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Transformative Affordability for System Architecture Design

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Abstract

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The US Department of Defense (DoD) has undergone major evolutionary shifts in recent years that include movement from a platform focus to a mission objective, from single-purpose solutions to systems with adaptive relevancy, from focus on primary systems only to embracing holistic solutions integrating enabling and support systems and from acquisition-only costs to complete life cycle cost analyses. Dr. Robert Gates, challenged contractors to define and deliver compliant **'80% solutions'.*** How does this affordability challenge change architecture design?

* Dr. Gates: "Finally, I concluded we needed to shift away from the 99 percent exquisite, service-centric platforms that are so costly and so complex that they take forever to build and only then are deployed in very limited quantities. With the pace of technological and geopolitical change and the range of possible contingencies, we must look more to the 80 percent multi-service solutions that can be produced on time, on budget and in significant numbers." 22nd Secretary of Defense, from remarks at the Naval War College, Newport, RI, 17 April 2009.

Tom Herald Biography

- Senior Fellow for Lockheed Martin, Mission Systems & Training business unit in Orlando, FL
- INCOSE ESEP
- Past President of INCOSE – Orlando Chapter
- BSEE, MSEE and Systems Engineering doctorate from the School of Systems & Enterprises at Stevens Institute of Technology
- Book: "Obsolescence Management Forecasting: for Strategic Operational System Sustainment Decision Making"
- IBM and Lockheed Martin defense-sector solutions
- Adjunct Professor for Systems Engineering at Stevens Institute of Technology and Adjunct at the University of Central Florida
- Interests include the system engineering linkages of supportability parameters, obsolescence, and technology insertion considerations proactively influencing affordable system designs and sustainment

Abstract

Customer Shifts in focus:

- From a platform focus to a mission objective
- From single-purpose systems to solutions with adaptive relevancy
- From focus on primary systems only to embracing holistic solutions
- Integrating enabling and support systems
- From acquisition-only costs to complete life cycle cost analyses
- Dr. Robert Gates, challenged contractors to define and deliver compliant **'80% solutions'**

How does this affordability challenge change architecture design?

Abstract

Dr. Robert M. Gates
22nd United States Secretary of Defense
Remarks at the Naval War College, Newport, RI on 17 April 2009

"Finally, I concluded we needed to shift away **from the 99 percent exquisite**, service-centric platforms that are so costly and so complex that they take forever to build and only then are deployed in very limited quantities. With the pace of technological and geopolitical change and the range of possible contingencies, we must look more **to the 80 percent multi-service solutions** that can be produced on time, on budget and in significant numbers."

Perspective is Reality ... Right?

- Varying Perspectives of **Affordability**
  - Acquisition vs. Life Cycle vs. Total Ownership
  - Affordability = Functionality for what I can afford
  - Buyer vs. Operational User
  - Sec Def Dr. Robert Gates: 80% vs. exquisite solutions
  - Differences in Operations, Environments and Internationally

Perspective is Reality . . . Right?

- Varying Perspectives of **Architecture**
  - DoD Service vs. International vs. Commercial vs. Space
  - Microsoft Office vs. Model-based design
  - DoDAF (or UPDM) vs. ad hoc documentation

- No longer good enough to only do one! We are at a tipping point fueled by finances, legacy extensions, etc.

Platform to Mission Solutions

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"Always design a thing by considering it in its next larger context – a chair in a room, a room in a house, a house in an environment, and an environment in a city plan."

Eliel Saarinen, Finnish Architect

Customer's changed focus:

- System/platform to missions
- Single-purpose to adaptive
- Single baseline to evolvable
- Design focus to full life cycle
- Acquisition to TOC
- 80% Solutions?

Helsinki, Finland Railway Station

So where does this leave us?

- Affordability is not so much a single definition:
  - A trade space of domain-relevant affordability attributes
  - Stakeholder-relevant Value metrics for each attribute
- Architecture must be “a clear, understood set of boundaries that form a relevant solution trade space”
  - Boundaries formed by legacy constraints, standards, laws, interfaces, aesthetics, etc.
  - What is considered “inside” the boundary? Primary system only, enabling systems, development environment, testing environment, nominal operations and interoperability.

Let's look at "Architectures" first
How to measure a great Architecture?

- Architectural Attributes
  - Work from Line Johannesen and Dr. Dinesh Verma (INCOSE Fellow)
  - Next Page for details
  - More of an internal system-centric focus
  - Attributes of repeatable Architectural Goodness

D. Verma and L.H. Johannesen, "An Evaluation Framework for System Architectures," Systems Engineering, Journal of the International Council on Systems Engineering, 2004.

