – To Be Views
Passive: One Design Choice
Uniform: All Parts Are Equal

The Gardener: Plant, Fertilize, Weed; Repeat.

Dynamic: Constant Change
Competitive: Crops compete
Scale Free: 80-20 Rule

(DeRosa 2007)

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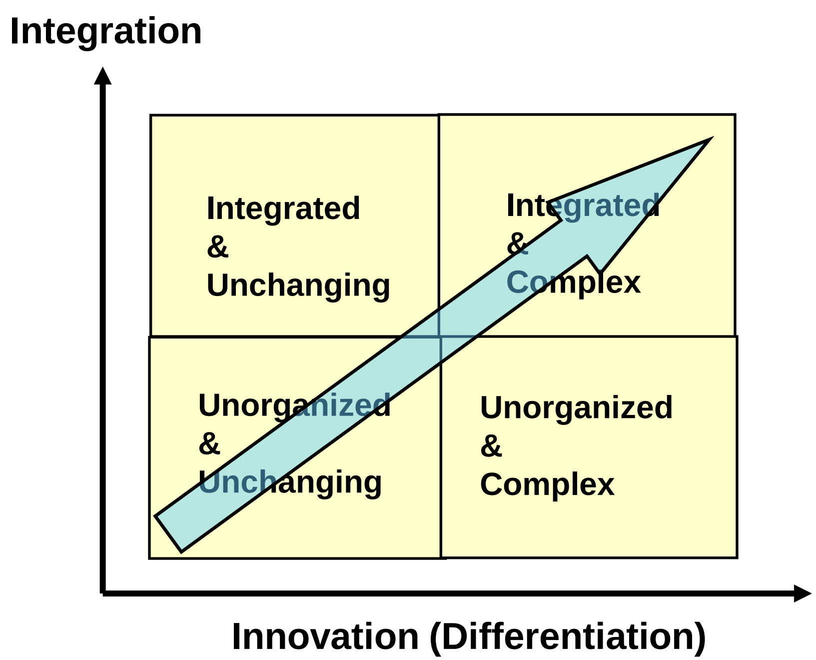
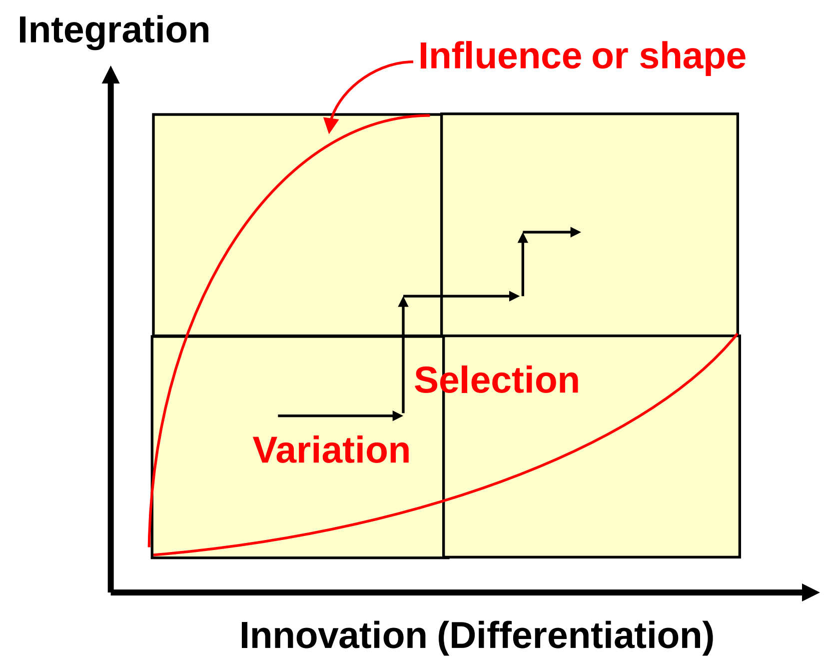
Increasing Complexity by Iterative Variation and Selection Techniques; SE Process Moving to ESE





A "realized" enterprise re-invents itself through a process of continual innovation and integration.*

The ESE process must shape the integration and innovation environment.**

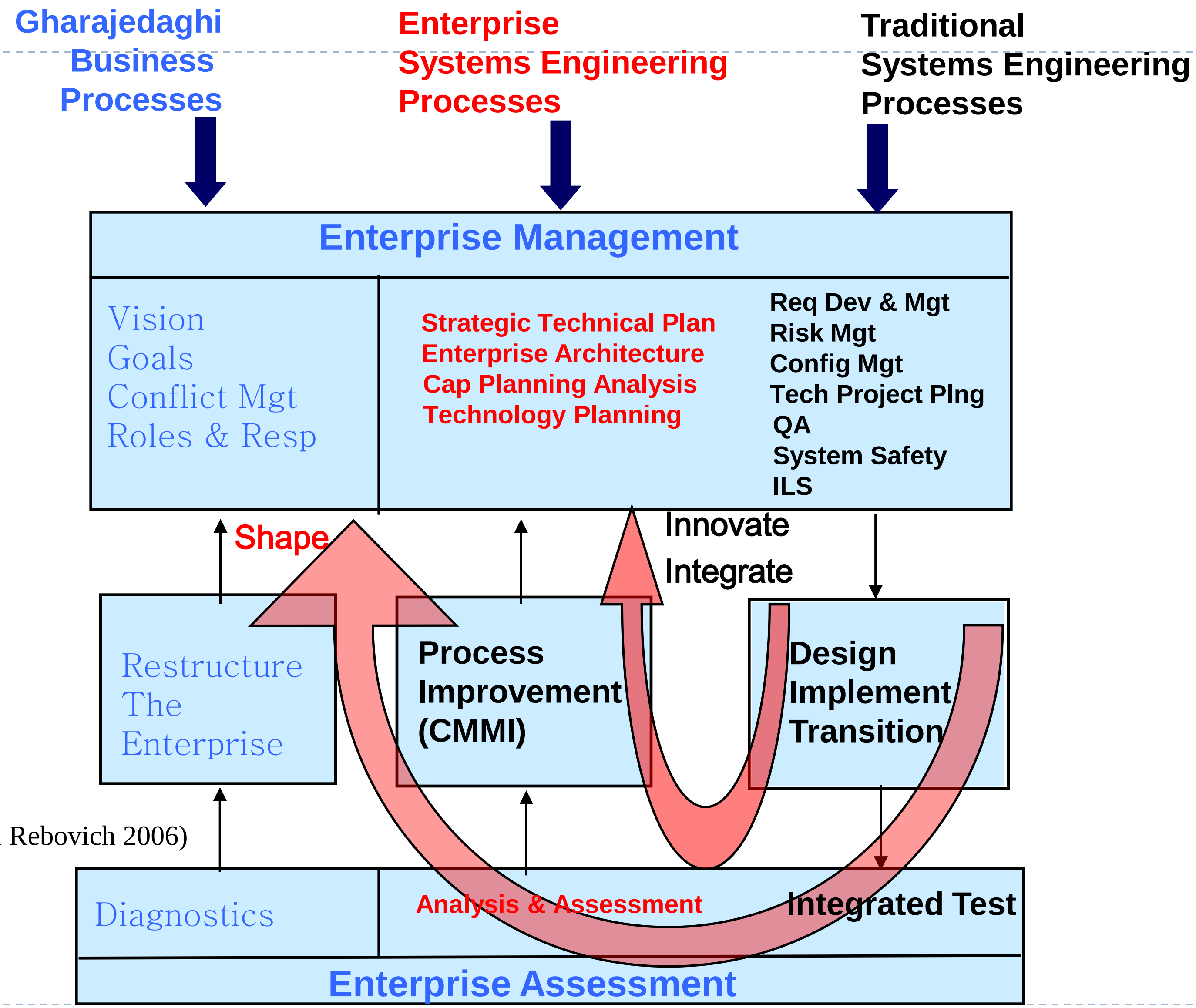
* After (Gharajedaghi 1999 and 2005)

** After (Axelrod and Cohen 2000)

(DeRosa 2006)

(White 2008a) (McCarter and White 2007)

ESE Processes in Context



(DeRosa 2006)

(DeRosa 2005a)

(Swarz, DeRosa, and Rebovich 2006)

(White 2008a)

Architecture-based Enterprise Systems Engineering (AESE)

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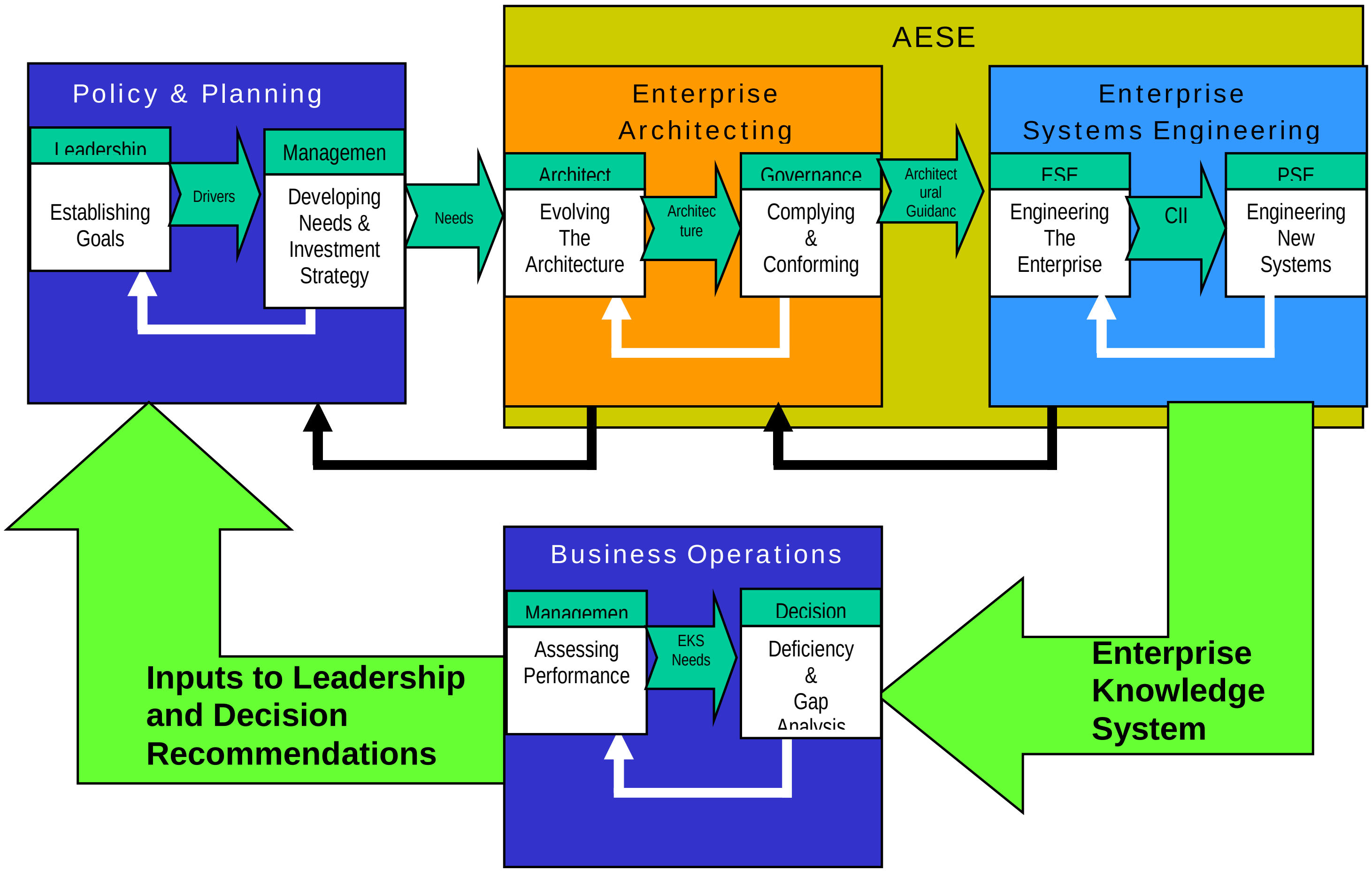
The Enterprise



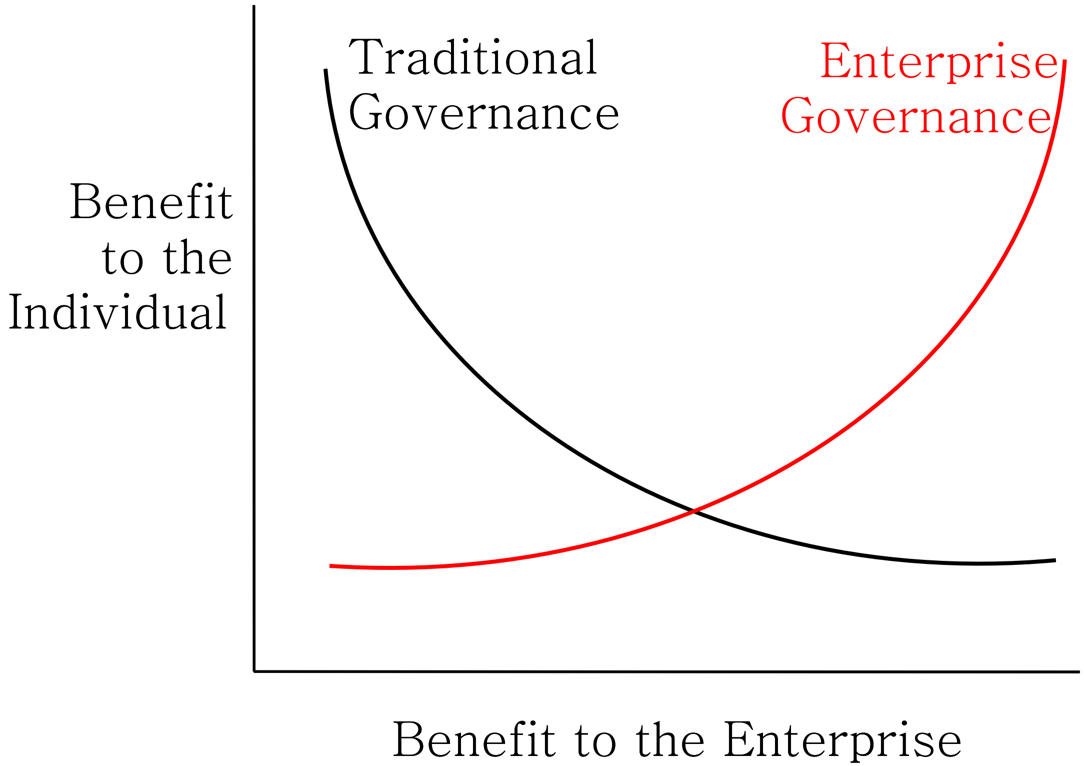
From: Harold W. Sorenson, "Architecture-based Systems Engineering (ASE) for the Enterprise—An Overview." Course offered by University of California at San Diego (UCSD). January 2004. used with his permission.

But Who Does All This!?

- People have asked
  - Who is responsible for making all this happen?!
  - Who actually "engineers the environment" of the enterprise to accelerate its evolution?
- These are good questions.
- The CSE regimen is akin to enterprise "governance".
- This role of exercising the regimen can be taken by people with respect, authority, power, and "purposeful cohesion".
- It seems likely that this "governing body" would be external to the enterprise, although not necessarily.

