COMPLEXITY CONFERENCE WHITE PAPER

COMPLEX VENTURE ACQUISTION

LINDA J. VANDERGRIFF, D.SC.

LINDA.J.VANDERGRIFF@AERO.ORG

Printed in the United States of America

ABSTRACT

This white paper provides initial insights on how to accommodate the demands that are not being met by the 20th Century System Engineering model[1]*. Complicated isolated systems and physical capital dominated systems of systems lent themselves to traditional "grand, all-at-once" 20th Century system engineering. The complexity concepts explored in "complex systems" literature also focus on a limited set of complicated asset and connectivity only solution sets. As observed in Complexity Theory, it is not necessary for a solution to be large in scope, complicated, or have a high number of interfaces to exhibit complex behaviors. Rather 21st Century solutions deal with behaviors arising from the interdependence of users, technology, and context often referred to "wicked" problems. It is important to clearly define a model to inform the Architecting and Systems Engineering Acquisition best practices. To do this one must first explore the fundamental differences in defining, developing, and implementing complicated systems and complex ventures*[2]*. The proposed Complex Venture model builds upon the insights derived from chaos and complexity theories; observations of several acquisitions successes and failures; and my doctoral research on decision support for Agile Enterprises.*

---

[1] Reductionist theories fall short of the real world experience (e.g., neuroscience, meteorology, physics, computer science, evolutionary computation, economics, earthquake prediction, heart cell synchronization).

[2] A complex venture is an undertaking that exhibits the ability to self-adapt to changes in its co-evolving context, its internal capabilities, and its stakeholder interest using coherent principles and integrated resources to provide solutions with the desired behavior and value for one specific project or in a continuing enterprise.

CHAPTER 1. INTRODUCTION

Lissack[a] (2000) identified the current business and system engineering approach as a 17th century invention. It represents the world as a machine with linear mechanistic behaviors that result from simple cause and effects. In this model, the organization consists of separate parts (e.g. division of labor) that do separate functions (e.g. sequential flow processes) with little interaction except for control and reporting communications. The model includes an hierarchical worldview where top management is in control and makes decisions, and production line workers implement them (Apte, Beath, and Goh[b], 1999). It assumes that well-informed long-term deliberations make good long-term commitments of resources for forecastable futures.

All models of the world are, by their very nature, imperfect approximations of reality. Significant misunderstanding has arisen by confusing a model's representation of reality and reality itself. The model's ontological commitments only reflect a decision on what is important to value and practical to ignore about the real world. Systems Engineering has made a set of ontological commitments that focused on the physical capital assets that were relevant to successful Industrial Age solutions.

However, model assumptions can blind the modeler to real world effects. An instructive example of the implications of such ontological commitments is the electronic circuit "lumped element" model as described by Davis and Shreobe[c] (1983). The circuit is modeled as components and connections. The model represents signals flowing instantaneously along the connections and limited change occurring in the components. This model is very effective for its use, but it does not support electrodynamics well. When the signal propagating speed is finite, a simple in/out behavior no longer models the resistor adequately. A better model exhibits the complex behavior of an extended medium through which the electromagnetic wave propagates. This example is analogous to the difference between the expected behavior of the complicated "widget" system and the observed complex behavior of new solutions.

Industrial Age complicated isolated systems and physical capital dominated systems of systems within a slowly changing context lent themselves to a traditional "grand, all-at-once" 20th century system engineering approach (Bechtold, 2003)[d]. These methods included decomposition and assembly line development processes reflected in the currently used engineering "V." The focus for these systems is widgets controlled through requirements and interface specifications with forecastable or boundable technology trends. Unfortunately, this approach does not reliably scale up when addressing large, complex Intelligence Age[3] solutions in a co-evolutionary context.

An indicator of one problem with 20th Century Systems Engineering is the inordinate amount of time and effort expanded to define the "new" lexicon for Intelligence Age solutions. Confusion seems to surround the definition of "System",

---

[3] Kirk Tyson coined term Intelligence Age in 1997. The currently used term the Information Age was coined by AT&T marketing and represents the messy transition from physical capital dominant Industrial Age to the intellectual capital dominant Intelligence Age. Here Intelligence is the translation of measurement, data, information, knowledge, wisdom into a user frame of reference to support decision-making and implementation.

