Systems Engineering in the Information Age: The Challenge of Mega-Systems

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Operation Enduring Freedom: an Early Glimpse at the Future

Unprecedented Collaborative Engagement with Networked Forces

- SOF forces request Close Air Support
- F-14 providing Close Air Support out of weapons
- F-14 crew employ onboard sensors to mensurate target
- Crew passes target data - *via voice* - to AWACS
- B-52 enabling successful target kill with precision munitions
- Time to Target 18 Minutes

- *No requirement or architecture anticipated it*
- *Not achieved by any single system*
- *May never happen again in exactly the same way*

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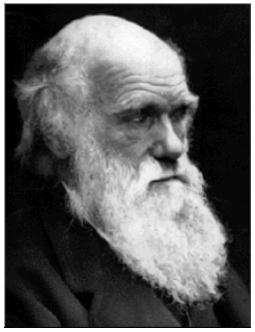
Demand for Agile, Adaptive Responses

- **Convergence of multiple trends**
  - **Uncertainty of strategic environment demands *agile/adaptive* response**
  - **Seek to leverage information as a *competitive source of power***
  - **Information revolution provides *tools* to interconnect a wide range of elements**
    - **Computing/Storage**
    - **Networking**
    - **Wireless**
    - **Assurance…**
  - **Moving from bottom-up requirements to top-down capability-based acquisition approach**
- **Leading to growing emphasis on large-scale, richly interconnected "systems" that bridge traditional organizational. functional and programmatic boundaries… *"Mega-systems"***

Same logic applies in defense, government agencies and commercial worlds



Charles Darwin 1809-1882

"It is not the strongest of the species that survive, nor the most intelligent, but the ones most adaptable to change"

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The Challenge for Systems Engineering

- Trend away from stand-alone component systems (platform-centric) to richly interconnected and increasingly interdependent systems that cross traditional boundaries
  - System of Systems, Family of Systems…
  - Enterprise and “extended enterprise”-wide systems

- The systems we are being called on to help acquire appear to be *qualitatively* distinguishable from those that have been traditionally and successfully addressed using "traditional" system engineering.
  - To what extent do the SE practices and processes that evolved in post WWII era apply to this new class of systems?
  - Where they might not apply, what new practices and processes might be required?

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A Working Definition

- **Mega-systems defined as "*large scale, potentially complex systems that are formed by the integration of separately developed systems to provide functionality beyond that achievable by its component systems*"**
- **Cross traditional boundaries (organizational, functional, programmatic…)**
- **Significant human dimension which contributes to**
  - **Complexity of behavior**
  - **Continued evolution**

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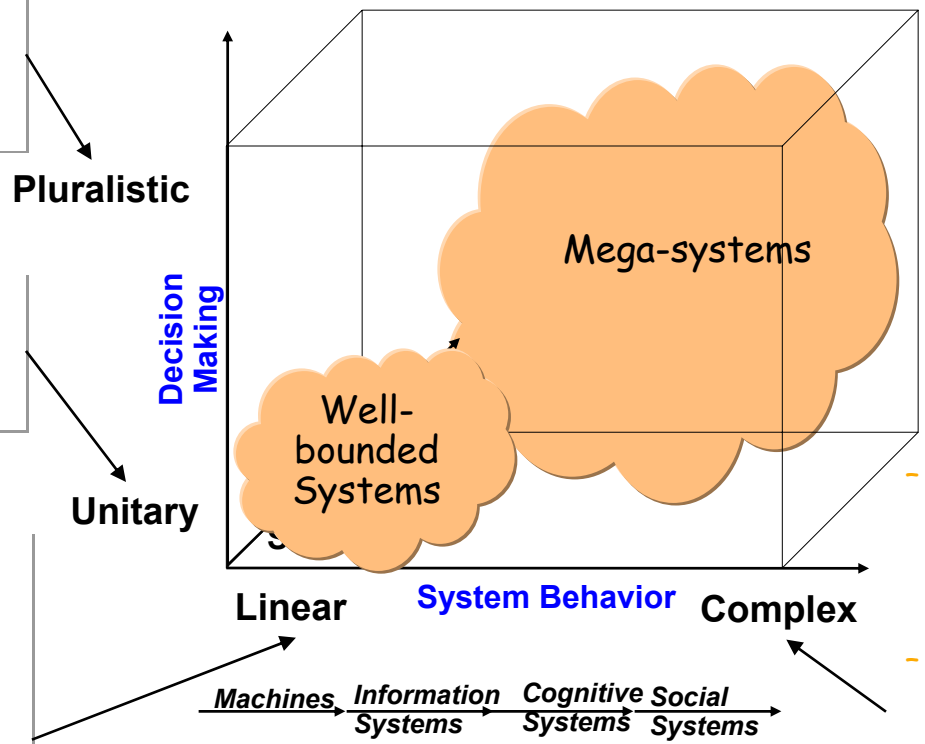
Framework for Exploring Mega-Systems