(White 2005)

Challenge of Enterprise Governance



Enterprise Governance Must Reverse the Traditional Rewards Curve

(DeRosa 2006)

(White 2008a)

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Problem: Failing Acquisition Programs

[References] are from (White 2008a)

Also, refer to (Charette 2008)

Partial List of Major Cost Over-runs and/or Schedule Slips

Reasons: Mismanagement, "Conspiracy of Optimism," and the "Way the World Works"

Agency	Program	Budget ($M)	Cost or Cost Factor ($M)	Schedule &/or Schedule Factor	Status/Reasons
Census Bureau [5]	Handheld Computers	600	1300 (est.)	2006-2010 [6]	Reducing order/ Mismanagement and cost overruns
Coast Guard [7]	Deepwater—national security cutter	24,000 (total)	385 to 681/ship (est.)	1+ year slip since 2002	Ongoing/Technical risks; aggressive trial schedule
U. S. Navy [8]	Littoral Combat Ship	27,500 55 ships	220 to 531-631/ship	1+ year slip on 2 year estimate	Unrealistic cost and schedule; building while still designing
DoD [9]	Joint Strike Fighter	300,000 [10]	55,000+ increase; 23,000 in 2006-07	12 to 27 months slip since 2004	Ongoing/Unstable design; inefficient manufacturing of test aircraft
DoD [11]	F/A-22 Raptor	259,000 [12]	10,200 overrun	1999-2003 2+ years slip	Ongoing/Award fees not performance based
FBI [13]	Virtual Case File (web-based)	92	170; 100+ loss	2001-2004 22 months late	Failed; restarted/ Mismanagement; unrealistic schedule
IRS [14]	Fraud Detection	21 [15]	18.5	2 years	No working product/ Technical update mistakes
NASA [16]	Earth Observing Data/Information Core System	766	1200 (est.)	2+ years slip	Ongoing/ Lack of analyses for costs-plus award and fees
NOAA [17]	National ... Environmental Satellite System	331 (2008) [18]	123 unearned bonus	4 years	Less capability/ Award fee not performance based

(White 2008a)

Program Performance and Award-Fee Payments on Selected DoD Development Programs* See Notes Page

Acquisition Outcomes	Comanche Reconnaissance Attack Helicopter	F/A-22 Raptor Tactical Fighter Aircraft	Joint Strike Tactical Fighter Aircraft	Space-Based Infrared System High
R&D Cost Increase Over Baseline	$3.7 B – 41.2%	$10.2 B – 47.3%	$10.1 B – 30.1%	$3.7B – 99.5%
Acquisition Cycle Time Increase Over Baseline	33 mo – 14.8%	27 mo – 13.3%	11 mo – 5.9%	More than 12 mo
% and Total Award Fee Paid to Prime Systems Contractor**	85% - $202.5M paid through 2004	91% - $848.7M	100% - $494.0M	74% - $160.4M

See DoD programs on preceding chart

* Source: DoD submissions to GAO, contract d
(analysis) http://www.gao.gov/new.items/d066
** Adjusted for rollover: When calculating the %
fee paid to date/(total fee pool – remaining fe
remaining fee pool when those fees were still available to be earned in future evaluation periods.

Huge award fees despite lack of mission capability and poor cost and schedule performance!

(White 2008a)

Abridged

"*So…,*" asks the Chief Engineer "*What do I go do?*" (Norman 2007)

Douglas O. Norman

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8 April 2008

2nd Annual IEEE Systems Conference
7-10 April 2008, Montreal, Quebec, Canada

(Norman and White 2008)

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What We Do Today

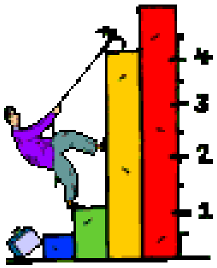
- Programs tend to be insular, why? Because of the way the acquisition world works! Because of
  - Existing expectations and incentive structures
  - The manner of (and rigidity of) thought (It takes a crisis to change.)
  - What good engineers do
- But, what do engineers do? (What feeds the insularity?)
  - First set of questions asked by a Chief Engineer
    - What are the boundaries for this system?
    - What is the limiting case this system?
  - Second set questions:
    - What is expected? (requirements question)
    - When is it expected? (schedule question)
    - What resources do I control? (cost question)
  - Third (and perhaps the most important) question:
    - Ho

This is a poor fit to the enterprise goal!

(Norman and White 2008)

What We Do Today (Concluded)

- Unfunded mandates from above
  - E.g., for greater interoperability and horizontal integration
  - Are dwarfed by
    - The stovepiped mentality of legal/financial constraints
    - And *especially*, how one is measured and rewarded (or penalized).
- Despite the imperative needs, the prevailing culture of most organizations is <u>against</u> the sharing of information.
  - Usually there are penalties (not rewards) for sharing!
- Similarly, if a service, e.g., of either an infrastructure or application nature, is to be provided for the common good, who ultimately bears the burden?
  - Rather than being rewarded, such a provider often experiences
    - Greater pressure to continue supplying that service to additional users, or to the same users with enhancements



(Norman and White 2008)

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What Might We Do Differently?

- From a system Chief Engineer's point of view:
  - Know my system's <u>*fundamental unique value*</u> (FUV) which is offered to the enterprise
    - How does one recognize *FUV*?
  - Know how others will/could interact with this fundamental unique value
    - Concept of *technical intimacy*
  - Implement casual interaction mechanisms initially
    - Reduces needed *a priori* agreements among offeror and users
    - Increases likelihood of being composed into flows
    - Provides guideposts on using limited resources for more-intimate interaction mechanisms
      - Apply where most valued
  - Provide a mechanism for reducing the integration barrier
    - Developers networks

(Norman and White 2008)

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Here's An Analogy

- Suppose each offeror concentrates on their FUV and strips down their offering to that + a good interface(s).
- Pretend the collection of such potential capabilities are like LEGO™ blocks.
- Most users then should be able to assemble a collection of LEGO blocks to create a capability they need in the near term for an important mission.
  - Because of the rough edges they won't be perfect but it will do the job.
  - The process can be iterated taking different needed LEGOs and either warehousing or returning those no longer relevant for the moment.
- Proposal: The producers of the LEGOs that get used are rewarded, and thereby are be… …nue developing … he same … ew LEGOs for potenti… se.

(Norman and White 2008)

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Example of a Future Way of Achieving ESE Mission Capability in Systems Acquisition

- Determine the *fundamental unique value (FUV)* of each system
- Share FUVs in a developers' network and concentrate on interfaces to make your FUV as widely available as possible
- Users will be able compose urgent operational capabilities quickly through selecting FUVs to do the job
- A working analogy to have is that of LEGO blocks, where each LEGO block corresponds to a FUV
- Developers get rewarded only *after* their LEGO block is utilized in this way in the field

(White 2008a)

- Note this is *not* the way the acquisition world works today!

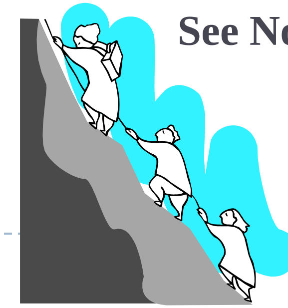
Reducing The Integration "Barrier"

- Put in place a *developers' network*, i.e., points-of-presence with offered functionality exposed as live services.
- Integration is an existing, open-ended problem for achieving the agility, demanded by the push for net-centricity.
  - To date, when we expect to integrate with an existing system, we usually get a copy for our own development environment.
  - This requires a long-term commitment to this foreign system.
  - This is resource intensive and is untenable when there are many such systems with which to integrate.
- As *developers' networks* are stood-up and used, a new dynamic for design, development, and use may emerge.
  - Given the lower barriers to use and integration, this dynamic will support exploration and discovery.
  - Systems may be de-constructed into composable parts, and then (re-)integrated into collections providing user capabilities.
  - Initially, those elements of unique value, being exposed and made available in venues such as developers networks, create new opportunities for those close to the network "edges" to assemble the approximations (or realizations) of the needed capabilities.

(Norman and White 2008)

See Notes Page

A Large Unmet Challenge



- These aims will not be achieved on a large scale anytime soon since the prevailing economic and business structures really don't support them well.
- Nevertheless, we should endeavor to continue experimenting with these techniques in pockets of opportunity.
- Such efforts might be successful and will, by example, gradually change, for the better, the way the world works.
- There are many problems to be overcome; it's going to take a different mindset and creative leadership to accomplish change.
- Collections of composable elements of valuable functionality should help the end users to go beyond what they have now, i.e.,
  - Self-service (i.e., building their own tools and solutions using local talent and discretionary funds)
  - Reciting their perceived needs in the form of written requirements that then enter the formal acquisition system

(Norman and White 2008)

Here's An Example of Fundamental Unique Value

See Notes Page

- What's a FUV of the U.S. Air Force's Air Operations Center's (AOC's) Theater Battle Management Core System (TBMCS)?
- It's the Air Tasking Order (ATO)—*but is it?*
- What if you're a pilot about to enter your aircraft with a compact disk, or whatever, that contains the information needed to complete a successful mission.
  - If I come along with a laptop, or whatever, ask for your CD, then change the code, and hand it back, how would you feel?
  - Chances are you would not accept it and would refuse to fly the mission because your success may be jeopardized.
- So the fundamental unique value of is the integrity of the ATO, it's credibility based on the authoritative, competent source
  - Not the software in or sheet of paper on which the A written!

(Norman and White 2008)

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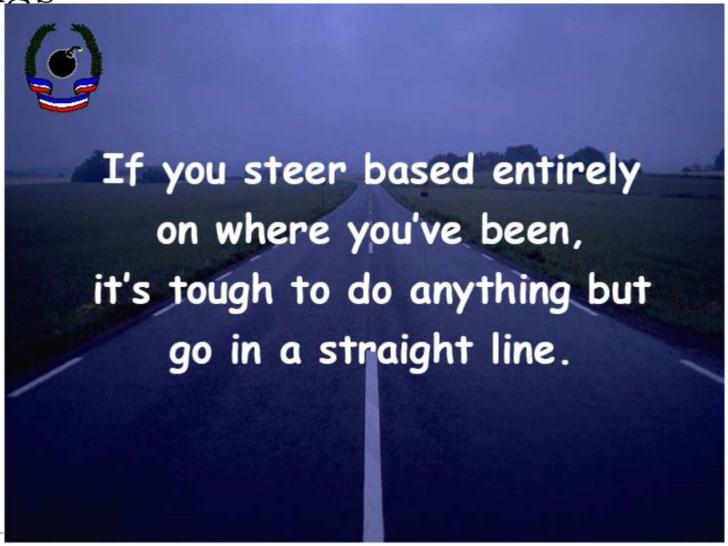
Summary

- "So…," asks the Chief Engineer "What do I go do?"
  - Know and concentrate on your system's fundamental unique value provided to the enterprise
  - Have multiple ways to interact with your FUV
    - Favor casual methods initially
    - Then more intimate methods where demonstrated need exists
    - Make it easy for others to "integrate" with your offering(s)
  - Design with <u>replaceability</u>, not reuseability, in mind
    - This also favors your use of others' offerings
  - Monitor the actual use of your offering
    - Collect field experiences and let that inform change

It's an achievable start!



(Norman and White 2008)

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Complex Adaptive Systems Engineering

- Conventional SE is insufficient and sometimes counterproductive, in addressing the most difficult SE problems.
- As an alternative that may work better, we offer a Complex Adaptive Systems Engineering (CASE) methodology.
  - *Create Climate for Change*: Create a climate for engineering the environment of the System. Continually plan for agile, constructive change (accelerating the processes of natural evolution) through proactive dialog with stakeholders, especially customers.
  - *Architect a Strategy*: For the System, within its various system, system of systems (SoS), enterprise, and/or complex system contexts.
  - *Target Outcome Spaces*: Describe the customer's mission/vision in terms of one or more desired outcome spaces, <u>not</u> solutions.
  - *Reward Results*: Work with the customer and a governing body to create appropriate incentives.

(White 2010a)

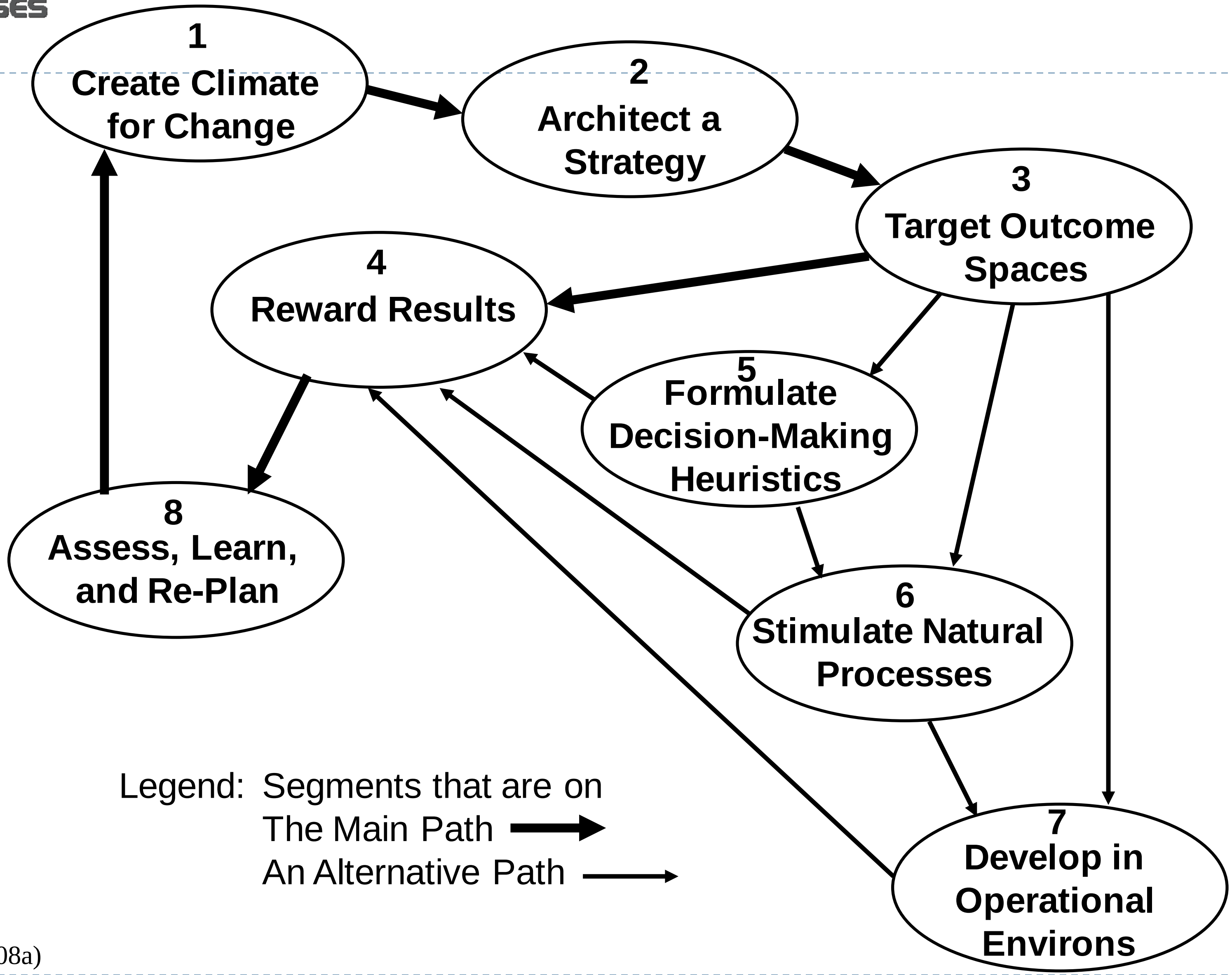
See Notes Page

Complex Adaptive Systems Engineering (Concluded)

- CASE methodology (concluded)
  - *Formulate Decision-Making Heuristics*: Discover and promulgate management heuristics that will help the customer better know *how* and *when* to make decisions.
  - *Stimulate Natural Processes*: Continually "stir the pot" by introducing variation (innovation) and selection (integration) while shaping and enabling future constructive change, and trying to avoid chaos and stasis, respectively.
  - *Develop in Operational Environs*: Create a bias for developing evolutionary improvements of the System in actual operational environments with real users.
  - *Assess, Learn, and Re-Plan*: Continually evaluate overall results and trends focusing on the "big picture," and revisit all the above activities in an iterative fashion to improve their application.

