System Supportability and Life Cycle
Product Support:
A Systems Perspective

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Current Situation
What We Need to Do Better

Requirements
• Adapting to changing conditions
• Matching operational needs with solutions
• Overcoming biases of Services and others
• Moving to transform military

PPBES
• Laying analytical foundation for budget
• Aligning budgets with acquisition decisions

Personnel and Readiness
• Treating people as a resource

Acquisition
• Acquiring systems-of-systems
• Making system decisions in a joint, mission context
• Transitioning technology
• Assessing complexity of new work and ability to perform it
• Controlling schedule and cost
• Passing operational tests
• Ensuring a robust industrial base

Sustainment
• Controlling O&S costs
• Reducing logistics tails
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System Design Life Cycle Models: An Automotive Example (VOLVO Car Corporation)
**System Design Life Cycle Models: A Telecom Example (NOKIA Networks)**

**Program initiated**
- Program proposal ready
- Program plan ready
- Ready for integration
- Ready for verification
- Ready for Ramp-up
- Capability for Volume Deliveries

**E-1**
- Define
  - Program to start resources

**E0**
- Plan and specify
  - Program established
  - Commitment of features, resources and milestone dates.

**E1**
- Design and implement
  - Specification done
  - "Proof of concept" *
  - HW implemented
  - Real HW and SW main verification starts.
  - SW is module tested and proof on product functionality exist (=SW implementation ready).

**E2**
- Implement and integrate
  - HW done and HW in maintenance mode.
  - HW and SW main verification starts.
  - First SW build made.
  - Proof of product architecture

**E3**
- Verify
  - Trial deliveries can start (Optional)
  - Functional tests done and HW fulfills legal type approval requirements

**E4**
- Ramp-up
  - Volume deliveries can start

**E5**
- Program completed (optional)

Optional Milestones can be moved.
I.e. E1 and E1.5 dates can be the same.

* Core functionality can be i.e. control plane, signal goes through (typically not call yet). Exact contents of core functionality is need to be defined in E1.
System Design Life Cycle Models: A Workstation Example (SUN Microsystems)

Illustration 1 - Sun PLC Process Overview
The IBM AMS Systems Engineering Process defines deliverables and a series of Reviews (1)

- **Need / Opportunity Identification**
  - Conceptual System Specification
  - Component Architecture
  - Detailed Design

- **Customer Baseline**
  - Business Requirements Review (BRR)
  - Systems Requirements Review (SRR)
  - Preliminary Design Review (PDR)
  - Critical Design Review (CDR)

- **Components**
  - Business Requirements Specs.
  - RTVM
  - System Level Architecture
  - Component Requirement Specs
  - Component RTVM
  - Component Test Architecture
  - Component Design
  - Component Test Plan

- **Legend**
  - Customer Provided
  - Systems Engineering Provided
  - Component Developer Provided
The IBM AMS Systems Engineering Process defines deliverables and a series of Reviews (11).

- **Detail Design**:
  - Design Baseline
  - CDR
  - Comp. Design
  - Comp. Test Plan

- **Development**:
  - Test Baseline
  - System Test Strategy
  - System Test Data
  - Test Traceability Matrix

- **Test and Production System Update**:
  - Test Readiness Review (TRR)
  - System Test Plan / Test Cases
  - Release Content
  - Move to Prod. Plan

- **New Production System**:
  - Production Baseline
  - Production Readiness Review (PRR)
  - Deployment Plan
  - Data Migration Plan

- **Service Provider**:
  - Customer Provided
  - Systems Engineering Provided
  - Component Developer Provided
  - System Test Provided
  - Service Delivery / Managed Ops Provided
Systems Engineering is “problem solving and solution delivery.” A key pre-requisite to good “problem solving” is good “problem definition.” Now this has other pre-requisites!

Some key best practices:

- **Early phases:**
  - Translating customer needs (business and technical) into key acceptance criteria - 5 to 7 critical customer requirements agreed to in measurable/testable form.
  - Identifying requirements and then managing them (and tracing them) through the subsequent development, integration, testing, deployment, and support phases.

- **Middle phases:**
  - Translating the requirements into an “architecture” that becomes a “linkage” between what the customers want and what the developers will build... the concept of an architect as the linkage between the homeowner and the builder.