"Systems of Systems"[4], "Federated Systems", "Complex Adaptive Systems", "Enterprises", "Mega Systems", "Meta Systems", etc. The problem arises from the focus on the system model of interacting "widgets" that change slowly, if at all, in the development and delivery timeframe, the non-co-evolutionary nature of the system and its context, and the inability to address the value of timely reliable intelligence.

Several attempts have been made to put a Band-Aid on this 20th Century worldview by creating Operational or Enterprise Architectures, advocating Horizontal Integration, proposing complex systems engineering, using network models[5], developing technology portfolios, and identifying non-materiel solutions. Thus, continuing the debate about a system composed of "things that interact" while Systems Engineers focus completely upon the widget's decomposability, control and predictability, and linear implementation methods.

This white paper provides initial insights on how to accommodate the demands that are not being met by the 20th Century System Engineering model. Since models or metaphors are a "basic structural form of experience, through which human beings engage, organize, and understand their world" (Morgan[e], 1983), it is important to clearly define the models used to inform the Architecting and Systems Engineering Acquisition processes. Thus, this paper explores fundamental differences between defining, developing, and implementing under the Complicated Systems and Complex Ventures models. This exploration lays the foundation for research into better frames of reference for Complex Venture representation[6]. It builds upon the insights derived from chaos and complexity theories, observations of several acquisitions successes and failures, and my doctoral research on Decision Support for Agile Enterprises.

---

[4] Term coined by M. Maier in 1996. The terms includes integration of operationally distinct systems, rapid evolution of needs and technologies, disparate stakeholders, distributed development, and dependence upon intelligence sharing infrastructure

[5] Significant modeling of Complex Ventures has been done using network models and topology. Some of the insights gained from this work are used here but it outside the scope of this paper to summarize all this work.

[6] Similar to the way that a polar coordinate system is a simpler means of representation than Cartesian coordinates for some cases of problems.

CHAPTER 2. CHAOS THEORY

An Architect or Systems Engineer encountering this field would first ask, "What is Chaos?" shortly followed by, "How will it cause me problems?" Some Systems Engineers immediately react to perceived negative impacts of chaos and attempt to reduce or eliminate it. Unfortunately, as observed by Wolfram (2002) the strictures this engenders on the potential solution space is very large. It also does not reflect the experienced Intelligence Age realities.

The science of chaos has developed a very specialized language that is easily confused by those not involved in the scientific investigation. It is important for understanding the acquisition of complex ventures that terms such as chaos, complexity, and nonlinearity are not used indiscriminately.

In work done on Complex Adaptive Systems research (Kauffman[f], 1995; Waldrop[g], 1993; Langton[h], 1992; Wolfram[i], 1986) system behaviors were classified into four distinct classes or zones of Chaos:

Class I	Steady State
Class II	Static patterns or oscillation between fixed states
Class III	Wild variation with no predictable pattern
Class IV	Extended transients[7]

