# *Enterprise Architecture of Emergent Complex Adaptive Systems*

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# *Challenges of Today's Defense Programs*

Changing missions
- Cold War vs. Low Intensity Conflicts
- Dynamic threats
  - IEDs
  - cyberwarfare

Programs are part of a larger System of Systems

Rapidly evolving technology
- Technology may be a generation old in 6 months
- Technology may be obsolete within two years

Defense programs often have a life cycle measured in decades
- Field support through end of life can be challenging
- New systems must be interoperable with legacy and future systems

Technology refresh of deployed systems elusive
- Increased performance
- Lower cost
- Scalability


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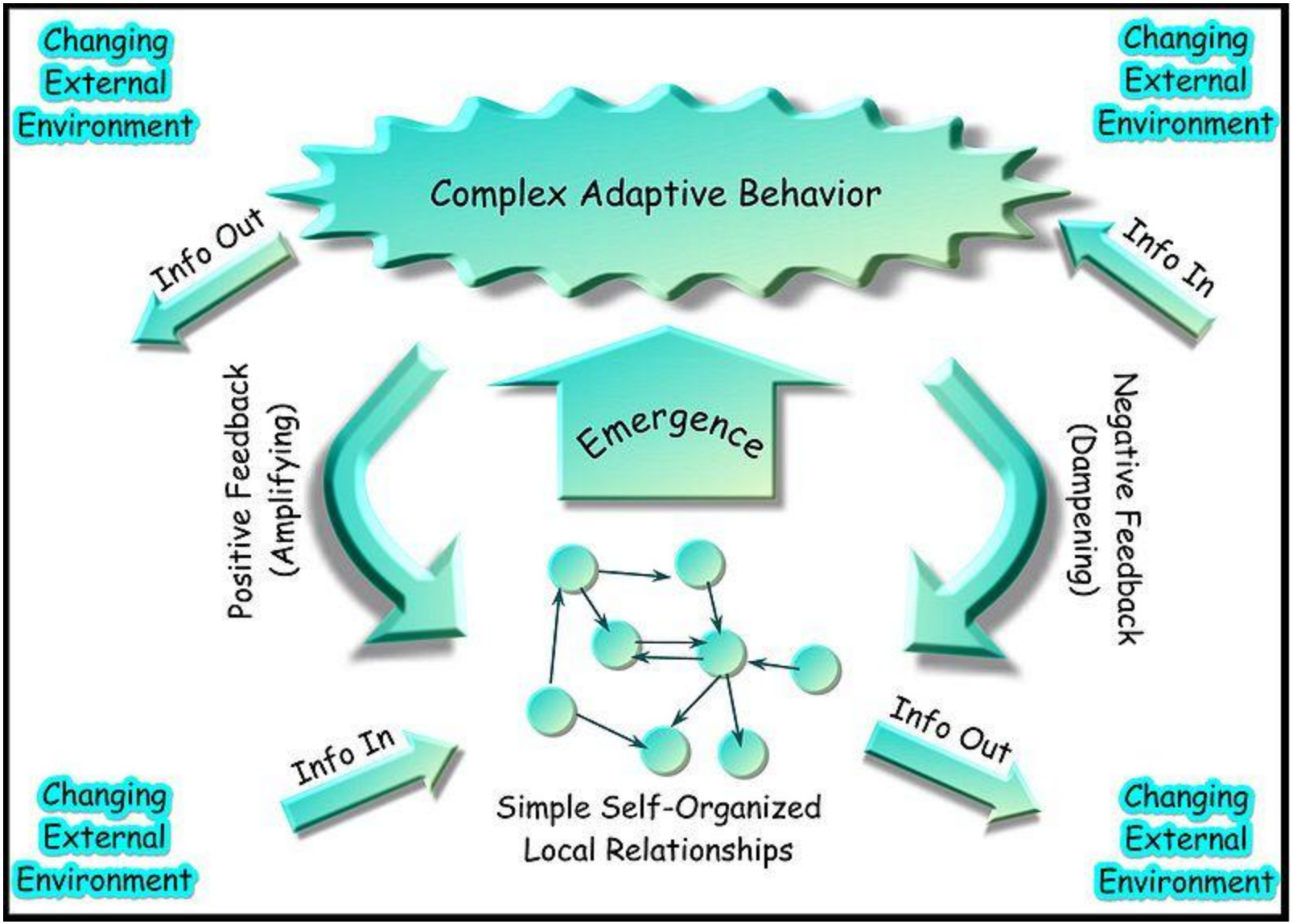