Architectural "Goodness" Attributes

Commonality

- **Physical Commonality (system)**
  - **HW Commonality**
    - Number of Unique LRUs
    - Number of Unique Fasteners
    - Number of Unique Cables
    - Number of Unique Standards Implemented
  - **SW Commonality**
    - Number of Unique SW Packages Implemented
    - Number of Languages
    - Number of Compilers
    - Average Number of SW Instantiations
    - Number of Unique Standards Implemented
- **Physical Familiarity (From other systems)**
  - % Vendors Known
  - % Subcontractors Known
  - % HW Technology Known
  - % SW Technology Known
- **Operational Commonality**
  - % of Operational Functions Automated
  - Number of Unique Skill Codes Required
  - Estimated Operational Training Time - Initial
  - Estimated Operational Training Time - Refresh from Previous System
  - Estimated Maintenance Training Time - Initial
  - Estimated Maintenance Training Time - Refresh from Previous System

Modularity

- **Physical Modularity**
  - **Ease of system element upgrade**
    - Lines of modified code
    - Amount of labour hours for system rework
  - **Ease of operating system upgrade**
    - Lines of modified code
    - Amount of labour hours for system rework
- **Functional Modularity**
  - **Ease of adding new functionality**
    - Lines of modified code
    - Amount of labour hours for system rework
  - **Ease of upgrade existing functionality**
    - Lines of modified code
    - Amount of labour hours for system rework
- **Orthogonality**
  - Are functional requirements fragmented across multiple processing elements and interfaces?
  - Are there throughput requirements across interfaces?
  - Are common specifications identified?
- **Abstraction**
  - Does the system architecture provide and option for information hiding?
- **Interfaces**
  - # of Unique Interfaces per System Element
  - # of Different Networking Protocols
  - Explicit versus Implicit Interfaces
  - Does the architecture involve implicit interfaces?
  - # of Cables in the System

Standards Based

- **Open Systems Orientation**
  - **Interface Standards**
    - # of Interface Standards/# of Interfaces
    - Multiple Vendors (Greater than 5) Exist for Products Based on Standards
    - Multiple Business Domains Apply/Use Standard (Aerospace, Medical, Telecommunications)
    - Standard Maturity
  - **Hardware Standards**
    - # of Form Factors/# of LRUs
    - Multiple Vendors (Greater than 5) Exist for Products Based on Standards
    - Multiple Business Domains Apply/Use Standard (Aerospace, Medical, Telecommunications)
    - Standard Maturity
  - **Software Standards**
    - # of proprietary & unique operating systems
    - # of non-std databases
    - # of proprietary middle-ware
    - # of non-std languages
- **Consistency Orientation**
  - Common Guidelines for Implementing Diagnostics and Performance Monitoring and Fault Localisation
  - Common Guidelines for Implementing OMI

RMT

- **Reliability**
  - **Fault Tolerance**
    - % of mission critical functions with single points of failure
    - % of safety critical functions with single points of failure
  - **Critical Points of Delicateness (System Loading)**
    - % Processor Loading
    - % Memory Loading
      - How critical is this?
    - % Network Loading
      - How critical is this?
- **Maintainability**
  - Expected MTTR
  - Maximum Fault Group Size
  - Is system operational under maintenance?
  - Accessibility
    - Are there space restrictions?
    - Are there special tool requirements?
    - Are there special skills requirements?
- **Testability**
  - # of LRUs covered by BIT (BIT Coverage)
  - Reproducibility of Errors
    - Logging/Recording Capability
    - Create system state at time of system failure?
  - Online Testing
    - Is system operational during external testing?
    - Ease of access to external testpoints?
  - Automated Input/Stimulation Insertion

Any more Architectural Attributes?