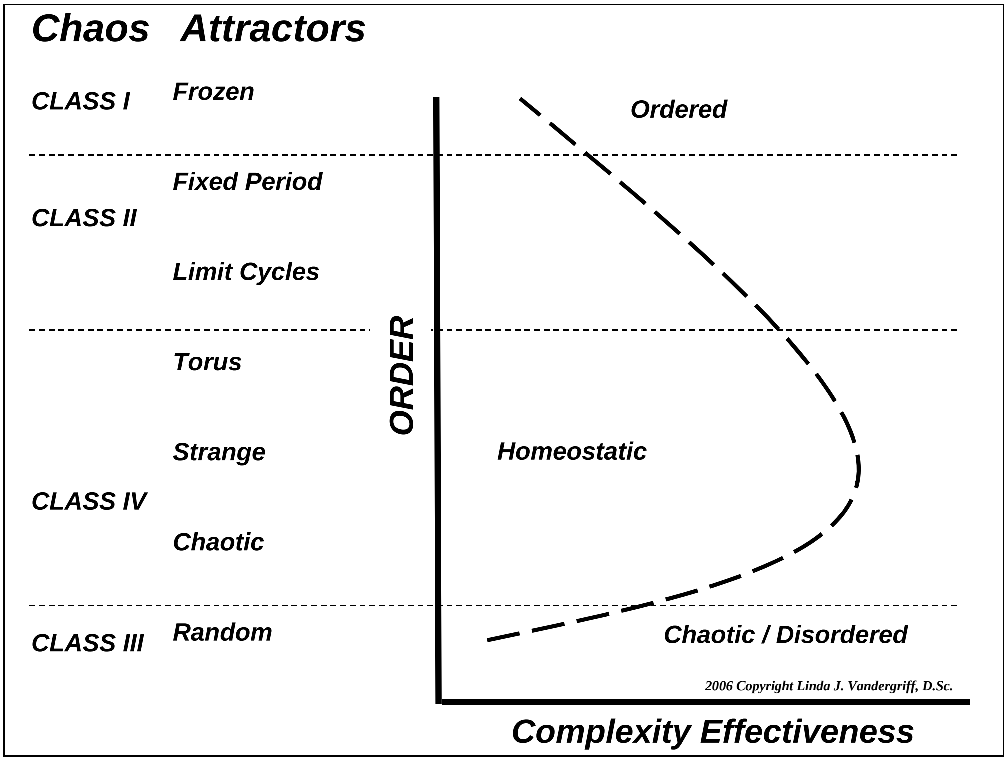

Figure 1 Mapping of Complexity Effectiveness versus Venture Order

---

[7] Actually operates between Class II and Class III

Santosus (1998) simplified this into three zones: Stable (Class I & II), Chaotic (Class III), and Creative (Class IV). In Figure 1, the Chaos Classes are mapped to the degree of order. Complexity effectiveness is plotted for the various classes and the applicable attractors.

Industrial Age systems were designed to operate in the Class I and II, with steady states and static patterns of continuous growth toward fixed predictable goals. Conner[j] (1998), in his book *Managing at the Speed of Change and Leading at the Edge of Chaos,* asserts action in the Class IV (e.g., "edge of chaos") provides an enterprise the ability to succeed in the Intelligence Age environment. The venture operating in this regime realizes the maximum benefit of short-term stability, while retaining capacity to nimbly change. Although behavior is predictable over the short "transient" time, over a long term it is unpredictable. Thus, the important concepts that empower the capability to work in Class IV are real time situational awareness, agent empowerment, and coherent leadership. This class requires innovation, learning, and planning for the leaders and members of the Complex Venture. (Stacey[k], 1996; Plelan[l], 1995)

In my research, I have identified that Complex Ventures exhibit four different change coping characteristics: robustness, flexibility, adaptability, or agility. In Class III, ventures must be robust enough to withstand or flexible enough to bend and recover from constant change. In Class IV, ventures can adapt to the new states or conditions or become agile to avoid or leverage new states or conditions. Thus, a decision based on the desired operational behavior must be made on what set of coping characteristics should be used as the Complex Venture experiences the various Classes of Chaos. Not recognizing the Chaos Class context contributes to increased probability of cascading failures and decreased numbers of leveraged opportunities.

CHAPTER 3. COMPLEXITY THEORY

Complicated and complex models of reality have inherently different characteristics and descriptions. Lissack and Roos[m] (2000) have described the differences between a model of the world that has discrete, yet complicated, structure and one that has interdependent complex structure. The insight, they explain, lies in the roots of the two words. “Complicated” uses the Latin ending “plic” that means, “to fold” while “complex” uses the “plex” that means, “to weave.” Thus, a complicated structure is one that is folded with hidden facets and stuffed into a smaller space. On the other hand, a complex structure uses interwoven components and context that introduce mutual dependencies and produce more than a sum of the parts. In today’s solutions, this is the difference between a myriad of connecting complicated “stovepipes” with varying description lengths over scales and effective complex “integrated” solutions composed of both simple and complex systems varying over time to increase fitness.

The textbook Systems Engineer’s decision space assumes a closed system[8] that is decomposable, linear, and predictable. The proposed Complex Venture model describes properties found in open systems[9] that violate all three of these assumptions. Interconnection and flow of energy, information, and materials with the context dominate Common Venture model properties. Thus, the architect and systems engineers’ focus is on the relationships of the evolving nodes[10] and the environment/context that provide the desired capabilities as opposed to previous emphasis on static node construction with measurable qualities.

Initial realization of a need for more than standard systems engineering for modern solutions was first articulated as a need for “interoperability.” Systems Engineers identified architecting products and standards to help develop integrated solutions composed of many simple and complicated systems. Interfaces were negotiated through interface requirements documents. As the systems expanded, the number of interface requirement documents grew. This led to unexpected conflict and loss of flexibility. To alleviate this problem, modularity and standard interfaces were championed to reduce complexity and interconnectedness.