(White 2010a)

CASE Methodology



(White 2008a)

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Activity 1: Create Climate for Change

- Convince government organizations and leaders (e.g., customers, and other System stakeholders) to adopt a self-organizational approach to creating solutions.
  - Understand customers' environments.
  - Pursue a learning process.
  - Together suggest potential policy changes.
  - Identify and approach those who might adjust policies, formulate new policies, or mandate changes.
  - Work with other stakeholders to surface issues, harmonize mutual interests, and propose solutions.

(White 2010a) (White 2008a)

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Activity 2: Architect a Strategy

- With customers and other System stakeholders, determine how to engineer an environment that enables the System to evolve well.
  - Discuss, define, and analyze the
    - Nature of the problem
    - System boundaries
    - Desired outcome spaces
    - Relevant organizations
    - Potential stakeholders
  - Decide *What* and *Whom* to control (if possible) or influence, and *How*.
  - Include and induce the activation of a governing body.
  - Keep options open.

(White 2010a) (White 2008a)

See Notes Page

Activity 3: Target Outcome Spaces

- Describe and share (as widely as possible) the customers' or users' mission and vision in terms of desired outcome space(s), including specific goals.
  - Describe them in ways that are
    - Clear, succinct, and compelling
    - Oriented toward (mostly qualitative) expressions of outcome space capabilities
    - Devoid of specific (mostly quantitative) solutions
  - Continually adapt and reshape the outcome spaces.

(White 2010a) (White 2008a)

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Activity 4: Reward Results

- Work with System stakeholders and a governing body to
  - Establish incentive structures that motivate developers to realize desirable outcomes more rapidly.
  - Judge outcomes that ensue, and reward contributors in proportion to how well the mission is satisfied.
  - Publicize the rewards with supporting information on what was accomplished and why.

(White 2010a) (White 2008a)

See Notes Page

Activity 5: Formulate Decision-Making Heuristics

- Discover management heuristics that improve decision-making processes.
  - Discuss potential decisions with stakeholders.
  - Jointly assess if enough information exists to make such decisions, and take appropriate action otherwise.
  - Support the stakeholders as they take action.
  - Observe and record System behavior.
  - Share useful heuristics with others.

(White 2010a) (White 2008a)

See Notes Page

Activity 6: Stimulate Natural Processes

- Continually stir the pot seeking to further innovate and integrate.
  - Encourage frequent interactions to foster competition and cooperation among System constituents.
  - Manage uncertainty considering opportunity and risk.
  - Design, propose, conduct, and evaluate new concepts.

(White 2010a) (White 2008a)

See Notes Page

Activity 7: Develop in Operational Environs

- Develop evolutionary System improvements with users in operational surroundings and circumstances.
  - Emphasize safety.
  - Participate in field experimentation.
  - Use laboratories for prototyping and subsystems.

(White 2010a) (White 2008a)

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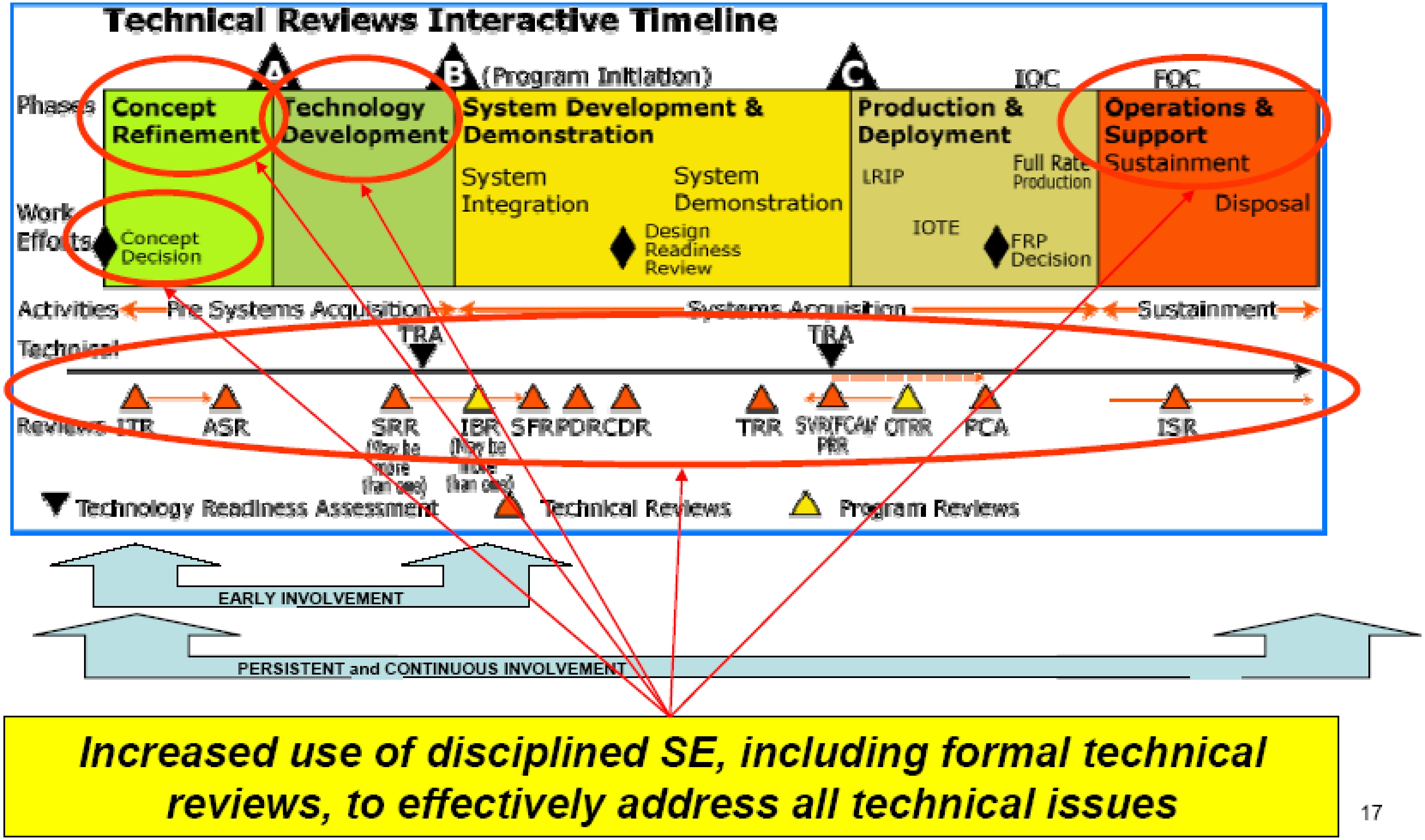
Activity 8: Assess, Learn, and Re-Plan

- Evaluate overall results, revisit CASE activities, and alter the methodology as appropriate.
  - Focus on understanding surprises.
  - Adjust your strategy.
  - Refine CSE principles.
  - Record lessons learned and document case studies.
  - Celebrate successes

(White 2010a) (White 2008a)

Driving SE Back Into Programs
[Good Systems Engineering Plans (SEPs) Are Key]



(White 2005a)

(Schaeffer 2005)

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Abridged

So What?, and What Do They All Mean?!

Systems Engineering Life Cycle stages

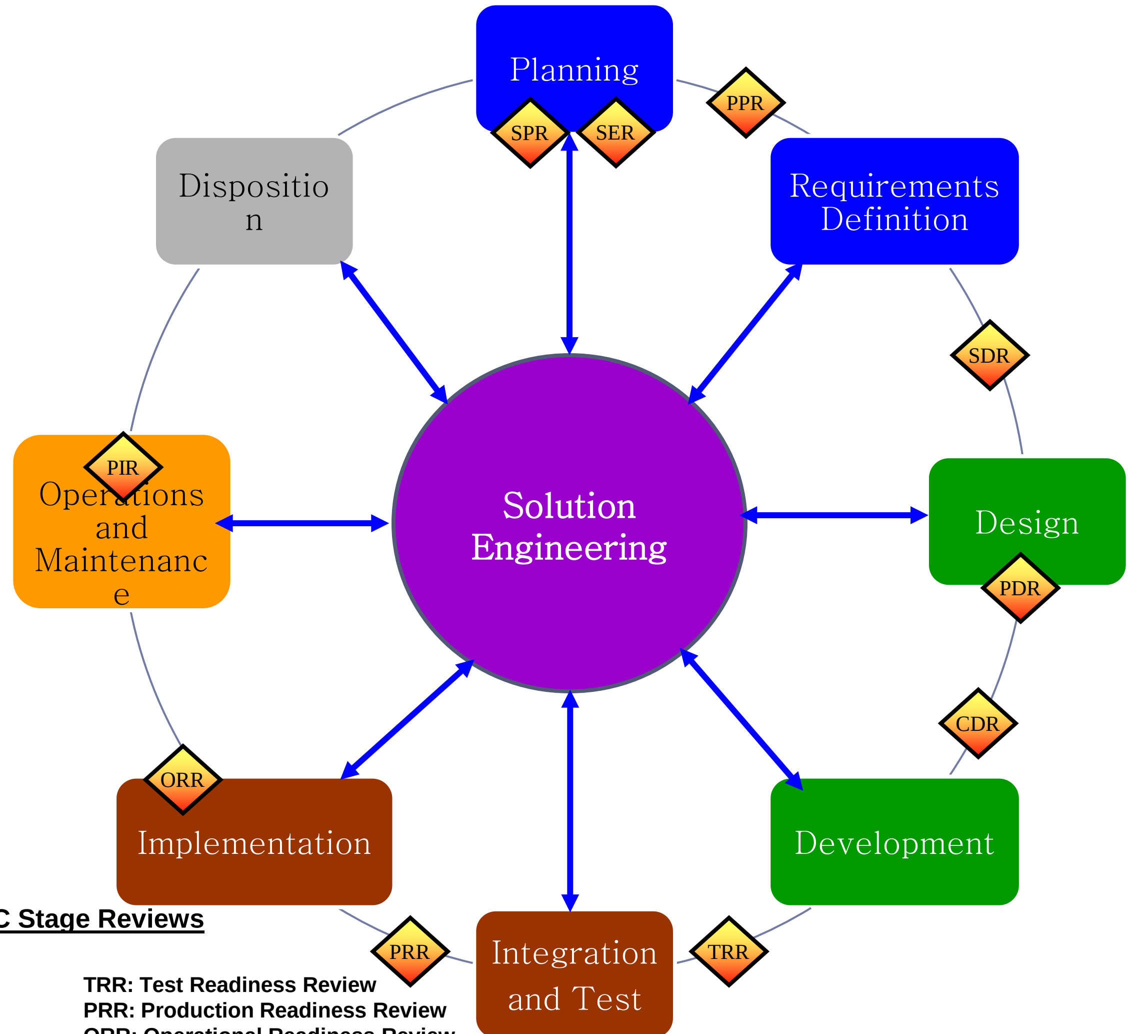
B. E. White, Ph.D.—13 September 2012—7:00 p.m. – 9.45 p.m.
California State University – Northridge – 13 September 2012

CAU←SES (“Complexity Are Us” ← Systems Engineering Strategies)

Outline/Introduction

- Traditional Systems Engineering Life Cycle (SELC)
  - For each stage of SELC [omitted
    - Purpose
    - Stage review milestones
    - Features
      - Key points
      - Goals
      - Lessons Learned
  - SELC Tailoring [omitted here]
- Systems Engineering Activities (SEA) Profiler
  - For each systems engineering activity
    - Purpose
    - Key points
    - Goals
  - Use at MITRE
- Complexity

Systems Engineering Life Cycle (SELC)



SELC Stage Reviews

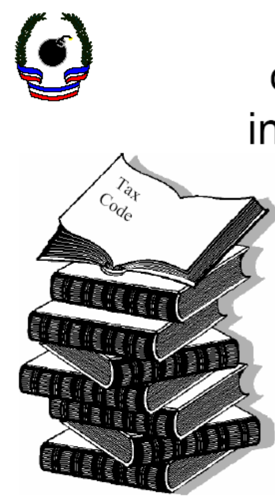
SPR: Study Plan Review
SER: Solution Engineering Review
PPR: Project Planning Review
SDR: System Definition Review
PDR: Preliminary Design Review
CDR: Critical Design Review

TRR: Test Readiness Review
PRR: Production Readiness Review
ORR: Operational Readiness Review
PIR: Post Implementation Review

See Notes Page

Non-Traditional/Conventional Systems Engineering Life Cycle

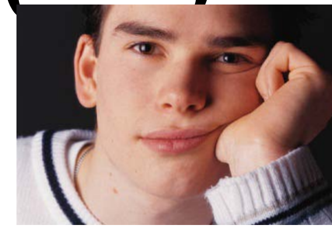
- An alternative perspective or view of the SELC, perhaps a little more modern approach derived from
  - “System of Systems (SoS)” Engineering
  - “Enterprise SE”
  - “Complex SE”



The significance of a thing is usually inversely proportional to **the length** of its explanation.

Systems Engineering Activities (SEA) Profiler

See Notes Page



Version 4 – 4 Jan 09

Systems Engineering Activity (SEA) Profiler

Typical Systems Engineering Activity	*Left End of Slider*	*Left Intermediate Interval*	*Center Intermediate Interval*	*Right Intermediate Interval*	*Right End of Slider*
Define the System Problem	Establish System Requirements	Adapt to Changing Requirements; Re-Scope	Revise and Restate Objectives	Try to Predict Future Enterprise Needs	Discover Needed Mission Capabilities
Analyze Alternatives	Conduct Systems Tradeoffs	Model/Simulate System Functionalities	Perform Systematic Cost-Benefit Analyses	Include Social and Psychological Factors	Emphasize Enterprise Aspects
Utilize a Guiding Architecture	Apply an Existing Framework	Develop Architectural Perspectives (Views)	Really Define (Not Just Views of) Architecture	Adapt Architecture to Accommodate Change	Embrace an Evolutionary Architecture
Consider Technical Approaches	Employ Available Techniques	Research, Track, & Plan for New Technologies	Research and Evaluate New Technical Ideas	Pro-Actively Plan for Promising Techniques	Explore New Techniques and Innovate
Pursue Solutions	Advocate One System Approach	Consider Alternative Solution Approaches	Investigate Departures from Planned Track	Iterate and Shape Solution Space	Keep Options Open While Evolving Answer
Manage Contingencies	Emphasize and Manage System Risks	Mitigate System Risks and Watch Opportunities	Sort, Balance and Manage All Uncertainties	Pursue Enterprise Opportunities	Prepare for Unknown Unknowns
Develop Implementations	Hatch System Improvements Off-Line	Prepare Enhancements for Fielding	Experiment in Operational Exercises	Develop in Realistic Environments	Innovate With Users Safely
Integrate Operational Capabilities	Test and Incorporate Functionalities	Work Towards Better Interoperability	Advance Horizontal Integration As Feasible	Advocate for Needed Policy Changes	Consolidate Mission Successes
Learn by Evaluating Effectiveness	Analyze and Fix Operational Problems	Propose Operational Effectiveness Measures	Collect Value Metrics and Learn Lessons	Adjust Enterprise Approach	Promulgate Enterprise Learning

Convenient Labels (<u>Only; interpret them</u>): Traditional Systems Engineering (TSE) — Complex Systems Engineering (CSE)

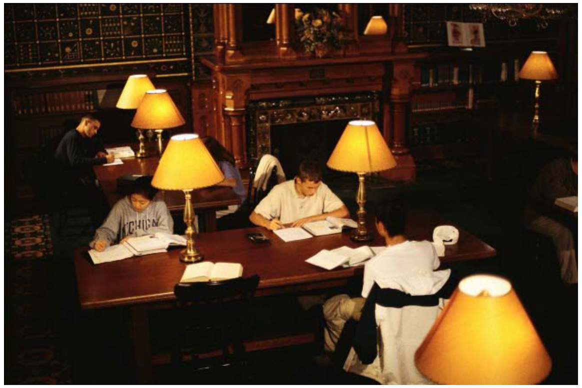
Aggregate Assessment of Above Slider Positions

(White 2010b)

See Notes Page

SEA Profiler 1st Column

- Typical SE Activities
  - Define the system problem
  - Analyze alternatives
  - Utilize a guiding architecture
  - Consider technical approaches
  - Pursue solutions
  - Manage contingencies
  - Develop implementations
  - Integrate operational capabilities
  - Learn by evaluating effectiveness



- Think of these (not mutually exclusive) activities as
  - Generic tasks performed continually, in parallel, and iteratively
  - Dependent upon the application domain and current timeframe.