- Possible additional considerations:
  - Operational Measures of Effectiveness
  - Domain-specific KPPs and MOPs
  - Security (segregation and modularity)
  - Interoperability and Networking (Next higher level)
  - Supply chain Impacts (Next lower level)

- Consideration Examples coming next:
  - Enabling system integration (USAF F-117)
  - Simplicity vs. Complexity (Marine Corps EPLS)

Enabling System Integration

i.e. Design for affordable support

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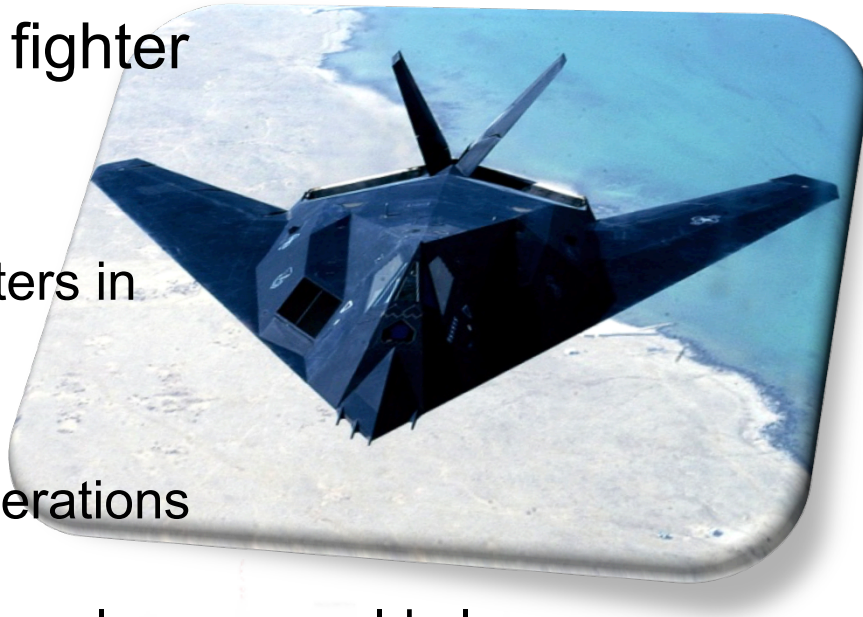
- Issue: Enabling systems often do not get 'equal design focus' and yet the impacts in the enabling systems often become program show-stoppers.
  - F-117 Nighthawk – First stealth fighter
    - Design focus was stealth attack
    - Disruptive technology
    - Most technologically-advanced fighters in aviation history. And still is today.
    - World-class mission capabilities
    - Enabling system operational considerations got a "back-seat".
    - The enabling logistics support system also was world-class; however, the costs for this support became a show-stopper



Simplicity vs. Functional Complexity

(Directly addresses Gates' 80% challenge)

- Designers are too often enamored with functional elegance and flexibility making everything in the solution a variable; however, this demands too much user interaction to properly provide inputs and interpret outputs.
  - Hazardous operations, soldiers wear Chem-Bio suits
    - Allow for system operations with bulky gloves
    - Extreme environments, fatigue, heat, cold, etc.

"I want my Marines to have their fingers on triggers and not on keyboards."

Gene Morin, PM, Marine Corp Embedded Platform Logistics System (EPLS)

Now, Let's look at Affordability ... What makes a system Affordable?

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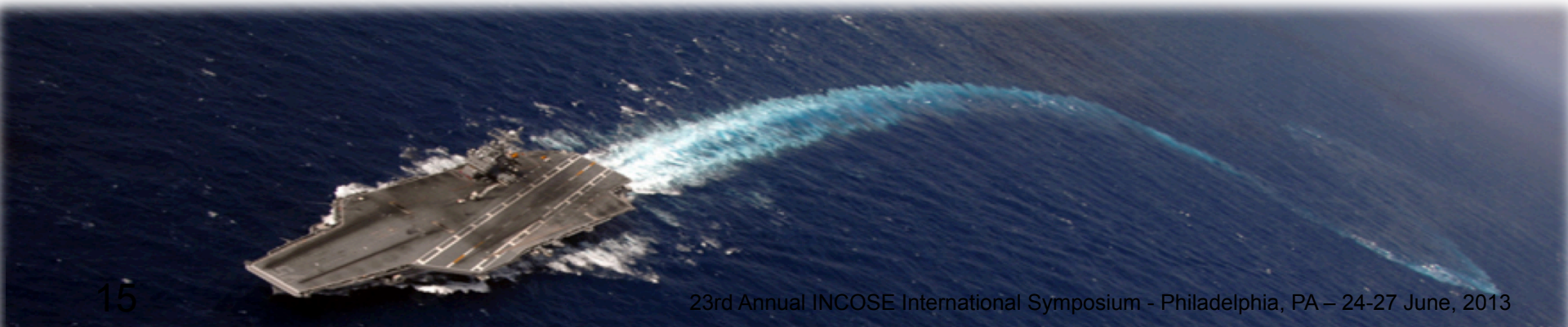
- Craft a domain-relevant Affordability trade space
- Identify/Understand the stakeholder-unique attributes
- Develop a utility curve of value for each attribute AND identify the sweet spots of those curves
- Collaborate with customer on capability compromises
- Integrate Affordability Requirements
- Attributes: Multiple ConOps (Adaptive Relevancy)



Define the Value function for each Affordability attribute.