The Complex Venture model representation is appropriate when the behavior is dominated by the interdependencies and flows, rather than the nodes. Thus, the measure of the “widgets”, connectivity, or the representation of reality such as description length[11] does not reliably predict the degree of complexity. The true indicator of a complex venture is its focus on the interdependence of the nodes and context over time to produce desirable benefits and behaviors.

---

[8] From Systems Theory a closed system is self contained and not influenced by its external environment.

[9] Open systems allow matter, energy, or information to flow into and/or out of the system making its behaviors subject to its surrounding environment and other systems. It is influenced by events outside of the actual or conceptual boundaries of the system. The discussion of the implications for the second law of thermodynamics is outside the scope of this paper, but is of great interest especially based on Wolfram’s (2002) experimental results in this area.

[10] These evolving nodes can be composed of complicated or simple systems providing various capabilities.

[11] In the example of the six blind men and the elephant, it does not change the elephant only its representation. A sighted person could give a more holistic description where the blind man would say a wall, a tree trunk, or a hose. Neither description makes the elephant complex or not complex.

CHAPTER 4. COMPLEX VENTURES INSIGHTS

Many desirable properties (e.g., innovation, adaptability) arise from the woven nature complex ventures. Three main characteristics of the Complex Venture model are summarized with insights into areas applicable to current Architecting and Systems Engineering practice.

- Dynamic Co-evolution: to maintain or even increase the fitness of the venture to a changing context.
- Emergent Behavior: providing more than the basic combination of the individual nodes and connections should generate.
- Non-linearity: results in small changes can, over time, have large impacts, while large changes can result in minimal effects.

4.1 FITNESS LANDSCAPE AND SELF-ORGANIZATION

Initially, Architects and Systems Engineers characterize Complex Ventures with a projected set of users, needs, uses, and technologies in a predicted set of scenarios. These co-evolve to fit an unknowable user set with potentially different needs, uses, and technologies.

The "fitness landscape[12]" is an n-dimensional construct used for describing the "fitness" between any solution state and its context. In a static fitness landscape, the hills and valleys do not change over the solution lifetime and, thus, linear planning is very effective and measures of performance are straightforward. The goal for every solution is to find and operate at the global maximum through efficiently improving performance of the driving measures.

However, one of the key understandings derived from the Complex Venture model is the unpredictable dynamic nature of the interdependence of the venture and its context. With the collapsing floats[13] (e.g., intelligence, technology, culture), the development time often is longer than the stable time represented by the float. Thus, the Complex Venture model must account for a context that is constantly evolving and morphing. This dynamic fitness landscape is like being at sea, where the wave peaks change position with time. With adaptiveness or agility, a complex venture can change locations in the fitness landscape and stay at a localized maximum. However, the solution fitness will also vary in time, even if it tries to stay stationary. (Lucas[n], 2002)

---

[12] An n-dimensional surface characterized as a mountain range with local peaks of higher fitness and valleys of lower fitness to the needs or goodness of the solution. This concept is used to describe the evolutionary pressures and goodness of solutions. The steeper the slope the greater the selection pressures are. The complex ventures fitness landscape changes dynamically changing.

[13] Hock, founder of Visa International, identified the "collapse of float." Before the world was so connected, concepts and things took time to travel. The knowledge about how to smelt iron took almost a century to cover the European continent, ushering in the Iron Age. Today, intelligence is available in minutes, if not seconds. Thus, information float has virtually disappeared. Technology floats are minimal, with new technology adoption happening in months or days. With cultural floats, popular trends sweep across the world almost instantaneously. (Hoffman, 2002)

Now consider the business environment, where it is not only the landscape that is changing, but, also, all the other organizations and technology solutions in the landscape. This then creates the "co-evolutionary fitness landscape."

The goal with a co-evolutionary complex venture provided capabilities that effectively[14] meet the user expectations and needs. The dynamic fitness landscape does not quickly map into functionality (e.g., engineering speak) that is used to develop today's systems. Rather it focuses completely upon usability or desirability of the provided behavior or capability (e.g., user speak). If the complex venture does not ensure the latter then little value will be derived. Today's ventures try to ensure user satisfaction with early and often customer/end-user evaluation and feedback to ensure developers deliver what is needed not what was originally proposed.