*http://en.wikipedia.org/wiki/File:Complex-adaptive-system.jpg*


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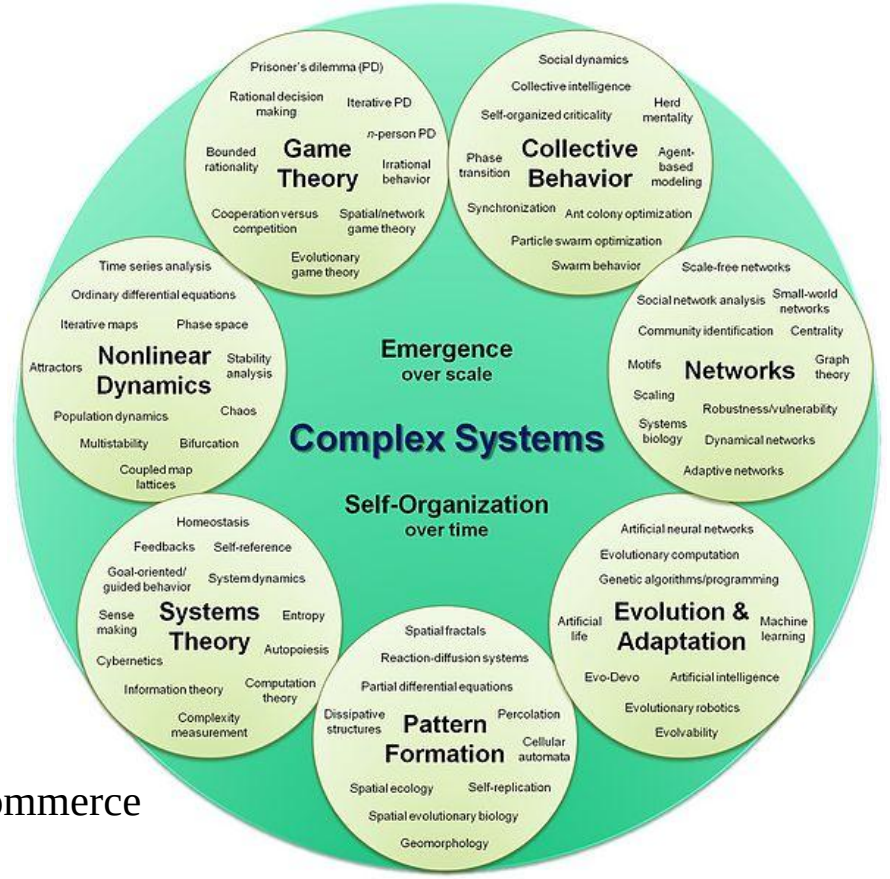
# *Examples of Emergent Systems*

- Weather
- Life
- Ecosystems
- Biosphere
- Natural Nuclear Reactor
- Societies
  - Swarming
  - Bee Colony
  - United States of America
- Synthetic
  - Interstate Highway System, Cities and Commerce
  - Internet




*http://en.wikipedia.org/wiki/File:Complex_systems_organizational_map.jpg*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## *Emergence of Natural Nuclear Reactor at Oklo Uranium Mine in the Gabon Republic, West Africa*

- Emerged from bacteria in an algal mat concentrating uranium *(at that time the uranium would not have needed enrichment)*
- Bacteria thrived in the radioactive environment which generated heat
- Ran for a million years with power output on the order of 100 kilowatts about 2 billion years ago
- Discovered in 1972 when the uranium ore was 200 kg short of $U^{235}$ because it was consumed in the reactor
- Caused considerable concern as to where the $U^{235}$ was diverted before investigations lead to this discovery


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# *Why are Complex Adaptive Systems Needed?*

- Systems are too complex to be fully understood by a single person
- System Lifespans exceed those of underlying components
  - DoD and Civil government programs have lifecycles measured in decades
  - COTS items lifecycles measured in months or years
- Total system upgrade difficult because it is a collection of many systems with different timetables
- Need to cope with paradigm shifts within systems lifespans
- Addressing issues of collaborative system development across multiple entities