- **Latter phases:**
  - Developing a test architecture, test plans and procedures that are traceable to the requirements for maximum focus and efficiency

Sounds very simple! A lot of organizations have developed processes that attempt to capture the above intent. But very few are able to execute it...
Successful implementation of SE needs...

- **The process must be “productized” for efficient implementation**
  - Globally consistent templates and processes,
  - Uniform and consistent metrics and lexicon (part of the SE culture)

- **Focus must be on the “necessary” and critical subset of the overall methodology and theory (Flexibility and Adaptability)**
  - Tailoring for time-to-market considerations
  - Tailoring for schedule and resource considerations
  - Risk tolerance must be explicitly considered in the tailoring process

- **Implementation must be organizationally supported and nurtured**
  - Linkage to strategic organizational goals is key

- **A well managed competency development program and a “community of practice**
One Response
TRL scale is a measure of maturity of an individual technology, with a view towards operational use in a system context. A more comprehensive set of concerns become relevant when this assessment is abstracted from an individual technology to a system context, which may involve interplay between multiple technologies. Such concerns include system-level integration and test, human factors (with an emphasis on information and data), and sustainability/supportability.
Concept Refinement Phase - The Initial Opportunity

INPUTS
- ICD
- AoA Plan
- Exit Criteria
- Alternative Maintenance & Logistics Concepts

Interpret User Needs, Analyze Operational Capabilities & Environmental Constraints

Develop Concept Performance (Constraints) Definition & Verification Objectives

Decompose Concept Functional Definition into Concept Components & Assessment Objectives

Develop Component Concepts, i.e., Enabling/Critical Technologies, Constraints & Cost/Risk Drivers

OUTPUTS
- Prelim Sys Spec
- T&E Strategy
- SEP
- Support & Maintenance Concepts & Technologies
- Inputs to:
  - draft CDD - TDS - AoA
  - Cost/Manpower Est.

Analyze/Assess Concepts Versus Defined User Needs & Environmental Constraints

ASR

Analyze/Assess Concept & Verify System Concept’s Performance

Analyze/Assess Enabling/Critical Components Versus Capabilities

Prototype 1

Risk Analysis

Prototype 2

Requirements Plan and Life Cycle Plan

Risk Analysis

Development Plan

Requirements Validation

Emulations

Software Requirements

Concept of Operation

Prototype 1 Development Plan
Concept Refinement Phase - The Initial Opportunity

Concept Refinement Phase –– The Initial Opportunity

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**Interpret User Needs, Analyze Operational Capabilities & Environmental Constraints**

**Develop Concept Performance & Verification Objectives**

**Decompose Concept Performance into Functional Definition & Verification Objectives**

**Decompose Concept Functional Definition into Concept Components & Assessment Objectives**

**Develop Component Concepts, i.e., Enabling/Critical Technologies, Constraints & Cost/Risk Drivers**

**ASR**

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A Simpler View!

Technical Reviews Interactive Timeline

System Readiness Levels, instead of Technology Readiness Levels

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Technology Development Phase - Capitalize on the Initial Assessments

**INPUTS**
- ICD & Draft CDD
- Preferred Sys Concept
- Exit Criteria
- T&E Strategy
- Support & Maintenance Concepts & Technologies
- AoA • SEP • TDS

**OUTPUTS**
- Sys Performance Spec
- LFT&E Waiver Request
- TEMP • SEP • PESHE • PPP • TRA
- Validated Sys Support & Maintenance Objectives & Requirements
- Footprint Reduction
- Inputs to: - IBR - ISP - STA - CDD - Acq Strategy
- Affordability Assessment
- Cost/Manpower Est.

- Demon & Validate Sys Concepts & Technology Maturity Versus Defined User Needs
- Integrated System Versus Performance Spec
- Demo System Functionality Versus Plan
- Demo Enabling/Critical Technology Components Versus Plan
- Design Validation and Verification

**Development Plan**
- Risk Analysis
- Prototype 3
- Models
- Software Product Design

**Interpret User Needs.** Analyze Operational Capabilities & Environmental Constraints

**Develop System Perf** (& Constraints) Spec & Enabling/Critical Tech Verification Plan

**Develop Functional Definitions for Enabling/Critical Technologies & Associated Verification Plan**

**Decompose Functional Definitions into Critical Component Definition & Tech Verification Plan**

**Develop System Concepts, i.e., Enabling/Critical Technologies, Update Constraints & Cost/Risk Drivers**

**Integration and Test Plan**
A Simpler View!

System Design for Operational Effectiveness, instead of just System Design

This was the emphasis in the Supportability Guide. This concept is also inherent in the Defense Acquisition Guide (DAG)
Design for System Operational Effectiveness