See Notes Page

SEA Profiler
2^{nd}-6^{th} Columns

- Left End of Slider. These activities characterize prescriptive SE utilizing the best known techniques that work well in less difficult situations where
  - One has a significant amount of control
  - Stakeholders are generally supportive
  - The environment is relatively stable
  - Requirements are well-defined
  - One can use reductionist techniques

- Left Intermediate Interval. These activities characterize techniques that apply in situations of significant but still moderate difficulty. One might associate these activities mostly with a "directed" system of systems (SoS).
- Center Intermediate Interval. These activities characterize techniques that apply in situations of moderate difficulty. One might associate these activities mostly with an "acknowledged" SoS.
- Right Intermediate Interval. These activities characterize techniques that may in situations of moderate to great difficulty. One might associate these activities mostly with a "collaborative" SoS.
- Right End of Slider. These activities characterize the emerging practic (or enterprise) SE utilizing specialized techniques that may apply in the situations where
  - One can only influence
  - Stakeholders are generally non-supportive
  - Requirements are ill-defined
  - One must use holistic techniques to improve enterprise capabilities

- One might associate these activities mostly with a "virtual" SoS.

Systems Engineering Activities (SEA)

If time limited …

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See Notes Page

Row 1: Defining the System Problem (1 of 9)

Define the System Problem

- Purpose
  - Take sufficient time up-front to establish a firm foundation. Where are we going, and how are we going to get there? Le… dmap!

- Key points
  - Early on in any SE endeavor, it is important to
    - Discuss
    - Understand
    - Try to define
    - Agree-to
    - Record
  - a clear statement of the fundamental or core system … e solved.
  - This process can and should be iterated as situations change.
- (Increasingly ambitious) Goals
  - Establish system requirements
  - Adapt to changing requirements; re-scope
  - Revise and restate objectives
  - Try to predict future enterprise needs
  - Discover needed mission capabilities

See Notes Page

Row 2: Analyze Alternatives (2 of 9)

Analyze Alternatives

- Purpose
  - Consider different ways to solve the problem, keeping the "headlight beams" broad enough to include a fair number of potential solutions but not so large that infeasible "landscapes" are highlighted.
- Key points
  - This SE activity can be viewed as a set of act consider various ways of solving the system and that might be started before other SE act

- (Increasingly ambitious) Goals
  - Conduct Systems Tradeoffs
  - Model/Simulate System Functionalities
  - Perform Systematic Cost-Benefit Analyses
  - Include Social and Psychological Factors
  - Emphasize Enterprise Aspects

See Notes Page

Row 3: Utilize a Guiding Architecture (3 of 9)

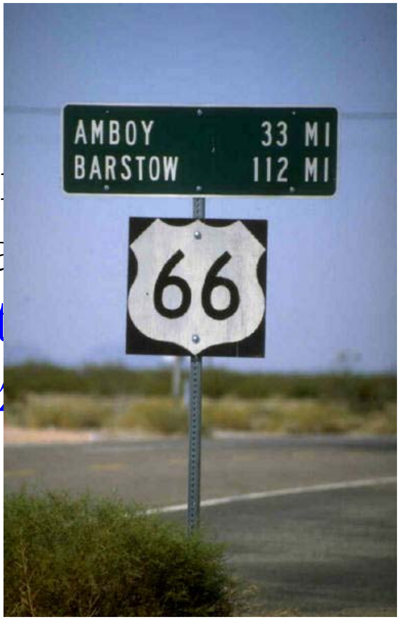
Utilize a Guiding Architecture

- Purpose
  - Create a "roadmap" for the systems development "vehicle" that can be continually exercised, providing navigation advice analogous to the Global Positioning System (GPS), for example.
- Key points
  - Develop and adopt a basic architecture to guide SE work. A good architecture should be stable and drive the system development. Use views of to communicate with others.
- (Increasingly ambitious) Goals
  - Apply an Existing Framework
  - Develop Architectural Perspectives (Vie
  - Really Define (Not Just Views of) Architecture
  - Adapt Architecture to Accommodate Change
  - Embrace an Evolutionary Architecture

Row 4: Consider Technical Approaches (4 of 9)

Consider Technical Approaches

- Purpose
  - Thoroughly explore feasible "routes" to solutions through a broad range of technical means.
- Key points
  - System developments and upgrades are imple by not only the application of technology but a technical approaches that may depend on polit economics, sociology, psychology, and organi change management.
- (Increasingly ambitious) Goals
  - Employ Available Techniques
  - Research, Track, and Plan for New Technologies
  - Research and Evaluate New Technical Ideas
  - Pro-Actively Plan for Promising Techniques
  - Explore New Techniques and Innovate



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Row 5: Pursue Solutions (5 of 9)

See Notes Page

Pursue Solutions

- Purpose
  - "Drive" the systems development safely and smartly, giving due consideration to alternative "routes" and "arrival times" while focusing on the current accepted approach.
- Key points
  - This class of activity naturally follows the so SE activities listed previously but can also be in an iterative fashion as the system developm upgrade progresses, especially when unfores difficulties materialize.
- (Increasingly ambitious) Goals
  - Advocate One System Approach
  - Consider Alternative Solution Approaches
  - Investigate Departures from Planned Track
  - Iterate and Shape Solution Space (adjust "headlights")
  - Keep Options Open While Evolving Answer

Row 6: Manage Contingencies (6 of 9)

See Notes Page

Manage Contingencies

- Purpose
  - Prepare management plans in advance and try to avoid being "stuck in traffic", i.e., wedded to a fixed approach, when "re-routing" the vehicle may be advantageous.
- Key points
  - One needs to expect things to go wrong (as well as right) so considerable attention must be paid to how to deal with uncertainties.

- (Increasingly ambitious) Goals
  - Emphasize and Manage System Risks
  - Mitigate System Risks and Watch for Opportunities
  - Sort, Balance and Manage All Uncertainties
  - Pursue Enterprise Opportunities
  - Prepare for [Rumsfeld's] Unknown Unknowns

See Notes Page

Develop Implementations

Row 7: Develop Implementations (7 of 9)

- Purpose
  - Instantiate the most attractive solution but remain flexible to opportunities to improve its effectiveness before fielding. Drive with purpose l
    
    h out for cops!”
- Key points
  - This set of activities is closely related to those of the SE activity Pursue Solutions but reflects what actually is being done materialistically (or n
    materialistically).
    
- (Increasingly ambitious) Goals
  - Hatch System Improvements Off-L
  - Prepare Enhancements for Fielding
  - Experiment in Operational Exercise
  - Develop in Realistic Environments
  - Innovate With Users Safely

See Notes Page

Integrate Operational Capabilities

Row 8: Integrate Operational Capabilities (8 of 9)

- Purpose
  - Ensure that the system improvements are integrated horizontally for inter-system interoperability with other users, as well as vertically for targeted users of this system. Arrive at the “destination” with all your “passengers and luggage” intact!
- Key points
  - This set of SE activities is most ass with the completion and delivery of system or system upgrade to the sp customer, and/or end user.
- (Increasingly ambitious) Goals
  - Test and Incorporate Functionalities
  - Work Towards Better Interoperability
  - Advance Horizontal Integration As Feasible
  - Advocate for Needed Policy Changes
  - Consolidate Mission Successes

Row 9: Learn by Evaluating Effectiveness (9 of 9)

See Notes Page

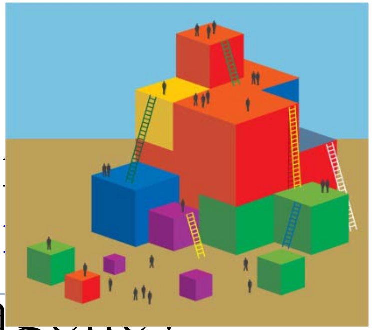
Learn by Evaluating Effectiveness

- Purpose
  - Increase present and future operational success by gathering, analyzing, and evaluating data and information generated by the fielding and use of the system. How was the "trip"?!
- Key points
  - This set of SE activities is focused on the continual evaluation of how well things are procee delivering needed capabilities to end use
- (Increasingly ambitious) Goals
  - Analyze and Fix Operational Problems
  - Propose Operational Effectiveness Meas
  - Collect Value Metrics and Learn Lessons
  - Adjust Enterprise Approach
  - Promulgate Enterprise Learning

Complexity (1 of 4)

- Traditional SELC
  - Essentially a linear, sequential, rigidly-controlled process
  - Typically involves tons of regulations and documentation requirements with which contractors must comply
  - The sponsoring agency often increases this bureaucratic burden
  - Tailoring is a valiant attempt to become more flexible

- SEA Profiler
  - Essentially a nonlinear, iterative, adaptable
  - Focuses on trusting constituents to concent
what's important in achieving needed capab
  - Aimed at improving mindset of sponsoring agency
  - Tailoring is inherent in (or built into) every aspect



Complexity (2 of 4)

- Complexity
  - Difficult to define
  - Many think complicated; it's much more!
- Complex Systems
  - Abound in nature
  - Inform systems engineering
- Future course(s)?
  - System of Systems (SoS) and SoS Engineering
  - Enterprises and Enterprise SE (ESE)
  - Complex Systems and Complex Systems Engineering (CSE)
- Prerequisite: Understanding of
  - Complex Systems Behaviors
  - Complex Systems Engineering Principles

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Complexity (3 of 4)

- Complex System Behaviors
  - A. Surprising Emergence
  - B. Evolves on Its Own as a Wh
  - C. Acts Robustly
  - D. Thrives on Diversity
  - E. Many Factors at Play
  - F. Stimulates Different Perspectives
  - G. Ever Changing
  - H. Informs the Observer
  - I. Performs Openly
  - J. Internal and External Relationships are Key
  - K. Self-Organized
  - L. Sensitive to Small Effects
  - M. Exhibits Tight and Loose Couplings

If time limited …

Abbreviated Behavior Definitions

A. Surprising Emergence

Favored definition: emergence is <u>un</u>expected

Surprises not easily explained are especially interesting

B. Evolves on Its Own as a Whole

System does whatever it pleases

Interactions make overall behavior unpredictable

C. Acts Robustly

<u>Population</u> of healthy system can survive harsh environments

Pay attention to flexibility and adaptability

D. Thrives on Diversity

Intricate and multifarious interrelationships

(White 2011)

Abbreviated Behavior Definitions (Continued)

E. Many Factors at Play

Seek shared ideas/preferences and be aware of discord

Identify and build common ground

F. Stimulates Different Perspectives

Build new and interrelated ideas collectively

Continually nudge system in desired direction

G. Ever Changing

Expect change

Establish process for managing uncertainty

H. Informs the Observer

Try to observe objectively

(White 2011)

See Notes Page

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Abbreviated Behavior Definitions (Concluded)

I. Performs Openly

Try to interpret specific causes of observed effects

J. Internal and External Relationships are Key

Ascertain most important interactions through experimentation

K. Self-Organized

Encourage purposeful human interactions

L. Sensitive to Small Effects

Slight changes of initial conditions can lead to very different results

M. Exhibits Tight and Loose Couplings

Group interactions of each category together

(White 2011)

Mindsets Illustration - Video

- Instructions
  - Those on (my) left side of room
    - Focus on 3 basketball playe[redacted] shirts
    - Count exact number of passes of their basketball during video
  - Those on (my) right side of room
    - Focus on 3 basketball players in black shirts
    - Count exact number of bounces of their basketball during video
  - Keep your eye on the ball!
    - Traditional Systems Engineering
  - But don't lose the big picture
    - Enterprise Systems Engineering

Play:
"selective attention test.wmv"

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Abridged

On Interpreting Scale (or View) and Emergence in Complex Systems Engineering

Brian E. White, Ph.D. (978) 443-3660

bewhite71@gmail.com

11 April 2007

1st Annual IEEE Systems Conference 9–12 April 2007
Hyatt Regency Waikiki Honolulu, HI

(White 2007c)

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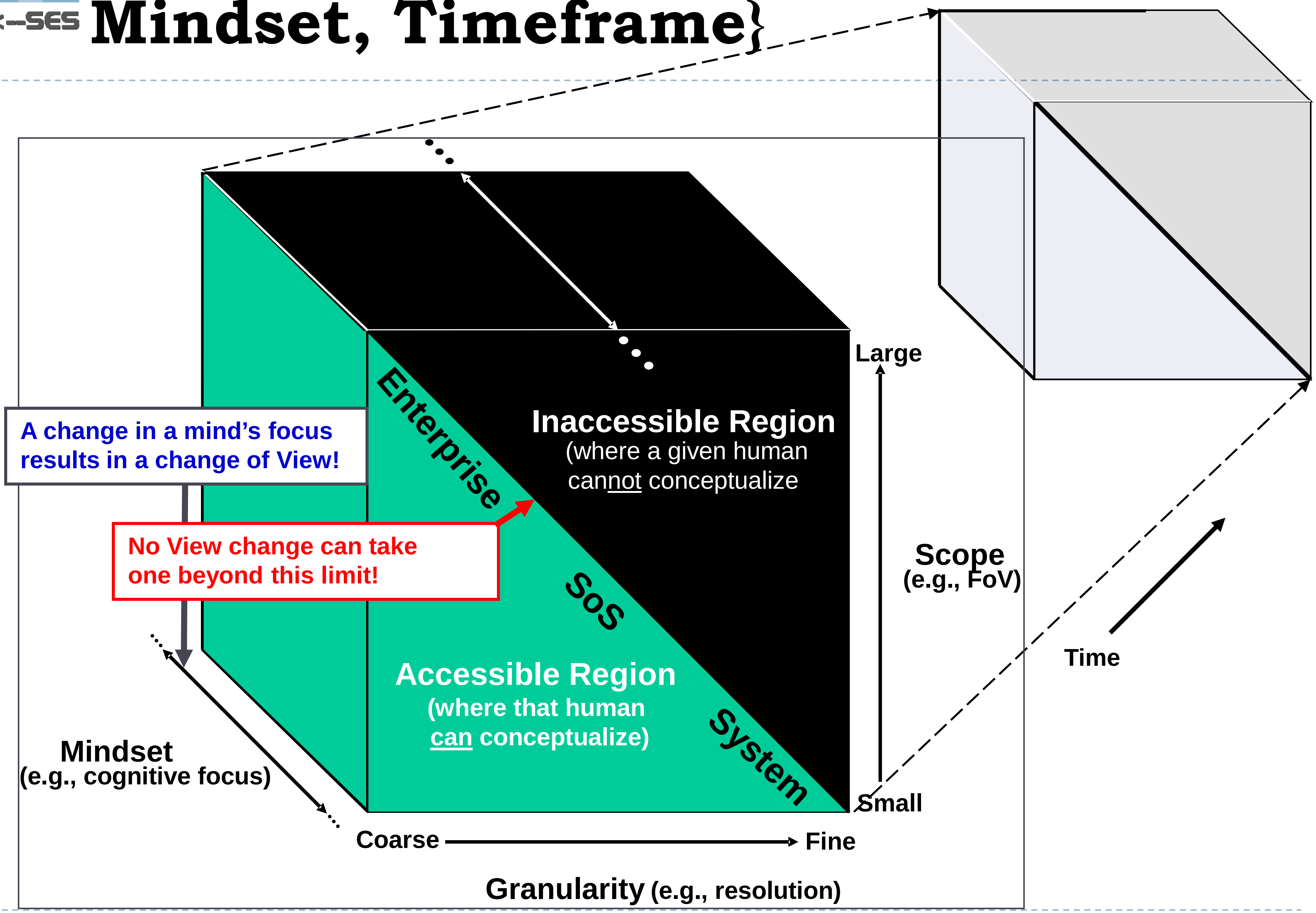
Scale or View