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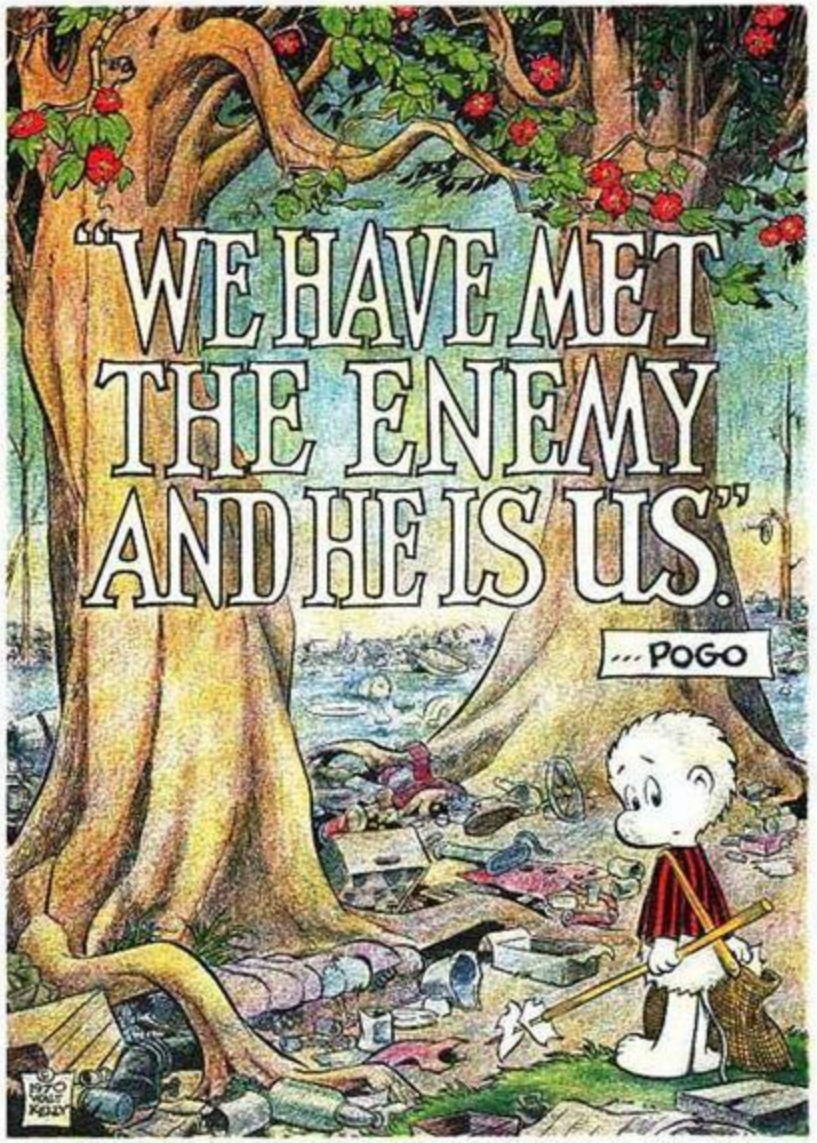
# *Classical Systems Engineering is No Longer Sufficient for the Solution*

"Insanity: doing the same thing over and over again and expecting different results."
*Albert Einstein*

- CMMI has brought us processes which ensure repeatability across programs
  - The systems still come in over budget, behind schedule and fall behind technologically
  - We then strive for the next level of CMMI

- Any intelligent fool can make things bigger and more complex... It takes a touch of genius - and a lot of courage to move in the opposite direction. *Albert Einstein*
  - Waterfall, V-Model, Spiral Development expand the scope (and complexity) in Classical Systems



Walt Kelly's poster for the first Earth Day

*http://en.wikipedia.org/wiki/File:Kellyposter1970.jpg*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# *Challenges of Developing Complex Adaptive Systems?*

- Defining the problem
- Defining a constantly evolving system
  - Current modeling tools fail to reflect evolving system
  - Best practices emphasize repeatability, discourage variety and stifle innovation
  - Need to identify deep patterns which foster emergence
- Acceleration of emergence
  - Incubate variants that will thrive
  - Curtail resources expended on suboptimal
  - Perils and risks of eugenics and unintended consequences
- Establishing a relevant value system uncorrupted by the observations
- Creating the incubator from which the system emerges
- Understand the consequences of each decision


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# *What is an Emergent Architecture?*