System Uptime

- Time to Failure (TTF)
  - Reliability/Operation

System Downtime

- Time to Support (TTS)
  - Supportability/Logistics
- Time to Maintain (TTM)
  - Maintainability/Maintenance

Design “Cause”
Operational “Effect”

Performance
- Reliability
- Maintainability
- Supportability
- Availability

Technical Effectiveness
- Operation
- Maintenance
- Logistics
- Process Efficiency

System Effectiveness
Operational Effectiveness

System Life-Cycle Cost/CAIV
As articulated in the Supportability Guide...
• SE must manage all requirements as an integrated set of design constraints
  – KPPs
  – Statutory
  – Regulatory
  – Derived performance requirements
    • Constraints
    • Usage, duty cycle, mission profiles
• Decomposition and allocation must address entire set at each level of recursion
• Integrated set of requirements and associated stakeholders are a primary driver for program staffing (non-trivial and a major source of program risk)

As articulated in the Defense Acquisition Guidebook…
Important Design Considerations
“The Fishbone”

- Architectural Impacts on System
- Open Systems Design
- Interoperability

Design Considerations
- Survivability & Susceptibility
- Software
- Anti-Tamper
- HSI
- Accessibility
- Sensitivity Missions
- System Security
- Information Assurance
- Corrosion Prevention
- COTS
- Disposal and Demilitarization
- Environment, Safety, Occupational Health

Design Tools
- Modeling & Simulation

- System Performance
  - Capabilities
  - Functions
  - Priorities
  - System Performance
    - Technical Effectiveness
    - System Availability
      - Reliability
      - Maintainability
      - Supportability
      - Productivity
    - System Efficiency
      - Operations
      - Maintenance
      - Logistics
    - Affordable Operational Effectiveness

- Life Cycle Cost / Total Ownership Cost

- System Availability
  - Reliability/Maintainability/Supportability
    - RAM, COTS
  - Productivity: Value Engineering, Quality, Manufacturing Capability

- Process Efficiency
  - Maintenance: Corrosion Prevention and Control, Accessibility, Interoperability, Unique Identification of Items
  - Logistics: Supportability
  - Productivity: Value Engineering, Quality, Manufacturing Capability
System Design for Operational Effectiveness, instead of just System Design

Let us consider System Architectures to illustrate the concept...
Evaluating Architectures from a Sustainment Perspective - Industry Sponsorship (COTS Focus)
• Architecture assessment conducted by three senior architects knowledgeable about the system

• Created a baseline for comparison with other alternatives

• Architectures are a strategic tool in today’s environment for increased competitiveness and profitability

• Good requirement definition, understanding of stakeholder/customer expectations is key
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System Development and Demonstration Phase

**INPUTS**
- Sys Performance Spec
- Exit Criteria
- Validated Sys Support & Maintenance Objectives & Requirements
- APB • CDD • SEP
- ISP • TEMP

**Outputs**
- Initial Prod Baseline
- Test Reports • TEMP
- Elements of Product Support
- Risk Assessment
- SEP • TRA • PESHE
- Inputs to: -CPD -STA -ISP
  - Cost/Manpower Est.

**Outputs**
- System DT&E, LFT&E & OAs, Verify System Functionality & Constraints Compliance to Specs
- Integrated DT&E, LFT&E & EOAs Verify Performance Compliance to Specs
- Individual CI Verification DT&E
- Fabricate, Assemble, Code to “Build-to” Documentation

**Outputs**
- Combined DT&E/OT&E/LFT&E Demonstrate System to Specified User Needs & Environmental Constraints

**Inputs**
- Risk Analysis

**Interpret User Needs, Refine System Performance Specs & Environmental Constraints**
- Develop System Functional Specs & System Verification Plan
- Evolve Functional Performance Specs into CI Functional (Design to) Specs and CI Verification Plan
- Evolve CI Functional Specs into Product (Build to) Documentation and Inspection Plan
- Fabricate, Assemble, Code to “Build-to” Documentation

**Integration and Test**
- Operational Prototype
- Detailed Design
- Code
Cost as an Independent Variable (CAIV): Design to Affordability Analysis (Strategic Decision Making)

Elements of Logistics Support:
- Supply Support (Spare/Repair Parts)
- Maintenance Planning
- Test/Support Equipment
- Technical Documentation/IETM
- Manpower/Personnel
- Training/CBT
- Facilities; PHS&T
- Design Interface; Computing Support

Technology/Standards Evolution and COTS Products Market Surveillance

System Test & Evaluation (Hot Bed Testing)
A Simpler View!