Most engineers are very talented in designing and delivering systems with complicated feature sets for very demanding requirements and specifications. They are, on the other hand, less adept at communicating solution benefits and performing trade-offs between "widgets" and non-materiel solutions. In addition, they have difficulty in translating stakeholder needs into non-materiel solutions.

In this complex fitness landscape with many hills and valleys, finding local optima can trap an organization into a sub-optimal choice, much like a troop of soldiers taking the wrong hill. The goal of any complex venture is to traverse the virtual fitness landscape looking to find high ground. If a solution is stable, it will settle and stay at the first maximum found. However, diverse empowered agents are more hyperactive and dither around to try to locate better maximums. Thus, it is important to allow self-organizing[15] units to form and to find the maximums. The key is to ensure that these self-organizing units or entities, acting selfishly, interact sufficiently to bring the whole venture toward a "sufficing" optimum. This drives a need for a diverse set of competitive self-organizing agents to sense and respond to a changing context. This in turn means more decision-making at the point of contact to improve "fit" to the changing context. It is imperative that those making the decisions and implementing them have communications and access to the venture intelligence, energy, and matter.

It is in this environment that "coherent" leadership proves invaluable. Pasternack º, (1998) states that enterprise "coherence is when all the components are mutually reinforcing." Coherence allows the activities of the organization to be based on a vision, purpose, identity, and context. Coherence allows forward, instead of purely Brownian, motion. (Lissack and Roos, 2000)

To ensure clear and consistent Complex Venture channels of communication (i.e., coherence) tools such as invariant and derivative architecture products, intelligence management tools, and Communities of Practices are useful.

---

[14] Effectiveness and timeliness, not efficiency, is valued in the one of a kind complex venture.

[15] Self-organization is the spontaneous appearance of large-scale organizational, spatial, temporal, or information order in a system of locally interacting simple entities.

Invariant architecture products are tools to help guide decision-making and monitor decision implementation and success. They perform this function through communicating the venture vision and the context objectives. In addition, derivative architecture products support sharing of knowledge learned about the Complex Venture, its rules and standards, its emergent behaviors, opportunities, and potential issues.

Intelligence management tools empower the individual agents with the capability for the observation and orientation that informs their real-time decision-making and implementation. This is much like the pilot's OODA loop[16][p][q] that allows adaptiveness and agility in combat.

Communities of Practice help in the socialization of tacit knowledge[17] not available in automated explicit knowledge[18] repositories. In addition, it may facilitate collaborative solutions that also exhibit Complex Venture benefits such as emergent solutions.

4.2 EMERGENT BEHAVIOR

Everyone has experienced emergent behavior. As Aristotle observed, "a whole is more than a sum of its parts." Emergence is a valuable consequence of the interdependencies of the threads and context. For human organizations, it translates into surprising creativity and innovation. (Fowler and Highsmith[r], 2001) For Complex Ventures it represents new capabilities, opportunities and potential issues. The emergent behavior, properties, or capabilities can be repeated, but are not usually predicted before evolution or initial combination occurs. These emergent behaviors have often been identified as disruptive technologies or outcomes. These complex behaviors are not always readily deducible or inferable from mere inspection of the components, connections, structures or component behaviors. The emergent behavior does not even have to be reversible.

Emergence of complex behaviors can be the result of a dynamic process evolution over time, collective behavior due to the interconnectedness of components and context, or combination rules of behavior or interaction.

Dynamic Process Emergence is an evolution of species or systems over successive generations. This type of emergence can be seen in what the Internet, with its many new applications, is becoming. Innovation and empowered agents find the best fit to the unknowable users, needs, and uses.

---

[16] Proposed by Col John Boyd (1987) the Boyd Cycle or the Observe, Orient, Decide, and Act (OODA) Loop. It represents a truly organic model of the informed decision cycle. It reflects Boyd's understanding of battle that the environment and the enterprise were ambiguous and unknowable, which tracks very well with the predictions of non-linear dynamics. (Beckerman, 1999) The only way to prepare and win was to select people well and train them appropriately. In the terms of this research, select good leaders, communicate clearly the leader's intent (coherence), be situationally aware, respond rapidly, and empower a diverse set of implementers.

[17] Knowledge that is not codified but held in people's heads; intuitive, experiential, judgmental, and context sensitive, it may be difficult to articulate.