*[Gartner – 2009]*

- Non-deterministic: *Using emergent architecture, to decentralize decision-making and enable innovation.*
- Autonomous actors: *Enterprise architects must now recognize the broader business ecosystem and devolve control to constituents.*
- Rule-bound actors: *Enterprise architects must now define a minimal set of rules and enable choice.*
- Goal-oriented actors: *Previously, only corporate goals mattered. Now, constituents acting in their own best interests alters this paradigm.*
- Local Influences: *No individual actor has data about all of an emergent system. EA must increasingly coordinate.*
- Dynamic or Adaptive Systems: *The system (the individual actors and environment) changes over time. EA must design emergent systems sense and respond to changes in their environment.*
- Resource-Constrained Environment: *The scarcity of resources drives emergence rather than an environment of abundance.*


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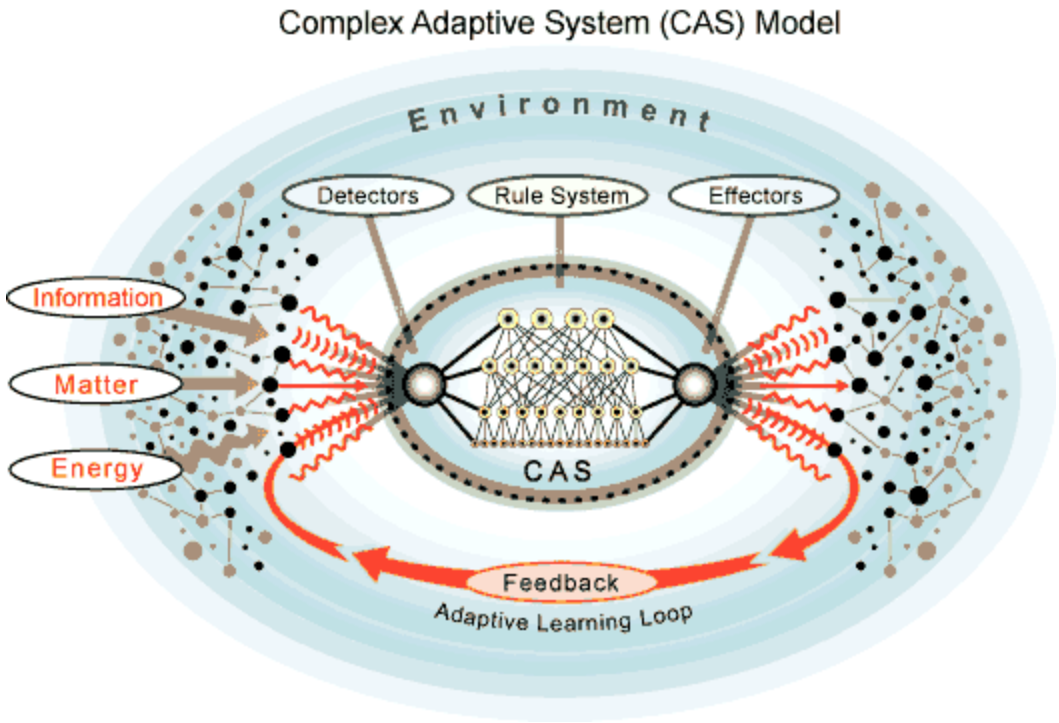
# *How does one build Emergent Complex Adaptive Systems?*

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# *Architecting for Emergence*

- Focus on boundaries, interfaces, rules and interactions of the entities
- Identify and characterize deep structures
- Minimize specifications of behavior that impede evolution and innovation
- Characterize domains of Emergent Complex Adaptive Systems

  (The Mess, The Environment, The Enterprise, The System)
- Tie the solution back to the problems using the value system to evaluate variants
- Create Information Model and automate information flow
- Distribute and delegate decision authority to lowest levels possible


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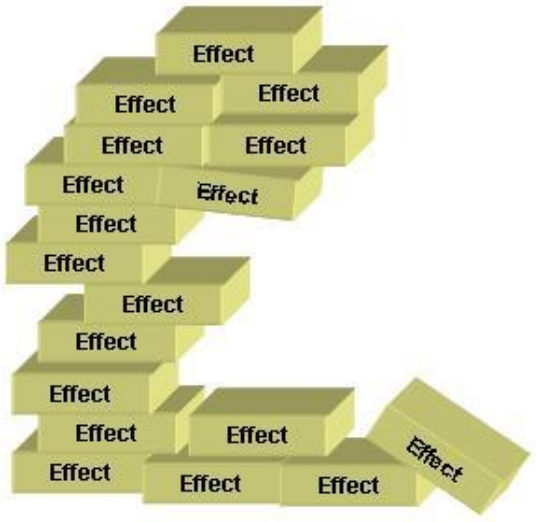
# The Mess