- Little or no agreement as to common goals and objectives; decision makers focus on *local concerns*

- *Agreement* as to the goals and objectives; decisions are made and implemented WRT common goals

- Behavior is regular, well understood and, to a large extent, *predictable*
- Relatively closed to the environment
- Components not purposeful; exist only as part of larger system



- Not all behavior directly observable; not all interactions are well understood
- Do not necessarily follow predictable rules of behavior; solutions to specific problems may have totally unexpected consequences
- Interact with environment and evolve

Key question: How to engineer and evolve a mega-system in the absence of familiar control mechanisms?

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Examples of Mega-Systems

Air Operations Center

- 1000-2000 people working around the clock in 2 shifts; ~70K ft^2 of space
- 100+ workstations
- ~$50M of planning & decision aids and infrastructure
- 30-80 apps being continually refreshed and occasionally upgraded and augmented; ~25 BIG apps
- Generates and manages 24 hour schedules for the application of airborne assets; 1 AOC per theatre.

Federal, State & Local Info Sharing

- Federal + ~18,000 state & local police organizations, majority ≤10 staff
- ~680,000 law enforcement officers
- ~100 different systems of which >30 are commercial
- Mutual distrust particularly about sharing case information
- Some successes (fingerprint file, national criminal information file)
- Growing privacy concerns

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Engineering “Mega-systems” is Messy

- Ambiguous boundaries
- Continuously changing expectations, including new opportunities not originally envisioned
- Technology obsolescence and emergence
- Shifting mix of cooperation and competition among participants and stakeholders

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What Seems to Work Well… And Not So Well

- The enablers
  - (Some) architectures, visions, engineering master plans…
- Continuous, broad-based involvement
  - Representatives from different organizations actively involved
  - Visible senior leader support
- Consensus around infrastructure and tenets
  - Open standards
- Guided, incremental developments
- Integration facilities (virtual and real)
- Experimentation, early field trials
- Response to real crisis
  - Overcome "tribal" tendencies
- Charismatic "champion" that can overcome process limitations

- Requirements and specs
  - Difficult to articulate how parts will work in context of the whole – lack lexicon
  - Desire for global specificity and completeness
- Multiple stakeholders, overly complex organizations
  - Separate agendas, distrust…
  - Process takes precedence
- Dealing with uncertainty
- Grand design
- Too long a horizon
  - Technology changes, expectations change, users change…
- Too narrow a view
  - Ignoring some key stakeholders
  - Technical solutions for non-technical issues (e.g. privacy)
- Acquisition across boundaries

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Implications for Engineering Mega-Systems

- Implication #1: Less emphasis on comprehensive, detailed requirements and specifications at the onset and more emphasis on incremental experimentation and trial
- Implication #2: Consensus around the enabling infrastructure and design tenets is the structured piece of the unstructured problem
- Implication #3: Make maximum use of existing collaborative engineering tools and practices and encourage the evolution of new techniques
- Implication #4: Capabilities that are deemed useful should be spiraled off the use
- Implication #5: Encouraged to evolve *in situ*

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Concluding Thoughts Intended to Provoke

NCO entails thinking differently about the process; we should also think differently about how we structure and implement solutions

Military Transformation*

- **What's In?**
  - Joint and Expeditionary mindset
  - Ad hoc fight in flat organization
- **What's Out?**
  - Long cycle times
  - Deliberate planning
  - Non-joint Conops, doctrine, or operations

Self-synchronizing forces based on commander's intent

IT-Based "Mega-Systems"

- **What's In?**
  - Complex adaptive systems mindset
  - Capability evolution in response to unanticipated events
- **What's Out?**
  - Long acquisition times
  - Grand design
  - "Local" requirements, design, or operations

Self-synchronizing developments based on agreed-to goals, infrastructure

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