Performance Based Logistics, instead of just Material Readiness, Spares Optimization, and the like...
Current Trends in System Development: COTS, Reusable and Common Platforms and Components

Reference Configuration
- Total 19 Chassis
  - BF-A
  - AP-A
  - BF-A
  - AP-A
  - BF-B
  - AP-A
  - BF-B
  - AP-B
  - BF-B
  - AP-B
  - BF-B
  - AP-B
  - BF-B
  - AP-B
  - BF-B
  - AP-B
  - BF-B
  - AP-B

‘98 Technology Update
- Total 15 Chassis
  - BF-A
  - AP-C
  - BF-A
  - AP-C
  - BF-B
  - AP-C
  - BF-B
  - AP-D
  - BF-B
  - AP-D
  - BF-B
  - AP-D
  - BF-B

‘00 Technology Update
- Total 7 Chassis
  - BF/SP
  - IP
  - BF/SP
  - IP
  - BF/SP
  - IP
  - BF/SP
  - IP
  - BF/SP
  - IP

Technology Refresh
- Total 7 Chassis
  - BF/SP
  - IP
  - BF/SP
  - IP
  - BF/SP
  - IP
  - BF/SP
  - IP

Processing Summary
1995-Level Technology
- 8 Beamformers - 75 GOPS
- 11 Allocatable Processors - 65 GOPS
- Total Throughput - 140 GOPS

1998-Level Technology
- 8 Beamformers - 75 GOPS
- 7 Allocatable Processors - 75 GOPS
- Total Throughput - 150 GOPS

2000-Level Technology
- 6 BF/Signal Processors - 240 GOPS
- 2 Information Processors - 30 GOPS
- Total Throughput - 270 GOPS

2003-Level Technology
- 6 Beamformers - 380 GOPS
- 2 Information Processors - 50 GOPS
- Total Throughput - 430 GOPS
Current Trends in System Development: Network Centric Warfare must be supported by Network Centric Logistics Planning

Sense demands and requirements at the Equipment Level . . .
Supply at the Fleet Level (Cross Platform) . . .
The Metrics...

- Operational Availability
- Operation Reliability
- Cost per Unit Usage
- Logistics Footprint
- Logistics Response Time

Multi-Asset, Multi-Echelon... Modeling and Simulation

An offer!!
Architecture Development:
Architecture Assessment and Evaluation - Telecom

Goal: Selecting the Best Base Station Architecture

1. Functionality
   - 2.1 Scalability
   - 2.2 Modularity
   - 2.3 Upgrades
   - 2.4 Compatibility and Consistency (Solution Harmony)
     - 3.1 Ease of HW installation
     - 3.2 Ease of SW installation
   - 3. Logisticability
     - 3.3 Serviceability and maintainability
     - 3.4 Learnability
     - 3.5 E-Business compatibility (move to 3.)
     - 4.1 Built in testing
   - 4. Testability
     - 4.2 Verification and acceptance testing
     - 4.3 Testing ease
   - 5. Commonality
     - 5.1 Hardware commonality
     - 5.2 Software commonality
     - 5.3 Operational commonality
     - 5.4 COTS and reuse
   - 6. Reliability and Availability
     - 7.1 Interfaces
     - 7.3 Orthogonality (Solution Harmony)
   - 7. Simplicity
     - 7.3 Orthogonality (Solution Harmony)
   - 8. Affordability
     - 8.1 Costs
     - 8.2 Timeliness and Profitability
     - 8.3 Customization
     - 8.5 Environmental Issues
   - 9. Future proofness issues
     - 9.1.1 Industry acceptance
     - 9.1.2 Business horizontalization
     - 9.1.3 Control over the product