World-Class Quality

Architecture and Model Based Systems Engineering For Lean Results

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"I have made this letter longer than usual because I lack the time to make it shorter"

Blaise Pascal

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Objectives

Provide some "lean results" motivation.

Describe some engineering problems from industry.

Describe motivation and advantages of architectures.

Describe motivation and advantages of models.

Provide some examples.

Answer any of your questions.

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Outline

Lean Results

Some Problems in Engineering

Systems Engineering Processes

Why Focus on Architectures?

Why Focus on Models?

The Future: Industry Standards and Tools

Summary

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The Quality Crisis

The cost of poor quality:

- **"In most companies the costs of poor quality run at 20 to 40 percent... In other words, about 20 to 40 percent of the companies' efforts are spent in redoing things that went wrong because of poor quality" (*Juran on Planning for Quality*, 1988, pg. 1)**

- **Crosby's Quality Management Maturity Grid states that if an organization doesn't know it's cost of quality, it's probably at least 20%. (Crosby, *Quality is Free*, 1979, pg. 38-39)**

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What is Lean?

Lean has its roots in quality and manufacturing, and is a recent popular movement in quality.

"Lean Production" is the name for the Toyota Lean Production System.

The following are major lean references (see references in back of presentation for full references):

- **"The Machine That Changed The World"**
- **"Learning to See"**
- **"The Toyota Way"**
- **"The Toyota Product Development System"**
- **"Lean Thinking"**

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Some Lean Principles - (1)

Establish customer defined value (i.e., identify the “value stream”). Process = “value”.

Continuously eliminate non-value added activities (e.g., waste, rework, defects).

Use leadership and standardization to create a lean culture.

Align your organization through visual communication.

Create an optimized process flow (e.g., “Flow”, “Pull”, “Just-In-Time”, “Leveled”).

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Some Lean Principles - (2)

Use lean metrics to manage the value stream.

Front-Load the process for maximum design space.

Build a learning organization to achieve lean and continuous improvement.

Adapt technology to fit your people and processes.

Strive for perfection through continuous improvement.

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Some Lean Results

MEASUREMENT	WORLD-CLASS BENCHMARK
Costs of Poor Quality (COPQ)	Reduced from ~33% to ~15% (e.g., cut COPQ in half)
Defect Removal Efficiency	70-90% defect removal before test
Post-Release Defect Rate	Six Sigma (i.e., 3.4 Defects Per Million)
Productivity	Doubled (e.g., in 5 years at ~20% a year)
Return on Investment	7:1 - 12:1 ROI
Schedule / Cycle Time	Reduced by 10-15% (e.g., per year)

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Some Engineering Problems

Numerous problems with requirements.

Too many defects (i.e., quality problems).

Lack of metrics (e.g., process improvement).

Major decisions made made subjectively or without data.

Management problems (e.g., poor risk management).

Lack of product integrity.

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Example Problem: Requirements

A research report from the Standish Group highlighted the continuing quality and delivery problems in our industry and identified three leading causes:

- Lack of user input
- Incomplete requirements and specifications
- Changing requirement specifications

- Reference: "Chaos", Compass, The Standish Group, 1997, used with permission.

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Problems with Requirements

According to the SEI [Christel 92], problems of requirements elicitation can be grouped into 3 categories:

1. Problems of Scope: the requirements may address too little or too much information.

2. Problems of Understanding: problems within groups as well as between groups such as users and developers.

3. Problems of Volatility: the changing nature of requirements.

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CMMI® Process Areas

Engineering:

- Requirements Management (REQM)
- Requirements Development (RD)
- Technical Solution (TS)
- Product Integration (PI)
- Verification (VER)
- Validation (VAL)

Support:

- Measurement and Analysis (MA)
- Process & Product Quality Assurance (PPQA)
- Configuration Management (CM)
- Decision Analysis and Resolution (DAR)
- Causal Analysis and Resolution (CAR)

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CMMI® Process Areas

Project Management:

- Project Planning (PP)
- Project Monitoring and Control (PMC)
- Supplier Agreement Management (SAM)
- Risk Management (RSKM)
- Integrated Project Management + IPPD (IPM)
- Quantitative Project Management (QPM)

Process Management:

- Organizational Process Definition + IPPD (OPD)
- Organizational Process Focus (OPF)
- Organizational Training (OT)
- Organizational Process Performance (OPP)
- Organizational Innovation and Deployment (OID)

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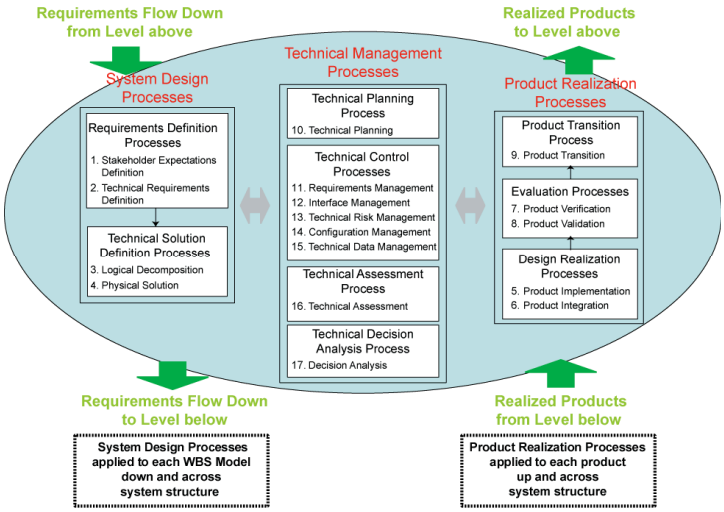
NASA Systems Engineering Requirements (NPR-7123)



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Why Architectures?