[18] Knowledge that is codified and articulated: appears in the form of documents, procedures and in databases.

Collective Behavior Emergence can occur over disparate size scale, such as the neuron interactions in a human brain that give rise to thought (even though the constituent neurons are not individually capable of thought). The collective behavior emergence can also result from disparate components used together to provide benefit that neither could address alone (e.g. lasers and fiber optics enhancing communications).

Combination Emergence can result from repurposing of ideas or systems in a new context or use. In addition, simple rule combinations can give rise to complex behaviors. A well-known combination emergent behavior illustration is geese and their flying "V" formation complex behavior. If one tries to describe this behavior using Industrial Age processes, it requires the explanation to be as complicated as the observed phenomena. The control of the behavior also requires the governing geese to know and process a vast amount of data about the environment, aerodynamic theories, etc. In other words, it is difficult if not impossible to generate this desirable behavior using the past complicated approach to system engineering.

The existence of emergent complex behaviors over scale, components, or rules challenges decomposability approach. This drives the need for coordinated acquisition strategies that provide balanced doctrine, organization, training, materiel, leadership, personnel, and facility (DOTMLPF) solutions rather than isolated technology only. These solutions are dynamically linked to the context, thus necessitating understanding of the desired acquisition roadmaps that inform decision-making, decision implementation, and progress tracking.

If complexity is limited or removed from the solution space through over-constraining or too tightly controlling the solution, then much of the value of emergent behavior is lost. This would result in an Internet that is static or slowly evolving, solutions that do not meet customer expectations, and very tired geese.

The darker side of Complex Venture and the context interconnectedness is the reality of co-evolution with feedback loops (e.g., damping and amplifying) and hysteresis[19] concerns. A typical result of this feature is the higher probability of cascading catastrophic failure unless appropriate venture/context sensing and response mechanisms are provided. Thus, Complex Ventures are often found with extensive situational awareness and empowered agents to ensure decision-making and implementation are done in a timely informed manner. Such a Complex Venture example is the Power Distribution System. Although each substation and power line is a component of the venture, the real measure of its benefit is the flow of electricity. To avoid cascading failures, the Power Distribution System needs to continually monitor and react to the changes in the flow/load of the system. A noticeable contributor in such a Complex Venture is the governance that incentivizes agent compliance with venture standards and protocols.

---

[19] History and prior states may have an influence on future states

4.3 NON-LINEARITY & PREDICTABILITY

French mathematician Henri Poincaré first observed chaotic behavior of non-linearity in his work to define the Three-body Problem. (Thuan[s], 2001; Peterson[t], 1993; Poincaré[u], 1947) The implications were not fully appreciated until the introduction of digital computers allowed demonstration of chaos in various systems, such as the now famous weather work done by Lorenz. (UMD[v], 2002; Thuan[w], 2001; Gleick[x], 1987) Nonlinearity of deterministic systems exhibits extreme sensitivity to initial conditions and small input changes that can have large effects over time. This makes Systems Engineering assumptions about long-term prediction impossible and long-term control ineffective.

Complex Ventures are coupled in a non-linear fashion and this means that unlike linear systems that are subject to the principle of superposition, they are more than a sum of their parts.

This means that over time or space, small perturbations may cause a large effects (aka the butterfly effect), and, in addition, large perturbations may cause little or no effect.

In the world of aerodynamics, aircraft designers have adapted this behavior into an advantage by making planes very sensitive to the environment and easily maneuverable. This being on the “edge of stability” requires computerized aircraft dynamics sensing and real-time adjustments with fly-by-wire systems. (Santosus[y], 1998) This being at the “edge of stability” results in high sensitivity to small changes in the environment with minimum force application for maximum maneuverability. Such is also the goal of the Complex Venture model where operating in chaos Class IV. This results in innovative, quickly responsive ventures that meet user expectations.

In addition, researchers have identified distinguishing features and associated behaviors found when operating in the Class IV. (Wheatley[z], 1999; Rosenhead[aa], 1998; Stacey[bb], 1993)

- Long-term prediction and control are impossible
- Knowing the future is not necessary to be prepared for it
- Diversity enables survival and creativity
- Learning is essential to organizational survival
- Pragmatic approach to present concerns
- The longer problems go unchecked – the more extensive their effect
- As effects are observed, unknown interdependencies become apparent
- Cause and effect are impossible to track and blame assignment is fruitless
- Use cases provide insight but not predictability

- Simplifying linear nature assumptions cannot be made and drive to more and more parameters to evaluate using current modeling techniques.