- Multi-scale (multi-view) analysis is crucial to CSE.
  - Different perspectives reveal patterns that help understanding.
  - Together, they elicit ideas for guiding a complex system towards more useful capabilities.
- {View} = {Scope, Granularity, Mindset, Timeframe}
  - Scope: What is included in an individual's conceptualization
  - Granularity: The ability of a person to discern and discriminate individual items of a conceptualization
  - Mindset*: What currently captures an individual's attention in a conceptualization
  - Timeframe: The time interval of an individual's

* "Mindsight" is a better word, perhaps, since that term emphasizes perspective and suggests more flexibility (due to Daniel J. Siegel, MD in Hawn 2011, p. xiv)

(White 2007c)

{View} = {Scope, Granularity, Mindset, Timeframe}



(White 2008a) (White 2007c)

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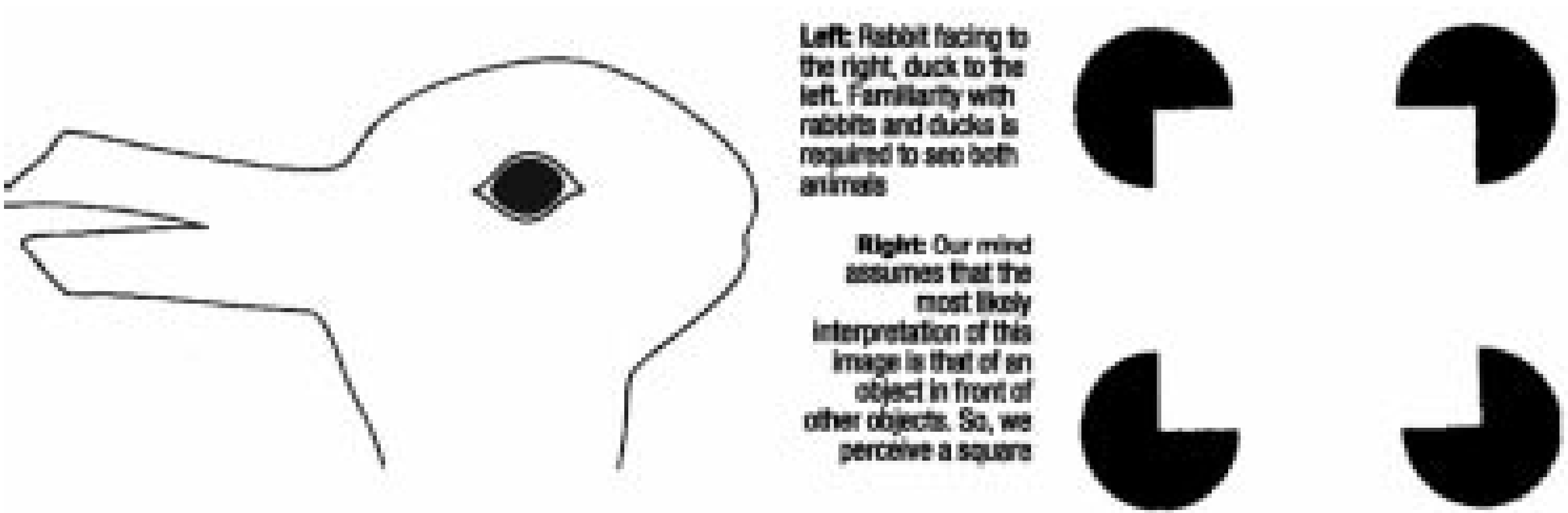
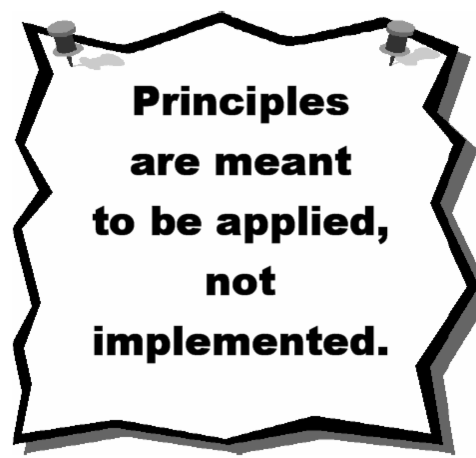
Changes in Mindset Result in Two Distinct Views



(White 2007c)

Complexity (4 of 4)

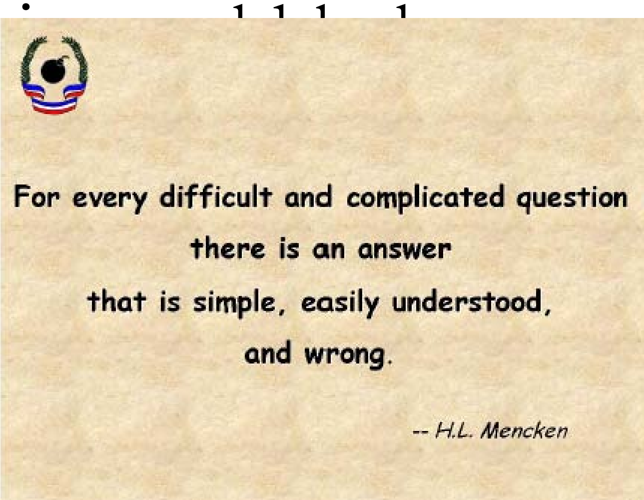
- Complex Systems Engineering Prin
  - 1. Bring Humility
  - 2. Follow Holism
  - 3. Achieve Balance
  - 4. Utilize Trans-Disciplines
  - 5. Embrace POET*
  - 6. Nurture Discussions
  - 7. Pursue Opportunities
  - 8. Formulate Heuristics
  - 9. Foster Trust
  - 10. Create Interactive Environmer
  - 11. Stimulate Self-Organization
  - 12. Seek Simple Elements
  - 13. Enforce Layered Architecture



* Political, Operational, Economic, and Technical

Humility

- Complex systems include people, and we must bring more humility to engineering the environment of complex systems, e.g., enterprises.
- Humility especially helps in understanding each other's definitions, i.e., we don't need to fully agree on our use of words, although th
us accelerate progress.
  - "The study of complex systems is the study of the world as it is, not as we want it to be."
    Brenda Zimmerman,
    Edgeware – Insights From Complex Systems
  - "Complex adaptive systems do pretty much as they damn please."
    John Holland, Hidden Order



(DeRosa 2007)

Recent thoughts on humility

- "The first product of self-knowledge is humility." Flannery O'Connor
  - www.reflectionforthe day.com. ©Tom Fitzpatrick. All rights reserved. *The Boston Globe*, 15 August 2012, p. G27
  - "Mary Flannery O'Connor (March 25, 1925 – August 3, 1964) was an American writer and essayist …" (Wikipedia, "Flannery O'Connor," 2012, http://en.wikipedia.org/wiki/Flannery_O'Connor)
- "Humility, it is sometimes said, doesn't mean thinking less of yourself. It means thinking of yourself less." Jeff Jacoby, "Where's the humility?" *The Boston Globe*, p. A13, 15 August 2012.
  - This editorial is mainly about Jamaica's Usain Bolt, the two-time Olympic Champion (2012 and 2008) in 100 m, 200 m, and 4×100 m relay races.
  - Other sports examples abound, Carli Lloyd (women's soccer), Ted Williams (baseball), Michael Phelps (swimming), Kobe Bryant (basketball), and [my additions:] Tiger Woods (golf) and
  - Mohammad Ali (boxing) (*Time*, "The 100 Most Influential People Of All Time," New York: Time Home Entertainment

Humility (Concluded)

1. Bring Humility

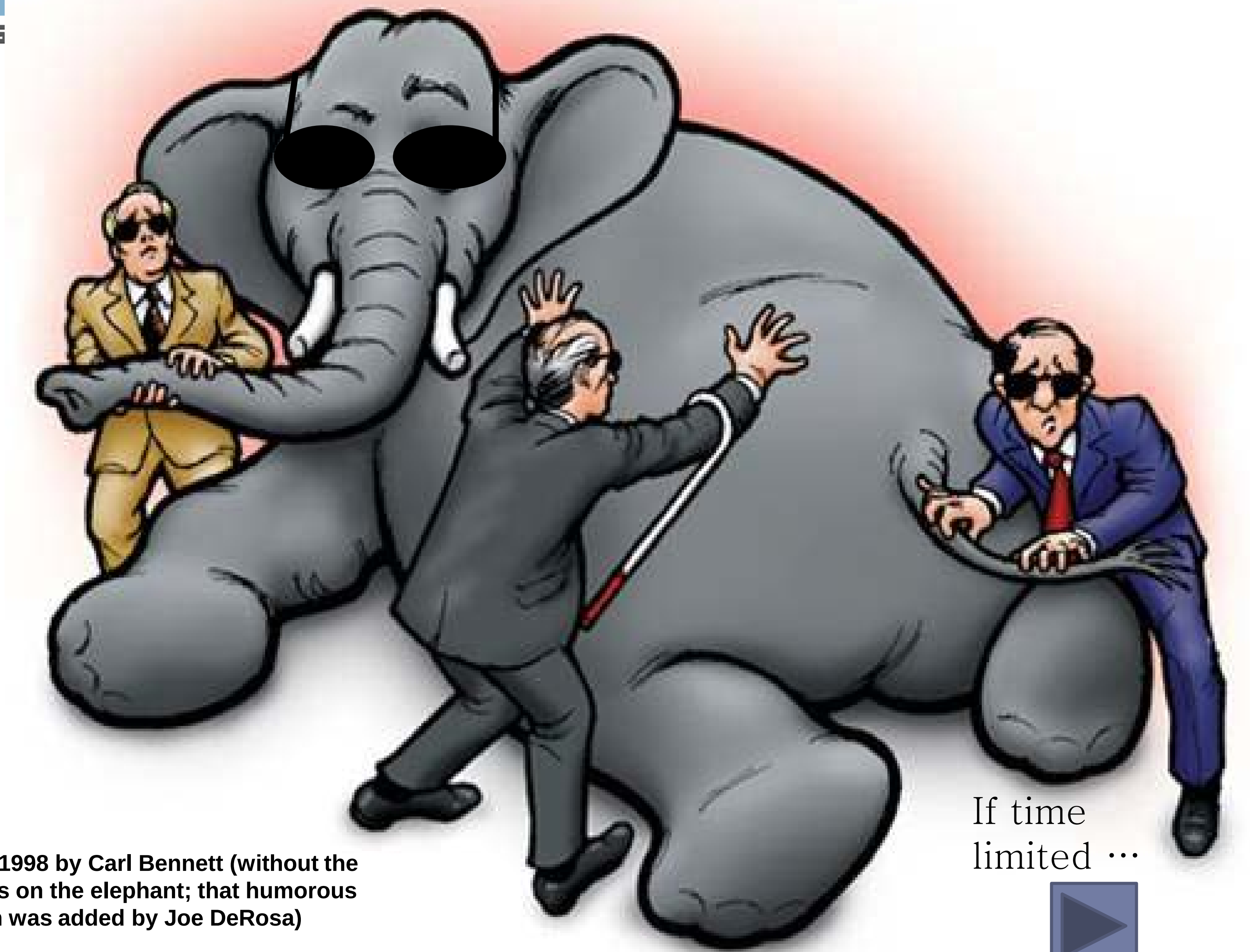
This has been attacked as unprofessional

What do you think?

Simple fixes often don't work in complex situations

One must watch and be prepared to try something else

But one is rarely sure just how long to wait



Copyright 1998 by Carl Bennett (without the sunglasses on the elephant; that humorous touch was added by Joe DeRosa)

If time limited …

Abbreviated Principle Definitions

2. Follow Holism

One cannot use reductionism

Complex system and its environment will have moved

Fundamental problem with government system acquisitions

3. Achieve Balance

Optimizing sub-systems detracts from efficacy of whole

Try to balance various sub-system thrusts

4. Utilize Trans-Disciplines

People are part of system.

"Trans-disciplines" like philosophy, psychology, sociology, organizational change theory, economics, and politics apply

(White 2011) (White 2010)

Abbreviated Principle Definitions (Continued)

5. Embrace POET
   - Deal with all four aspects
   - Understand stakeholders' values
6. Nurture Discussions
   - Every person sees differently
   - No one grasps whole truth
   - Leverage group's cognitive diversity
   - Understand how words are used
7. Pursue Opportunities
   - Too much emphasis on identifying/mitigating risks
   - Principal risk is <u>not</u> pursuing opportunities
   - Strike balance

(White 2011) (White 2010)

Abbreviated Principle Definitions (Continued)

8. Formulate Heuristics

Devise rules-of-thumb to help decision-makers

Time delays are tantamount

9. Foster Trust

Establishing trust is difficult and can be lost immediately

Try sharing some information

If echoed, share more and more.

(White 2011) (White 2010)

See Notes Page

Abbreviated Principle Definitions (Continued)

10. Create Interactive Environment

    Establish/maintain interactions and their reward structures

    Act and be responsive

    Don’t fight systems that cannot be influenced

    Solicit inputs from external observers

11. Stimulate Self-Organization

    This is natural state for living elements

(White 2011) (White 2010)

Abbreviated Principle Definitions (Concluded)

12. Seek Simple Elements

SE solutions are often too big and/or complicated

Design down-scale and assemble smaller adaptable units

13. Enforce Layered Architecture

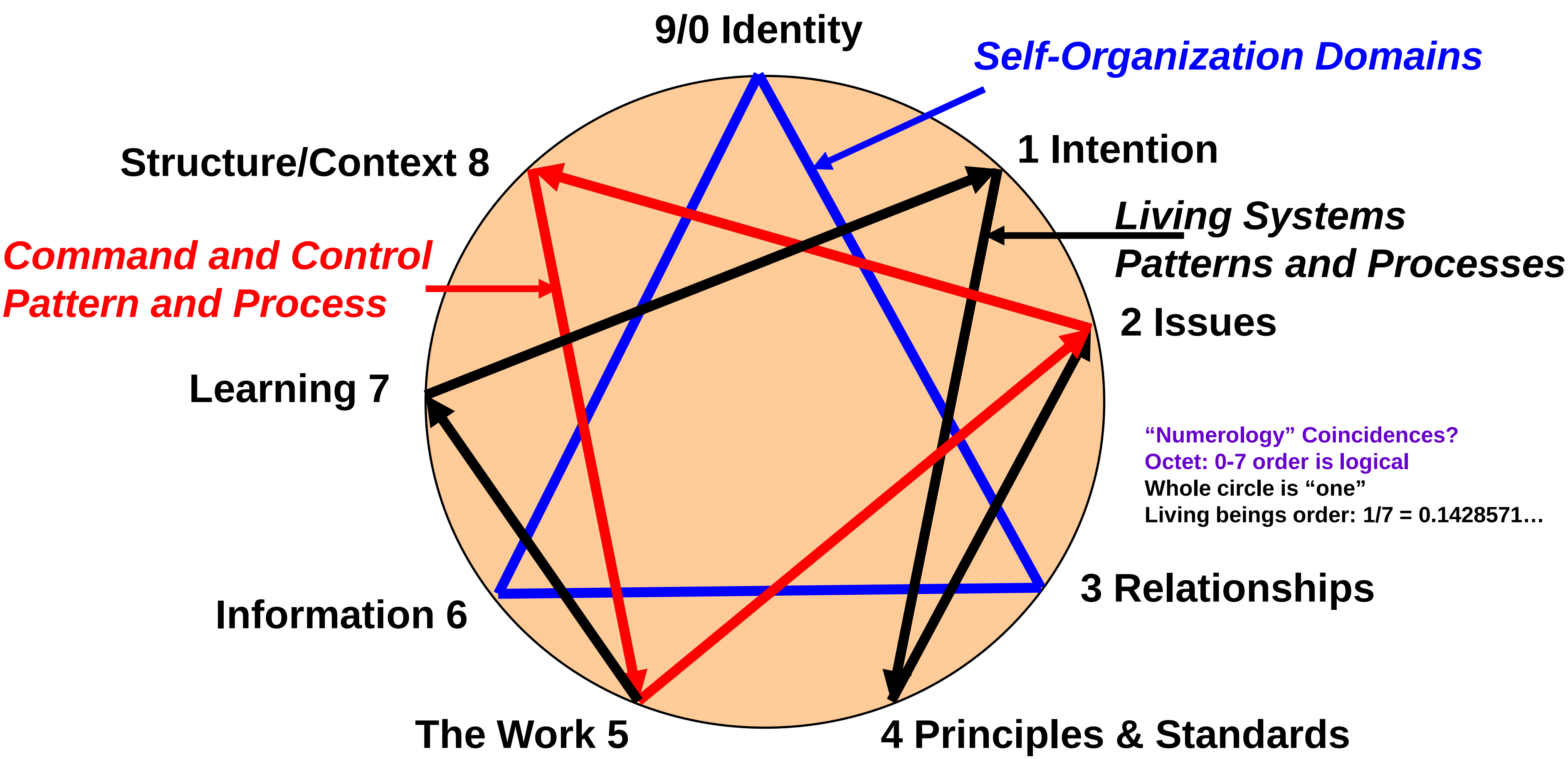
Apply layering principles

Each layer can be adapted to different conditions

Keep interface(s) between layers unchanged

(White 2011) (White 2010)

Re: Nurturing Discussions
The Enneagram Web*



(White 2008a)

* [Knowles, 2002, pp. 30, 32, 33, and 39]

Some Questions for the Nine Enneagram Perspectives*

- *Point 0 (Identity):* Who are we? What is our Identity? What is our history, individually and collectively?
- *Point 1 (Intention):* What are we trying to do? What are our Intentions? What is the future potential?
- *Point 2 (Issues):* What are the problems and Issues facing us? What are our dilemmas, paradoxes and questions?
- *Point 3 (Relationships):* What are our Relationships like? How are we connected to others we need in the system? What is the quality of these connections? Are there too many or too few of them?
- *Point 4 (Principles and Standards):* What are our Principles and Standards of behavior? What are our ground-rules, really? What are the un-discussable behaviors that go on, over and over?
- *Point 5 (Work):* What is our Work? On what are we physically working?