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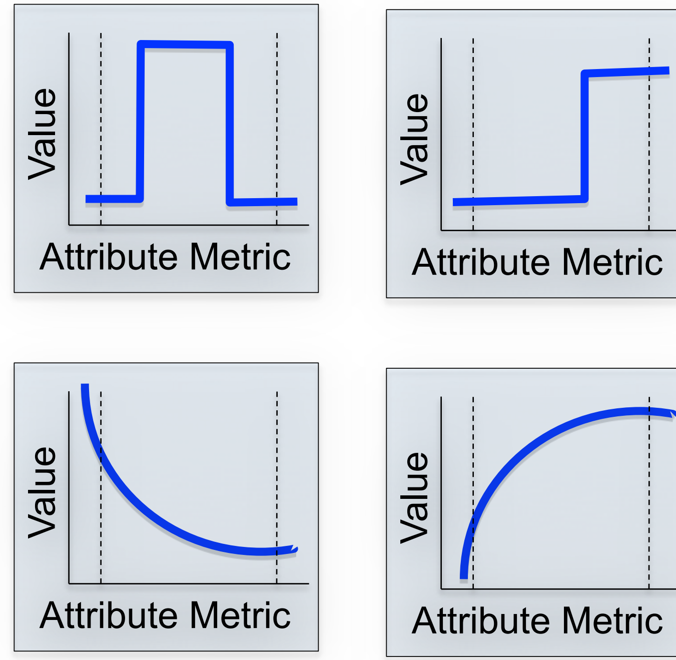
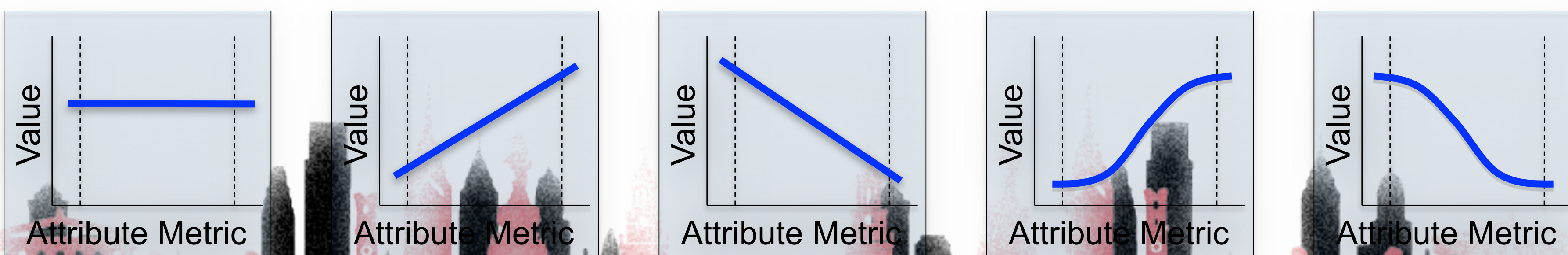
- Over the relevant range of interest, how does the attribute metric add value?
  - Constant or variable
  - Increasing or decreasing
  - Linear or exponential
  - Upper and Lower limits
- Function distribution
  - Uniform, Step, Normal, Linear
  - Exponential, Beta, Logarithmic
  - Ensure stakeholder agreement





Single Purpose to Adaptive Relevancy US Military Examples

- Adaptive Packages or Modules
  - JLTV – Joint Light Tactical Vehicle
  - PTDS – Persistent Threat Detection System
  - LCS – Littoral Combat Ship
    - 2 radically different and competing designs
  - FCS – Future Combat System
    - Changing threats
    - Wartime operations and natural disaster support and
    - Relevancy to the fight

Let's bring Architecture and Affordability Trade Spaces Together

One View: Affordability Attributes
Engineering for Affordability

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Systems Architecting: Perform rapid trades in the solution space in concert with customer

Rates/Capacity: Minimize infrastructure costs consistent with meeting mission success needs of the Enterprise

Value Engineering: Employ standard processes and tools that reduce cost through sustainment

Customer Intimacy: Understand stakeholders mission success and competitive landscape alternatives

Technology: Invest in disruptive technology that reduces cost

Business Model Innovation: Analyze risks and develop business models that align incentives among stakeholders