CHAPTER 5. CONCLUSION

Wolfram[cc] (2002) asserts that the 20th century scientific, mathematics, and engineering models focus unnecessarily limits the potential solutions. In fact, he observed that complexity theory allows progress on a large number of fundamental scientific problems not previously addressable. Current Architecting and Systems Engineering assumptions about decomposability, widget capital, and predictability lie at the heart of the problem with current Complex Systems Engineering best practices.

Although Architecting and Systems Engineering for complicated systems and Complex Ventures have some overlap, research is beginning to predict several differences in both assumptions and approaches. These are summarized here as a starting point for further discussion and experimentation within the Architecting and Systems Engineering community.

- Leadership, not control, with clear and consistently communicated venture-wide vision
    - Require clear definition of roles, responsibilities, and authority
    - Use architecture products to inform stakeholders' (i.e., agents) decision-making and trace decision implementation
    - Provide architecture vectors or outcome spaces not point designs with appropriate metrics help guide lower decisions
    - Apply appropriate development stimulants incentivizing agents to produce desirable capabilities and behaviors such as safety regulations, interoperability, etc.
- Address rapidly changing context and the co-evolutionary ventures
    - Understand the loss of float impacts upon acquistion
    - Knowing the future is not necessary to be prepared for it
    - Focus on needed capabilities early and delay technology implementations
    - Set key acquisition goals as adaptiveness/agility and effectiveness versus efficiency and stability
    - Assume minimal predictability with many potential futures
    - Buy insurance with options when indicated and terminate options when no longer needed
- Institute tiered situationally aware decision-making in both time and place
    - Communication is the key to the care and feeding of empowered agents
    - Diversity enables survival and creativity
    - Empowerd Agents enable timely effective fitness

  - Provide guidance and institute incremental changes
  - Integrate situational awareness and implementation monitoring
  - Ensure cross-disciplinary and virtual enterprise communications
  - The longer a problme goes unchecked (e.e., the further up the decision chain to resovle) the more extensive the loss will be
- Address all factors contributing to success
  - Identify relationship between products/services and business outcomes/value
  - Complex Ventures are defined by flows of intelligence, energy, and matter that provide value not implementation widget shopping lists and need to be described as such
  - Solutions must adress all contributing entities Doctrine, Organization, Training, Materiel, Leadership & Education, Personnel, and Facilities (DOTMLPF)
  - Identify needed capabilities, protocols, and standards

Author's Biography

Linda J. Vandergriff, D.Sc. is a Senior Engineering Specialist at The Aerospace Corporation, a non-profit Federally Funded Research and Development Corporation with oversight responsibility for the National Security Space Program. At Aerospace, she teaches specialty courses on "Architecture Frameworks" and "Complexity, Uncertainty, and Decision Making." She received a BS from the University of Tennessee in Engineering Physics, MS and postgraduate work in Electro-optical Systems Engineering from Southeastern Institute of Technology, and a Doctorate of Science in Engineering Management from George Washington University. Her dissertation focused on decision support framework for Intelligence Age Agile Enterprises. She continues to be an active contributor to the Knowledge Management Community of Practice at George Washington University. She has extensive experience in general and photonics domain-specific system engineering and architecting and in complexity theory engineering implications. Her 30 years of engineering experience include work to support the Strategic Defense Initiative as a Chief Engineer, Project Lead on a reconnaissance and surveillance system, and various experience in enterprise management, architecting, reconnaissance and surveillance system engineering, electro-optics development, multi/hyper/ultra spectral intelligence solutions, knowledge management application characterization, complexity theory, and performance/capability simulation. She is co-author of the National Science Foundation Scientific and Technological Education in Photonics (STEP) 8 Course curriculum on the Nature and Properties of Light. (1999).

---

[a] Lissack, Michael R. 2000. "Complexity Metaphors and the Management of a Knowledge Based Enterprise; An Exploration of Discovery." Doctorate in Business Administration diss. Oxfordshire, UK: Henley Management College.

[b] Apte, Uday M., Cynthia M. Beath, and Chon-Huat Goh. 1999. An analysis of the production line versus the case manager approach to information intensive services. Decision Sciences. 30, Iss. 4 (Fall): 1105-29.