(White 2008a)

* (Knowles 2002, pp. 28-29) *Note: Above text has been changed to read as "us," not "them."*

Some Questions for the Nine Enneagram Perspectives* (Concluded)

- *Point 6 (Information):* Do we know what's going on? How do we create and handle Information?
- *Point 7 (Learning):* Are we Learning anything? What are our Learning processes? What is the future potential?
- *Point 8 (Structure and Context):* How are we organized? What is our Structure? Where does the energy come from that makes things happen in our organization? Is our hierarchy deep or flat? What's happening in the larger environment, in which we're living and trying to thrive? Who are our competitors and what are they doing? What is the Context or surrounding environment in which we are living and working?
- *Point 9 (Our New Identity):* After we've moved through ~~these~~ questions, how has our Identity changed? Have we expanded and grown? What new things do we now know? What new skills do we now have?

(White 2008a)

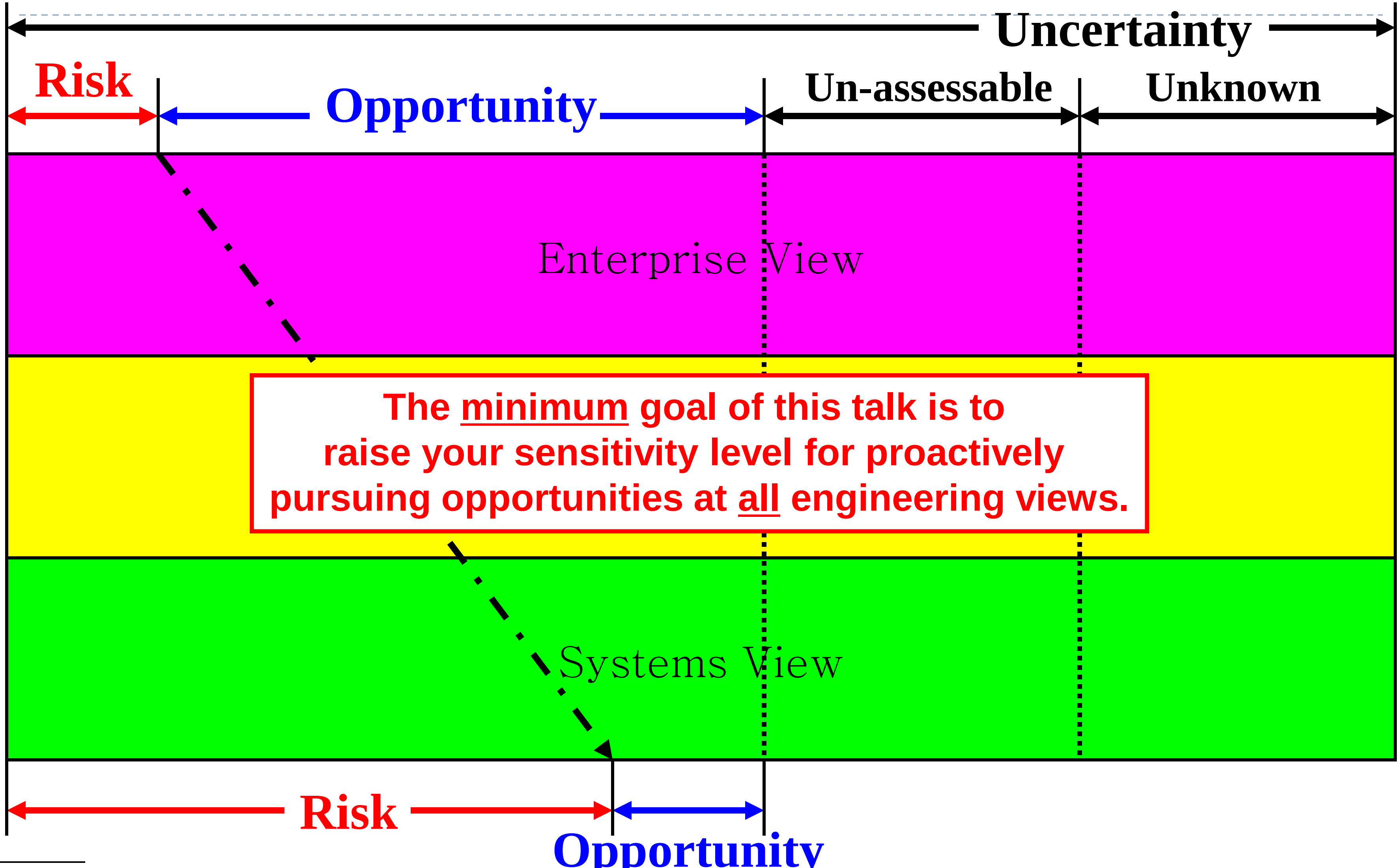
* (Knowles 2002, pp. 28-29) *Note: Above text has been changed to read as "us," not "them."*

Re: Pursuing Opportunities Boiling Frog Syndrome*

* http://www.google.com/images?hl=en&expIds=25657,27404,27601&sugexp=ldymls&xhr=t&q=boiled+ frog+ syndrom
1289742287035020&um=1&ie=UTF-8&source=univ&ei=1uffTK7ELYSs8AbLkfwb&sa=X&oi=image_result_group&ct=
=2&ved=0CEEQsAQwAw&biw=1139&bih=640

See Notes Page

Relative Importance of Opportunity



* (White 2011a) (White 2007) (White 2006a)

Concluding Remarks
[from (White 2006a)]

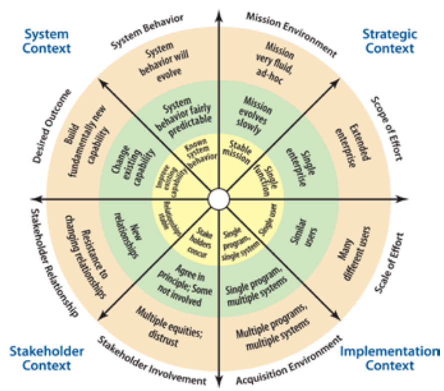
- The greatest enterprise risk may be in <u>not</u> pursuing enterprise opportunities.
- There is duality
  - In treating risks and opportunities
  - Between systems and enterprises
- Opportunity (as well as risk) management is a "team sport".
  - But ESE is the "big leagues" for opportunity management.
- Keep in mind there are unknowns and unknowables.
- Opportunities in ESE abound!
- Qualitative assessments of opportunity management
  - Tend to be more difficult for enterprises than for SoS or systems
  - Could easily change after learning more about ESE
- Our principal hypothesis: In ESE, be aggressive with opportunity and accepting of risk.
  - This is just the opposite of what seems to be the case in TSE!

Conclusion

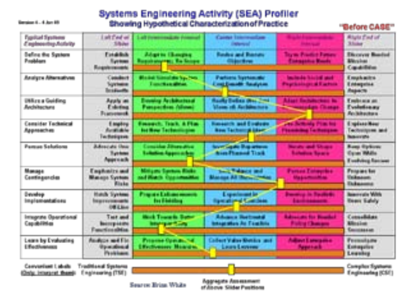
- SELC
  - You now know much about the traditional systems engineering life cycle, except that we have emphasized the SELC as a tailor able, non-linear process instead of the usual linear, sequential one.
- SE Activities
  - We have introduced a tool for characterizing what you are doing in systems engineering (SE) on your program/project.
  - Setting Systems Engineering Activity (SEA) Profiler “sliders” provides a snapshot of your current SE approach.
  - Use this tool in discussing the extent to which your approach makes sense considering your working environment and externally imposed constraints.
  - Also use it to compare and contrast your SE approaches
    - Over time on your program/project
    - With SE characterizations of other programs/projects.
- Complexity
  - Future educational opportunities exist for learning more about complex systems and complex systems engineering.

Putting It All Together…

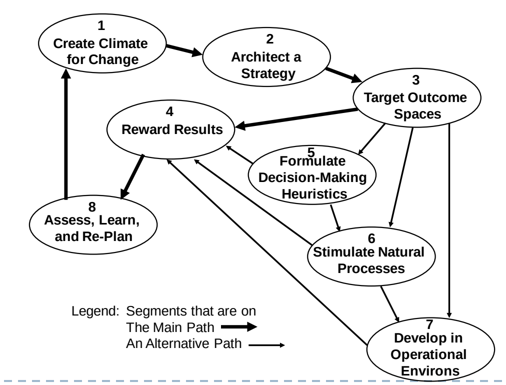
1. Characterize Your Environment



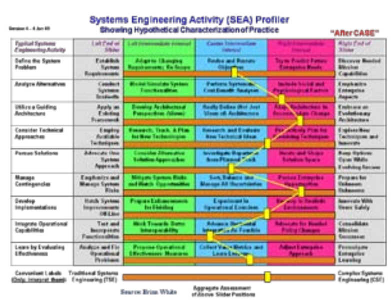
2. Characterize Your Current Approach



3. Apply CASE Methodology



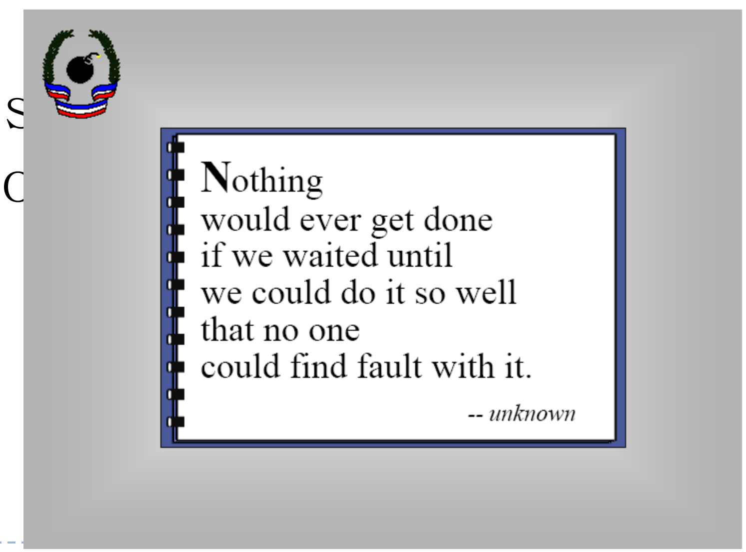
4. Characterize Your New Approach



(White 2008a)

Takeaways

- Complex Adaptive Systems Engineering (CASE)
  - Is offered as a complementary approach (to conventional or traditional SE) that may work better in our most difficult Government acquisition environments
  - Try it, you may like it! ☺
  - But CASE needs more case s
validate this approach and co



(White 2010a)

CAU<--SES

Augmented and Abridged

See Notes Page

A Personal History of Engineering Management Efforts

B. E. White, Ph.D.

CAU← SES: Complexity Are Us ← Systems Engineering Strategies

Engineering Management Workshop

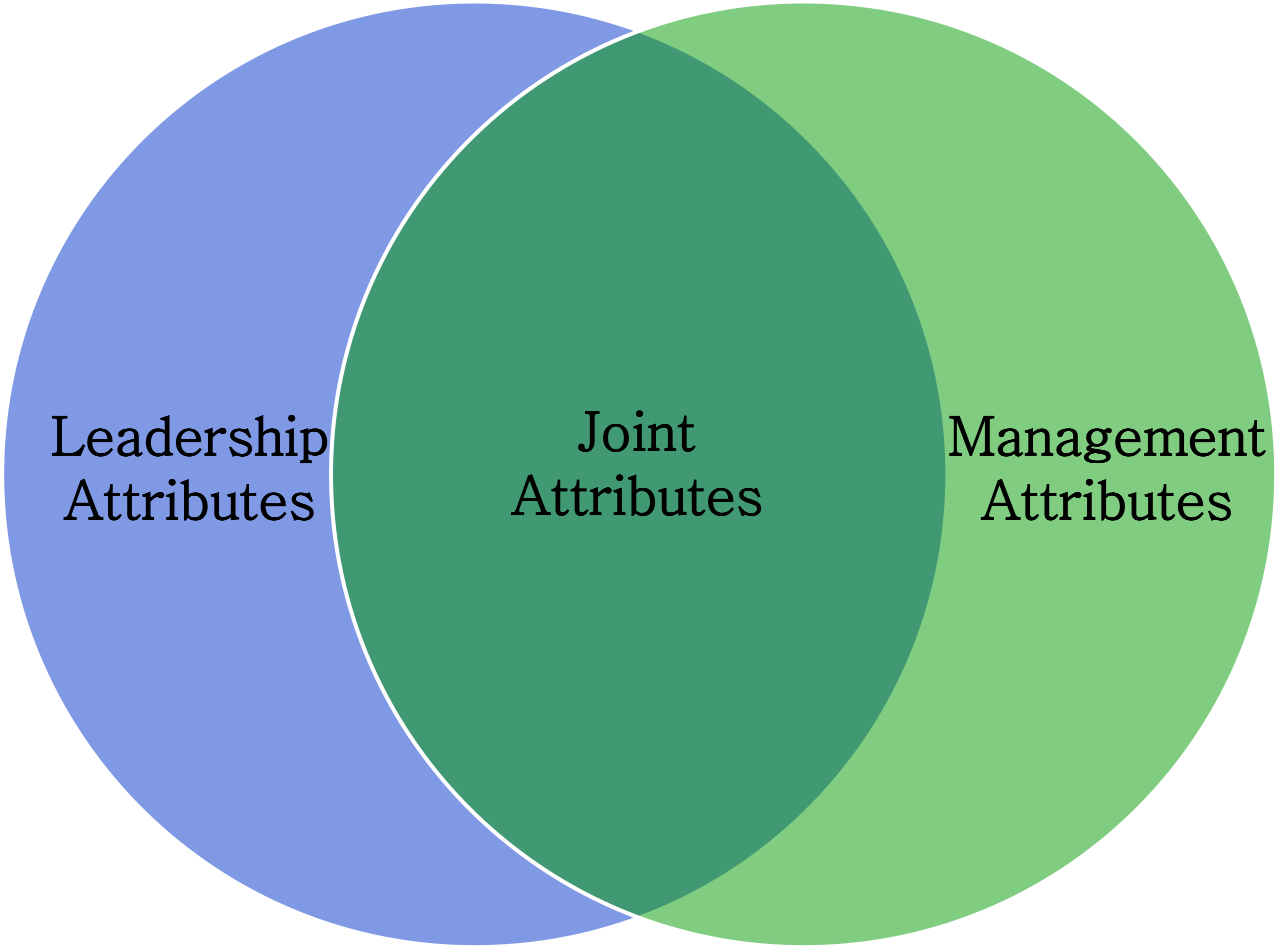
California State University – Northridge, 12 September 2012

CAU<--SES

Introduction/Outline

- Let's include leadership in engineering management!
- Some attributes of leaders and managers
- Sample leadership/management engineering aspects
- Litany of author's career experiences [omitted here]
  - Description of program or project example
  - Leadership/Management aspects that applied
  - Stories (as time permits)
- Workshop exercises [omitted here]
- Additional detail on several of the author's programs or projects selected by workshop participants [omitted here]

Leadership and Management Attributes Overlap



Leadership Is Important As Well As Management

- Leadership is generally viewed as overlapping but complementary to management (as depicted on the preceding chart). Some positive attributes often associated with good leaders and managers appear below. Those attributes that seem to be more characteristic in distinguishing leaders and managers are indicated in **bold-faced** type.