Cost and Schedule Estimation: Apply rigorous, validated tools and processes

6σ, CMMI, Baldridge: Continuously collect and analyze business data to drive improvements in all elements

Affordability Considerations Through the Life Cycle

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Concept / Capture	Development	Production/Build	Sustainment
• Business Develop • Make / Buy • Partnering / Subs	• Design for Support • Geographic collaboration	• 6 Sigma • Learning Curve • Baseline Evolution	• Global supply • PBL Models • Support the Design

Primary System Architecture | Design Arch | Production Arch | Support Arch

Value Engineering

Technology - Product | Produce Technology | Technology - Supply

Cost/Sched Estimate | Unit Cost – Learning

Rates | Rates & Capacity | Rates & Capacity

Customer Intimacy

Business Model (appropriate for life cycle phase)

6σ & Baldridge Driven | CMMI Driven

Integration & Test

Core Strategic Business Technology and Markets

System Complexity (Technical, Size, Processes, Tools, Artifacts, Partners, Subcontractors, etc.)

Business Model Innovation

- Even excellent needs analysis still assumes a-priori knowledge of the operational uses, environments, laws, etc.
- This is typically NOT a reasonable assumption.
- Acoustic Rapid COTS Insertion (ARCI)
  - Transformational Business Model:
  - Requirements are the variable; cost and schedule are locked
  - System obsolescence (support) and functional growth are merged
  - The system evolves capabilities annually
  - This approach fits Robert Gates' vision of 80% solutions NOW with GROWTH.

What can I do? F-35 Lightening II

- A focus on acquisition cost alone leaves many affordability opportunities unleveraged.
  - 70% of the O&S costs are determined when requirements are set.
  - Wait a minute . . . Isn't this a good thing if I do it right?
  - F-35 Multi-national and Joint-forces Fighter:
    - Mission Reliability (Operational Availability) is a Key Performance Parameter
    - KPP's: **Sortie Generation Rate, Logistics Footprint**
    - $135B or a 56% estimated TOC savings compared to legacy systems
    - Mission Reliability > 90%, 30-day self sustained mission
    - 12% or $16B is expected to come from Enabling System Automation Prognostics & Autonomics

What else can I do? Enabling System Integration

- Dr. Julian Goldman received the INCOSE 2010 Pioneer Award
  - Operating Rooms save many lives and also causing deaths
  - Extreme lack of integration (reliance on the Human integrator)
  - Cables everywhere, high false alarm rates, audible buzzer annoyances
  - At the next level up, FDA regulations are product-focused
  - Massachusetts General Hospital - “Operating Room of the Future”
  - Project ICE STORM (Integrated Clinical Environ)
    - Develop a data-driven mission perspective
    - “Pilot cockpit integration and data fusion” applied to operating room
    - “Status in a Glimpse”
    - Full integrated logging for after-action reviews

Some Take-away Thoughts

- Environment around us has changed radically
  - Financial urgency
  - Economic instability
  - Technology expanding exponentially
  - Legacy system life extensions with ever-expanding ConOps
- Customers undergoing many Changes
- Status quo of System Architecture design and processes is not good enough.
- Definition of Lunatic:
  - Someone who does the same thing over and over again, but each time expects different results!

The Challenges to you . . .

- Integrate enabling systems within your primary architecture
- Proactive evolution of new and legacy
- Cultural shift to Model-based trade studies and design
- Expand system relevancy boundary
- Define, discuss and document Affordability Attributes
- Develop affordability attribute value curves (KPP, MOP and MOE and relevant stakeholder attributes)
- Architect 3 system generations (past, present, future)
- Architect for a level above and a level below the system
- Explore Business Model innovations through life cycle
- Attribute-driven architecture design for Affordability
- Consider joining the INCOSE Affordability Working Group!

Ways to recognize that . . .
"You might just be Affordable"

Wisdom from Jeff Foxworthy, blue collar philosopher

- If your architecture has defined Affordability Attributes AND quantified value metrics, then . . .
- If your logistics system is fully integrated with the primary system for improved Operational Effectiveness, then . . .
- If your development environment uses model-based tools versus drawing pretty pictures in PowerPoint, then . . .
- If your system considers context 1 level up and 1 level down for consistency and interoperability, then . . .
- If your architecture can evolve with your customer's changing scope and needs, then . . .
- If your solution marries performance with beauty like Eliel Saarinen's train station, then . . .
- If –ility management is your favorite past time, then . . .

Questions?