---

[c] Davis, Randall, and Howard E, Shrobe, Representing Structure and Behavior of Digital Hardware, IEEE Computer, Special Issue on Knowledge Representation, 16(10):75-82. October 1983

[d] Bechtold, Richar. Planning and Managing the Development of Complex Software Systems. CrossTalk May 2003.

[e] Morgan, G. 1983. "More on Metaphor: Why We Cannot Control Tropes In Administrative Science." Administrative Science Quarterly 28: 601-607.

[f] Kauffman, S. A. 1995. At Home in the Universe: The Search for the Laws of Self-Organization and Complexity. Oxford, UK: Oxford University Press.

[g] Waldrop, M. Mitchell. 1993. Complexity: The Emerging Science at the Edge of Order and Chaos. NY: Touchstone Press.

[h] Langton, C. G., C. Taylor, J. D. Farmer, and S. Rassmussen, (Eds.). 1992. *Artificial Life II*. Redwood City: Addison-Wesley.

[i] Wolfram, S. (Ed.). 1986. *Theory and applications of cellular automata*. Singapore: World Scientific.

[j] Conner, Daryl R. 1998. Managing at the Speed of Change and Leading at the Edge of Chaos: How to Create the Nimble Organization. NY: John Wiley & Sons, Inc.

[k] Stacey, R. D. 1996. Complexity and Creativity in Organizations. San Francisco, CA: Berrett-Koehler.

[l] Phelan, Steven E. 1995. “From Chaos to Complexity in Strategic Planning.” Presented Paper at 55th Annual Meeting of Academy of Management, Vancouver, BC Canada. http://www.aom.pace.edu/bps/Papers/chaos.html.

[m] Lissack, Michael R. and Johan Roos. 2000. *The Next Common Sense, The e-Manager’s Guide to Mastering Complexity*. London, UK: Nicholas Brealey Publishing.

[n] Lucas, Chris. 2002. “Fitness and Synergy.” Introduction to Complex Systems. Kirshbaum, David. (Ed) Version 4.73 April 2002. Web Book: http://www.calresco.org/intro.htm.

[o] Pasternack, Bruce A. and Albert J. Viscio. 1998. The Centerless Corporation: A New Model for Transforming Your Organization for Growth and Prosperity. NY: Simon & Schuster.

[p] Boyd, John R. 1987. “A Discourse on Winning and Losing.” Unpublished briefing. August.

[q] Beckerman, Linda P. “The Non-Linear Dynamics of War.” White Paper posted at http://www.belisarius.com/modern_business_strategy/beckerman/non_linear.htm.

[r] Fowler, Martin and Jim Highsmith. 2001. “The Agile Manifesto.” Hypertext article, Software Development Magazine, August. http://www.sdmagazine.com.

[s] Thuan, Trinh Xuan. 2001. Chaos and Harmony: Perspectives on Scientific Revolutions of the Twentieth Century. NY: Oxford University Press.

[t] Peterson, Ivars, 1993. Newton's Clock: Chaos in the Solar System. NY: W. H. Freeman and Co. Publishers.

[u] Poincaré, H. 1946. The Foundation of Science. Lancaster, PA: The Science Press.

[v] UMD. 2002. Chaos Group website. University of Maryland http://www-chaos.umd.edu/chaos.html.

[w] Thuan, Trinh Xuan. 2001. Chaos and Harmony: Perspectives on Scientific Revolutions of the Twentieth Century. NY: Oxford University Press.

[x] Gleick, James. 1987. Chaos Making A New Science. NY: Penguin Books.

[y] Santosus, Megan. 1998. “Simple, Yet Complex.” CIO Enterprise Magazine, April 15. http://www.cio.com/archive/enterprise/041598_qanda_content.html.

[z] Wheatley, Margaret J. 1999. “When Complex Systems Fail: New Roles for Leaders.” Leader to Leader, 11 Winter. 28-34. http://leadertoleader.org/lederbooks/L2L/winter99/wheatley.html.

[aa] Rosenhead, Jonathan. 1998. “Complexity Theory and Management Practice.” Hypertext paper http://www.human-nature.com/science-as-culture/rosenhead.html.

[bb] Stacey, R. D. 1993. Strategic Management and Organizational Dynamics. London, UK: Pitman.

[cc] Wolfram, Stephen. A New Kind of Science. WolframMedia Inc. 2002.