- Leadership Attributes: Active, Admired, Ambitious, Analytical, Astute, Aware, **Big-Picture Oriented**, **Brave**, **Broad-Minded,** Caring, **Charismatic**, Clear, Communicative, Compassionate, Competent, **Conceptual**, Confident, Cooperative, Courageous, **Creative**, **Curious**, **Daring**, Dependable, Determined, Diplomatic, Economical, **Effective**, Expressive, Fair-Minded, **Faithful**, Flexible, Forward-Looking, Friendly, Gregarious, Honest, **Humble**, **Idealistic**, **Imaginative,** Independent, Industrious, Informed, **Inspiring**, Intelligent, **Intuitive**, **Loyal**, Mature, Opportunistic, **Original**, **Patient**, Persistent, Political, Principled, Private, Proactive, Results **Right-Brained**, Oriented, Self-Controlled, Sensible, Sincere, Steadfast, Straightforward, Supportive, **Trusting**, Willing, **Visionary**, Zealous

- Management Attributes: **Accountable**, Active, Admired, Ambitious, Analytical, **Anxious**, Astute, Aware, **Bottom-Line Oriented**, Caring, Clear, Communicative, Compassionate, Competent, **Controlling**, Cooperative, Courageous, **Detail Oriented**, Determined, **Efficient**, Dependable, Diplomatic, Confident, Economical, **Efficient**, Expressive, Fair-Minded, Flexible, Forward-Looking, Friendly, Gregarious, Honest, Independent, Industrious, Informed, Intelligent, **Left-Brained**, Mature, **Meticulous**, **Operational**, Opportunistic, Persistent, Political, Principled, Private, Proactive, **Protective**, Self-Controlled, Sensible, Sincere, Steadfast, **Skeptical**, Straightforward, Supportive, **Technical**, Willing, Zealous

- Good leadership, particularly considering attributes in bold, tends to be more critical than good management for achieving desirable outcomes envisioned by principal stakeholders.

Leadership/Engineering Management Aspects Considered in These Examples

- Leadership/Management Style
- Vision/Mission Emphases
- Short/Medium/Long-Term Focus
- System Boundary Definitions
- Contingency Planning Thrusts
- People Relationships Characterizations
- Humble/Confident/Conceited Attributes
- Selfish/Selfless-ness Tendencies
- Information Sharing/Trust Building
- Career/Program-Orientations
- Decision-Making Techniques
- Timeliness/Delay Awareness
- Political/Operational/Economic/Technical Considerations
- Technical Competencies
- Opportunity Pursuit/Risk Mitigation Trade-Offs
- Success/Adversity Handling
- Adaptability/Evolutionary Capacities

Aspect Characterizations by Program/Project (1 of 2)

Leadership/Management Aspect ₩ Program:	Technical Intelligence* – USAF (1962-1965)	Satellite Command Link* – MIT LL (1965-1967)	Communication to Submarines* – MIT LL (1967-1969)	Monte Carlo Methods – Univ. of Wisconsin (1969-1973)	Satellite Band-Pass Limiter – MIT LL (1973-1974)	BW Efficient Modulations* – MIT LL (1975-1976)	SatCom Architectures – MITRE (1977-1979)	Satellite Multiple-Access Network Control – MITRE (1979-1981)
Leadership/Management Style	Arrogant; Autocratic; Hierarchical	Encouraging; Guiding; Technical	Guiding; Technical; Programmatic	Academic; Benign; Suggestive	Arrogant; Demanding; Directive	Encouraging; Supportive; Technical	Political; Supportive; Technical	Encouraging; Supportive
Vision/Mission Emphases	Cold War; Military	Experimental Satellites	Technical Breakthrough	Esoteric; Research	Satellite Sharing	FDMA Low-Crosstalk Uplinks	Balanced System Costs	Accommodate Varied Users
Short/Medium/Long-Term Focus	Short	Medium	Long	Medium	Short	Long	Long	Short
System Boundary Definitions	Broad	Limited	Moderate	Limited	Limited	Moderate	Broad	Limited
Contingency Planning Thrusts	None	Some	Some	None	None	Some	Significant	None
People Relationships Characterizations	Respectful	Nurturing	Little	Independent	Little	Mixed	Respectful	Respectful
Humble/Confident/Conceited Attributes	Conceited	Confident	Confident	Conceited	Conceited	Confident	Conceited	Confident
Selfish/Selfless-ness Tendencies	Selfish	Selfless	Selfless	Selfish	Selfish	Selfless	Selfish	Neither
Information Sharing/Trust Building	Yes/Some	Yes/Yes	Yes/Yes	Yes/Mixed	Yes/No	Yes/Yes	Yes/No	Yes/Mixed
Career/Program-Orientations	Career	Program	Program	Career	Career	Program	Program	Program
Decision-Making Techniques	Political	Technical	Technical	Technical	Technical	Technical	Political	Technical
Timeliness/Delay Awareness	Some/None	None/None	Some/None	None/None	Yes/None	None/None	Yes/Yes	None/None
Political/Operational/Economic/Technical Considerations	All	All	All	Technical	All	All but Political	All	All but Political
Technical Competencies	Little	Lots	Lots	Outstanding	Yes	Yes	Yes	Some
Opportunity Pursuit/Risk Mitigation Trade-Offs	Opportunities	Opportunity	Opportunity	Opportunities	Opportunity	Opportunity	Risks	Opportunity
Success/Adversity Handling	Good	Poor	Good	Good	Okay	Excellent	Okay	Good
Adaptability/Evolutionary Capacities	Some/Some	Some/Some	Good/Good	Little/Little	Little/None	Good/Good	Little/Little	Good/Little

Aspect Characterizations by Program/Project (2 of 2)

Leadership/Management Aspect ₩ Program:	Private Small Business – SIGNATRON (1981-1986)	Freq.-Hopping (FH) Radios* – MITRE (1986-1993)	Civil Aeronautical Communication* – MITRE (1993-1997)	Division Managing Task Leaders – MITRE (1997-1999)	Military Global Grid Architecture – MITRE (1999-2002)	Class of Functions Architecture – MITRE (2003)	SE Process Office (SEPO) – MITRE (2003-2009)	Future Joint Tactical Data Link (JTDL)* – MITRE (2010)
Leadership/Management Style	Arrogant; Business; Moral	Demanding; Loyal; Programmatic	Competitive; Political; Technical	Autocratic; Controlling; Intimidating	Encouraging; Guiding	Autocratic; Political; Supportive	Conservative; Political; Technical	Directive; Political; Programmatic
Vision/Mission Emphases	Customer-Oriented; Profit	Anti-Jam Performance	Efficiency and Safety	Air Force SE	Layered Architecture	Counter Platform-Centricity	Best Practices	Software Radios & Interoperability
Short/Medium/Long-Term Focus	Short	Short	Medium	Medium	Long	Medium	Medium	Short
System Boundary Definitions	Moderate	Moderate	Broad	Limited	Broad	Moderate	Broad	Moderate
Contingency Planning Thrusts	Some	Significant	Much	None	Much	Some	Some	None
People Relationships Characterizations	Family	Family	Little	Absent	Caring	Absent	Little	Absent
Humble/Confident/Conceited Attributes	Confident	Conceited	Conceited	Conceited	Confident	Conceited	Confident	Conceited
Selfish/Selfless-ness Tendencies	Selfish	Selfish	Selfish	Selfish	Selfless	Selfish	Mixed	Selfish
Information Sharing/Trust Building	Yes/Mixed	Yes/Mixed	Yes/No	Little/No	Yes/Yes	Some/No	Limited/Little	Little/No
Career/Program-Orientations	Program	Program	Program	Program	Program	Career	Career	Career
Decision-Making Techniques	Business	Heuristic	Political/Technical	Political/Technical	Political/Technical	Political/Technical	Fact-Based	Political
Timeliness/Delay Awareness	Yes/Mixed	Some/Little	Yes/Yes	Yes/Some	Yes/Some	None/None	Yes/Some	Yes/Yes
Political/Operational/Economic/Technical Considerations	All	All	All	Political/Technical	All	All	All	All
Technical Competencies	Yes	Yes	Some	Yes	Yes	Some	Lots	Some
Opportunity Pursuit/Risk Mitigation Trade-Offs	Both	Both	Both	Risks	Opportunities	Opportunity	Risks	Risks
Success/Adversity Handling	Good	Excellent	Okay	Good	Good	Okay	Okay	Poor
Adaptability/Evolutionary Capacities	None/Little	Some/Good	Good/Little	None/None	Little/Some	Some/Little	Little/None	Little/None

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Abridged

See Notes Page

Systems Engineering Decision Making May Be More Emotional Than Rational!

Brian E. White, Ph.D.

9 July 2012

22nd Annual INCOSE International Symposium, Rome, Italy, 9-12 July 2012

Abstract
The Issue
Introduction

- Abstract
  - Do systems engineers decide rationally or emotionally?
    - Survey result: Most work-related decisions are made rationally but many, more emotionally than one might think.
- Introduction
  - Descartes was wrong! (Antonio Demasio)
  - We operate on our subconscious; make decisions emotionally; and are happy through relationships. (David Brooks)
  - Hypothesis: Systems engineers would say decisions are made rationally; and because it was politically correct.
  - Most I spoke with acknowledged emotional content.
  - Were survey responses genuine? Some agonized!

The Invitation

Decision Making Survey Invitation

- Decision Making Survey Invitation(s)
  - 20 minutes to complete
  - Excel format
  - Voluntary
  - Partially, if uncomfortable
  - Treated confidentially; reported in aggregate
- 468 requests sent
  - 60 respondents
  - 14.5% response rate

The Survey Questions (1/3)

- Q1) In your most recent project/program where systems engineering played a significant role, to what extent do you remember decisions being made based on reason vs. emotion, and how often was that?
  - Technology
  - Economics
  - Operations
  - Politics
  - Regulations
  - Programmatic Aspects
  - External Factors
  - Personal Factors
- For each part select one **(R, E) pair**
  - Primarily Rational: (R=100%, E=0%)
  - More Rational: (R=75%, E=25%)
  - About Equal: (R=50%, E=50%)
  - More Emotional: (R=25%, E=75%)
  - Primarily Emotional: (R=0%, E=100%)

See Notes Page

Questions (2/3)

- For each part select one **Frequency**
  - Almost Never: 1
  - Some Times: 2
  - Half Times: 3
  - Most Times: 4
  - Almost Always: 5
- Q2) In your personal life how would you characterize your own decision making?
  - Budgeting
  - Career
  - Entertainment
  - Family
  - Job
  - Recreation
  - Relationships
  - Shopping
- Q3) After having thought about and filled out this survey, characterize your planned overall future decision making.
  - Work Life
  - Personal Life

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Scoring (1/3)

- Each **(R, E) pair** was multiplied by **Frequency** (weight).
- For example, More Rational and Most Times yields

  $((R=75\%)\times 4,\ (E=25\%)\times 4) = (3, 1)$
- Larger R (E) score, more rational (emotional) decision
- R and E scores totalled for each question
- Array of any respondent's scores can be displayed in bar chart (next chart)
- All total scores for Row i were divided by number of respondents, N_i of Row i, to obtain average score

Scoring (3/3)

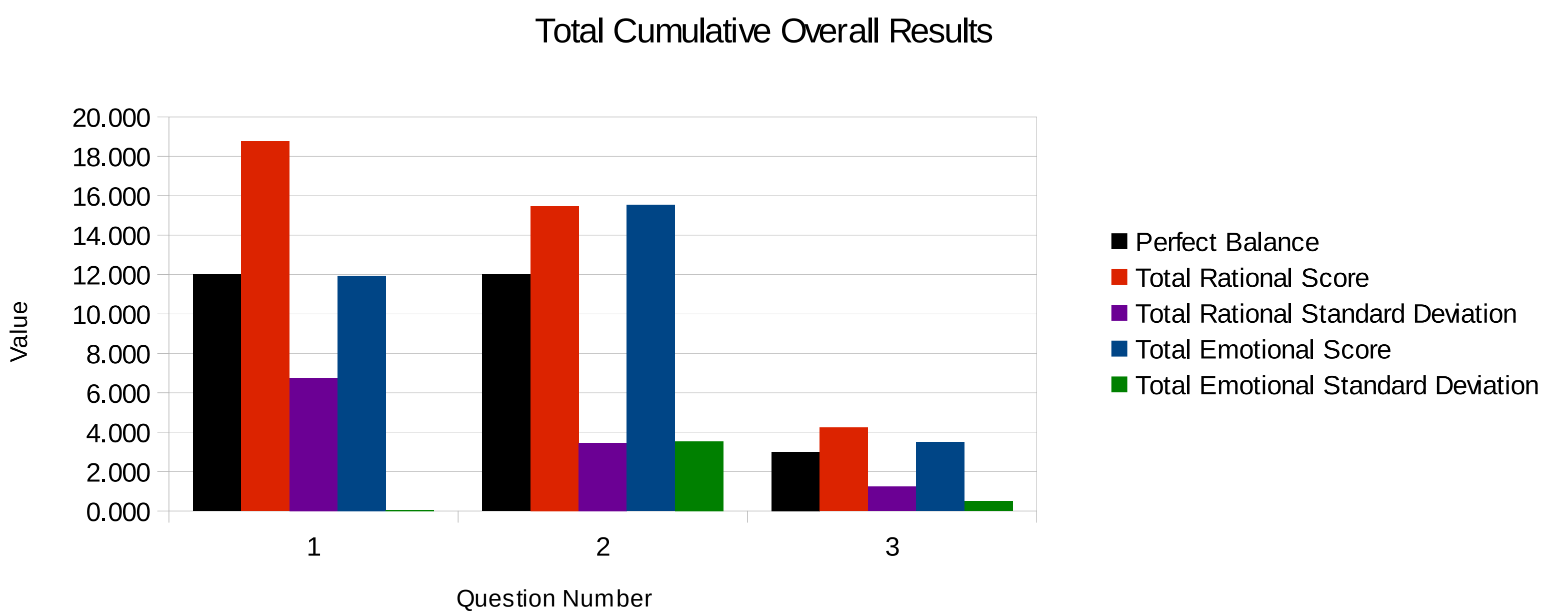
- Blank rows not scored; would bias results

- R or E score variance about balanced score = (avg. row score – 1.5) exp(2)
- Standard deviation = √ variance

- Nominal (with balanced selections of About Equal (R=50%, E=50%) and Half Times, Weight=3) total scores over
  - 8 rows of Questions 1 and 2 is (50%×3, 50%×3) × 8 = (12, 12)
  - 2 rows of Question 3 is (1.5, 1.5) × 2 = (3, 3)