- Approach as a system of interdependent problems
- Identify stakeholders, requirements and values
  - Stakeholders do not think in context of foreign models
  - Translate if necessary to Information Model
- Identify entities, roles and interactions
  - Characterize through models
  - Characterize evolution over time
- Identify constraints
  - Resources
  - Political
- Define Value System




*http://www.fs.fed.us/psw/topics/fire_science/craft/craft/Resources/assets/CumulEffects_blocks.jpg*

## WICKED PROBLEM


*http://robertweber.typepad.com/photos/uncategorized/2007/09/22/cartoon2_4.jpg*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# The Environment

- Characterize environment through models, behaviors and constraints
  - Layered models organize decompositions
  - Create multiple views representing each domain
  - Identify boundaries, interfaces and deep structures
  - Characterize evolution over time
- Characterize other systems which are part of the environment
- Characterize legacy systems which are both constraints and opportunities to leverage existing infrastructure
- Understand the System Dynamics before making changes
  - Deep structures provide opportunities for emergence
  - Minimize negative unintended consequences (outcome could also be positive)
- Characterize emerging and existing technology
  - Maturity, Interfaces, Capabilities


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# The Enterprise

- Approach as Enterprise of Enterprises
- Define Information Model
  - Allow for temporal evolution, and element diversity
- Define Operational Behavior Models of Enterprise
  - Governance, Workflow
- Define System Models
- Embed workflow processes in model infrastructure
- Implement and deploy models in tools and databases
- Extend modeling tools for temporal and diversity
  - Current generation tools support snapshots at an instance in time
  - Changing relationships of an entity over time is not handled well in current tools
- The Enterprise which builds the system is itself a Complex Adaptive System
- Emergent Enterprises cannot be centrally managed to the lowest level


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# *Architect Emergent Complex Adaptive System*

- Commit to tool based infrastructure using Information Model
  - Ensure referential integrity of complex system
  - Workflow is embedded in tool infrastructure
  - Reviews of views ensure composite integrity
  - Use information model to assess system effectivity and for impact assessment of architectural changes
- Classical Systems Engineering techniques are counter-productive
- Architecture is layered with corresponding models
- Focus on boundaries and interfaces between elements within layer.
  (Respect boundaries between layers).
- Innovate with novel approaches to meet the operational needs.
  (Question authority – tradition is not a constraint).
- Procured solution instances are different than architectural components.
  (Can be fully specified to allow life cycle support and may be replaced with new instances with enhanced capabilities fitting into the existing architecture).


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# About Us

**BBII** : A California Corporation founded in 1998.

- A small woman owned company with approximately 21 on demand employees and a number of additional subcontractors and consultants.
- An enterprise architecture and systems engineering consulting and support company.
- Uses a model based approach to information development and to improve the abilities and maturity of our customer's employees. With an Information Modeling approach to integrating program functions, BBII can provide the underlying framework to incorporate architectures (DoD-af and MoD-af)
- Provides employees and consultants with a broad range of experience in a variety of industries including Communications, C4ISR, Aerospace, Transportation, Emergency Response, Finance and Banking, Software Development and Cyber Security
- Provides experts in Enterprise Architecture, UML, SyS ML, DoD-af, Systems and Software Engineering and Architecture for program support and training.
- Provides a team to identify the model, modify the tools, write instructions, mentor and train staff, develop data, provides systems engineers, systems architects and engineering support. We also provide targeted skills workshops and skilled support staff who can tailor tools, migrate and enter data and direct data development.
- Maintains partnerships with a variety of tool vendors.
- Provides workshops (key for increased maturity and staff building). Topics include Enterprise Engineering, Systems Engineering, AE and SE Tools and Technology Development workshops.
  On the Job training (JIT) is offered in these areas.
- Customers include Boeing, Bombardier, CSC, Lockheed Martin, Northrop Grumman, NASA, SAIC, Sikorsky, the State of Texas, Pratt and Whitney and United Pan European Communications Co.


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