Numerical Data for All Groups (Table 3)
Overall Results for All Groups (Figure 11)

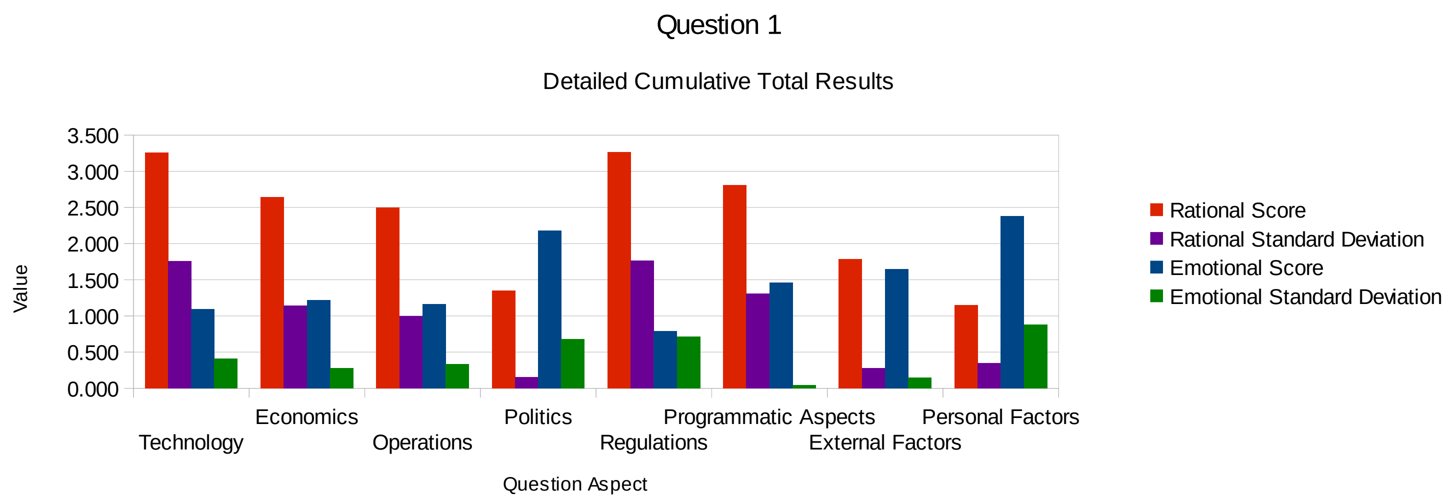
Question	Perfect Balance	Total Rational Score	Total Rational Standard Deviation	Total Emotional Score	Total Emotional Standard Deviation
1	12	*18.754*	*6.754*	*11.936*	*0.064*
2	12	*15.462*	*3.462*	*15.538*	*3.538*
3	3	*4.230*	*1.230*	*3.499*	*0.499*

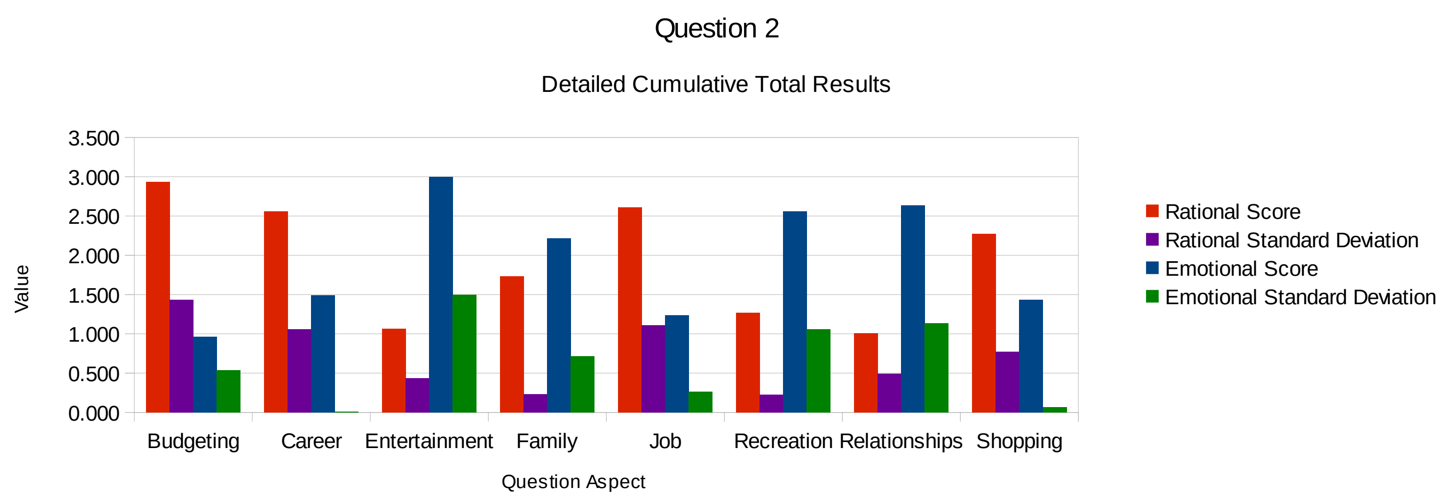


Combined (Total) Results of All Groups (3/5)

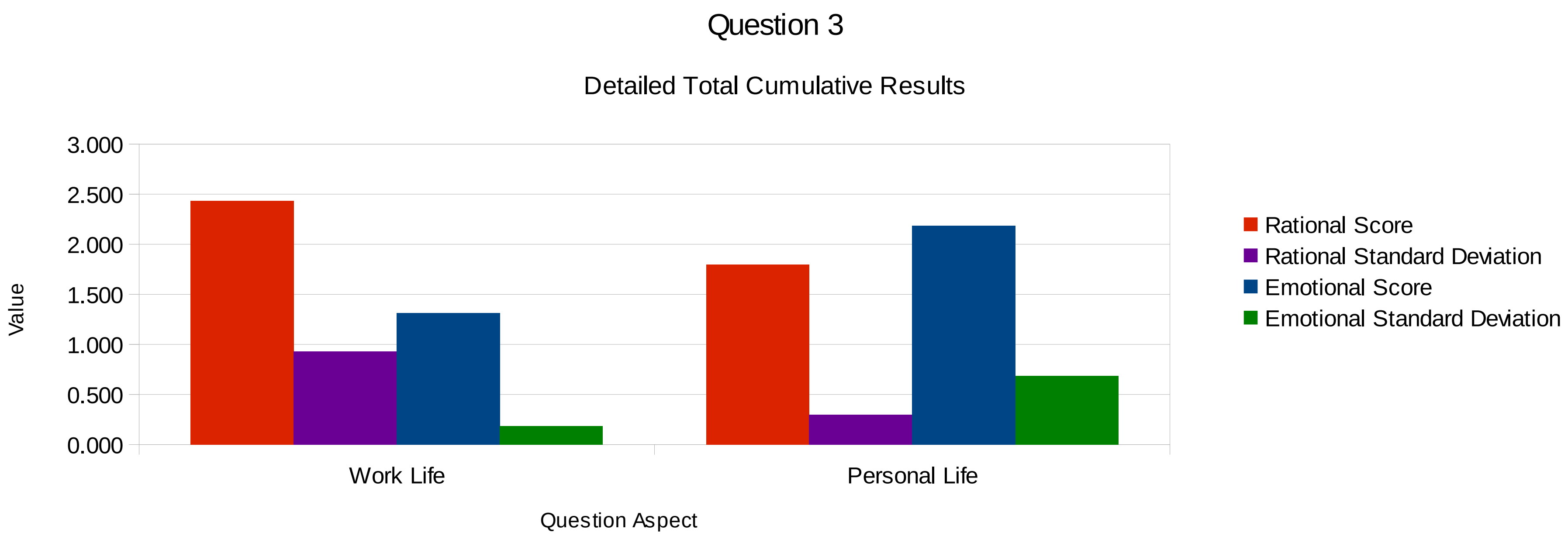
- Question 1
  - Personal Factors and Politics are largest in Emotional content.
  - External Factors and Programmatic Aspects come next.
  - Regulations and Technology have strongest Rational content.
  - Economics and Operations follow Programmatic Aspects in Rational content.
- Question 2
  - Entertainment, Relationships, and Recreation decisions have greatest Emotional content.
  - Followed by Family
  - Budgeting, Job, and Career have largest Rational content.
  - Followed by Shopping
- Question 3
  - Work Life promises to be significantly more Rational.
  - Personal Life is more Emotional.

Detailed Question 1 Results for All Groups (Figure 12)
Detailed Question 2 Results for All Groups (Figure 13)





Detailed Question 3 Results for All Groups (Figure 14)



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Conclusions

- Total results for all survey groups
  - Question 1 (Work Place)
    - Significant Emotional content in Personal Factors, Politics, Programmatic Aspects (just under perfect balance), and External Factors.
    - Rational dominates in Regulations, Technology, Programmatic Aspects, Economics, and Operations.
  - Question 2 (Personal Life)
    - Emotion dominates in Entertainment, Relationships, Recreation, and Family.
    - Career and Shopping are nearly perfectly balanced in Emotional content.
    - Budgeting, Job, Career, and Shopping have most Rational content.
  - Question 3 (Future)
    - Work Life is much more Rational
    - Personal Life is more Emotional
- Several correspondents questioned response authenticity and suggested Emotional component might be stronger in actual practice. I agree! ☺

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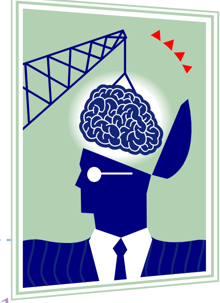

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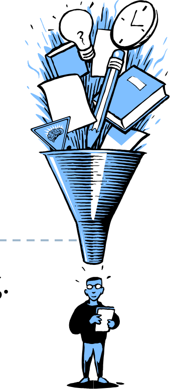

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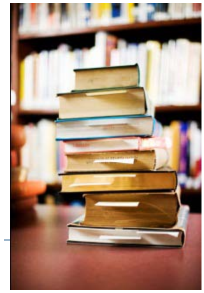

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Partial List of Abbreviations and Acronyms

ADOCS = Air Defense Operations Center System
AF = Air Force
AFB = Air Force Base
AFC = Air Force Center (CAFC2S)
AFMC = Air Force Material Command
AMC = Air Mobility Command
AOC = Air Operations Center
ARINC = Aeronautical Radio, Inc.
ASE = Architecture-based Systems Engineering
ASR = Acquisition Strategy Report
ATC = Air Traffic Control
AT&L = Acquisition, Technology, and Logistics
ATM = Air Traffic Management
ATO = Air Tasking Order
AWACS = Airborne Warning and Control System
BKCASE = Body of Knowledge and Curriculum to Advance Systems Engineering
BoK = Body of Knowledge
BRAC = Base Realignment and Closure
BW = bandwidth
C2 = Command and Control
C4ISP = Command, Control, Communications, Computers, and Intelligence Support
CAA = Civil Aviation Authority
CAASD = Center for Advanced Aviation Systems Development
CAFC2S = Center for Air Force Command and Control Systems
CAS = Complex Adaptive Systems
CASA = Center for Acquisition and Systems Analysis
CASTLE = Complex Adaptive Systems – The Leading Edge
CBA = Capabilities Based Acquisition

Partial List of Abbreviations and Acronyms (Continued)

CCN = Computers, Communications, and Networking
CCRP = Command and Control Research Program
CD = compact disc
CDR = Critical Design Review
CMMI = Capability Maturity Model Integration
CNS = Communications, Navigation, and Surveillance
COI = Community of Interest
CoT = Cursor on Target
COTS = Commercial Off-the-Shelf
CPA = Capability Planning Analysis
CS = Complex Systems
CSE = Complex-System Engineering (or cSE)
CSER = Conference on Systems Engineering Research
CTC = Concurrent Technologies Corporation
DARPA = Defense Advanced Research Projects Agency
DHS = Department of Homeland Security
DNS = Domain Name Service
DoC = Department of Commerce
DoD = Department of Defense
DoDAF = Department of Defense Architecture Framework
DOS = Disk Operating System
EA = Enterprise Architecture
E/A = Evaluation/Assessment
E/C = Enterprise and/or Complex
EE = Enterprise Engineering
EI = Enterprise Integration
ESC = Electronic Systems Center
ESD = Engineering Systems Division

Partial List of Abbreviations and Acronyms (Continued)

ESE = Enterprise Systems Engineering
ESEO = Enterprise Systems Engineering Office
FAA = Federal Aviation Administration
FDMA = Frequency Division Multiple Access
FEAF = Federal Enterprise Architecture Framework
FFRDC = Federally Funded Research and Development Center
FOC = Full Operational Capability
FoV = Field of View
Freq. = frequency
FRP = Full Rate Production
FUV = Fundamental Unique Value
GAO = General Accounting Office
GIG = Global Information Grid
GLONASS = Global Navigation Satellite System
GPS = Global Positioning System
GRCSE = Graduate Reference Curriculum for Systems Engineering
IBR = Initial Baseline Review
ICAO = International Civil Aviation Organization
ICD = Interface Control Document
IEEE = Institute of Electrical and Electronics Engineers
IG = Innovation Grant
ILS = Integrated Logistics Support
INCOSE = International Council on Systems Engineering
IOC = Interim Operational Capability
IOTE = Initial Operational Test & Evaluation
IR&D = Internal Research and Development
ISR = Independent Safety Review

Partial List of Abbreviations and Acronyms (Continued)

IT = Information Technology or Information Theory
ITR = Independent Technical Review
IVHS = Intelligent Vehicle Highway System
JEFX = Joint Expeditionary Force Experiment
JHU = Johns Hopkins University
Joint STARS = Joint Surveillance & Target Attack Radar System
JPDO = Joint Planning and Development Office
JWID = Joint Warfighter Interoperability Demonstration
LCSE = Linearity, Complexity, and Systems Engineering
LL = Lincoln Laboratory
LST = Linear System Theory
MI = MITRE Institute
MITRE = The MITRE Corporation
MIT = Massachusetts Institute of Technology
MOIE = Mission Oriented Independent Engineering
MSR = MITRE Sponsored Research
MTP = Maintenance Test Plan [or Package]
NASA = National Aeronautics and Space Administration
NAS = National Airspace System
NCOW = Net-Centric Operations and Warfare
NDAA = ???
NDIA = National Defense Industrial Association
NEAC = NAS Enterprise Architecture Council
NECSI = New England Complex Systems Institute
O = order
OOS&E = Operational Safety, Suitability and Effectiveness
OT&E = Operational Test and Evaluation

Partial List of Abbreviations and Acronyms (Continued)

OTRR = Operational Test Readiness Review
OUSD = Office of the Under Secretary of Defense
PCA = Physical Configuration Audit
PDR = Preliminary Design Review
PERT = Program Evaluation and Review Technique
POC = Point of Contact
POET = Political, Operational, Economic, and Technical
POM = Program Objective Memorandum
RTCA = (was) Radio Technical Commission for Aeronautics (is no longer an acronym)
SA = Situational Awareness
SAB = Scientific Advisory Board
SatCom = satellite communication
SE = Systems Engineering
SEBOK = Systems Engineering Body of Knowledge
SEP = Systems Engineering Plan
SEPO = Systems Engineering Process Office
SFR = System Functional Review
SoA = Service Oriented Architecture
SoS = System of Systems
SoSE = System of Systems Engineering
SoSECE = System of Systems Engineering Center of Excellence
SRR = System Requirements Review
STP = Strategic Technical Plan
SUA = Special Use Airspace
SW = software
TBMCS = Theater Battle Management Control System
TCT = Time Critical Targeting

Partial List of Abbreviations and Acronyms (Concluded)

TP = Technology Planning
TRA = Technical Readiness Assessment
TRR = Technical Readiness Review
TSE = Traditional Systems Engineering
UCSD = University of California at San Diego
U of I = University of Illinois
Univ. = University
URL = Universal Resource Locator
U.S. = United States
USAF = United States Air Force
USC = University of Southern California
UVM = University of Vermont