Architectures are very powerful because they:

- **Are graphical (a picture is worth a 1000 words) and can be powerful communication tools.**
- **Provide a framework for how components are related (e.g., interfaces, interdependencies, relationships) and how components fit together.**
- **Promote reuse (e.g., products, components, requirements, designs, tests, interfaces, etc.) and can improve productivity and quality.**
- **Can be modeled in an automated tool.**

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Architectures

Architectures consist of:

- **Components**
- **Interfaces, interdependencies, and other relationships among components**
- **Ordering and rules for putting components together**

Simple Architecture Example: Lego's

Numerous Types of Architectures:

- **Product and Domain Specific Architectures**
- **Business, Data, Technology, etc. Architectures**
- **Discipline Specific Architectures (e.g., software)**
- **Process Architectures**
- **Documentation Architectures**

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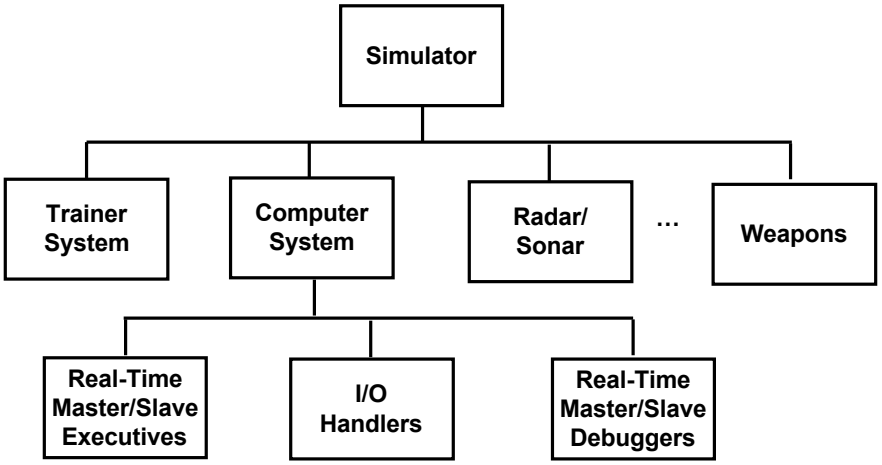
Example Product Architecture



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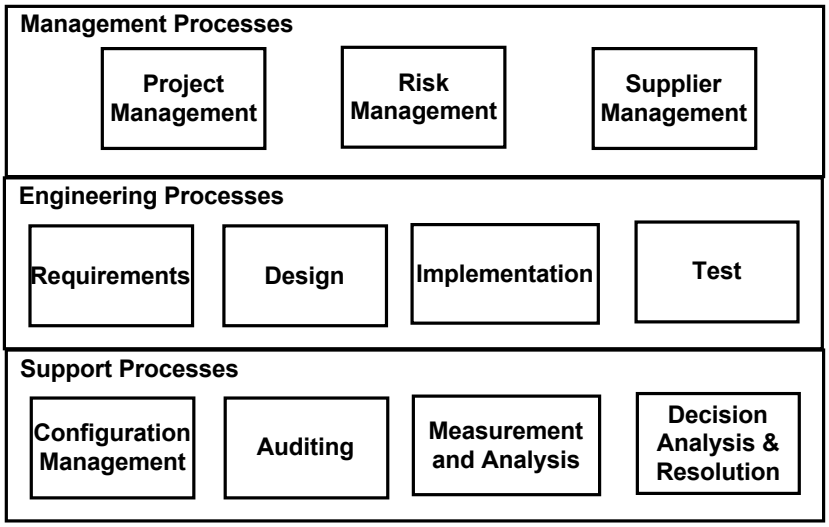
Example Process Architecture



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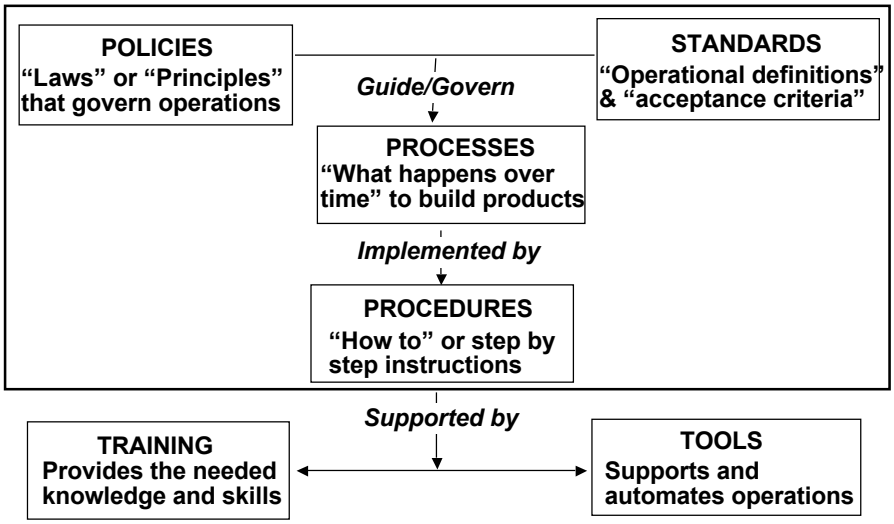
Documentation Architecture



• Slide adapted from"A Software Process Framework for the SEI Capability Maturity Model", CMU/SEI-94-HB-01

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Why Models?

Models are very powerful because they:

- Are graphical (a picture is worth a 1000 words) and can be powerful communication tools.
- Can scale up to complex systems and provide a tool to analyze complex relationships and dependencies.
- Promote reuse (e.g., products, components, requirements, designs, tests, interfaces, etc) and can improve productivity and quality.
- Can be represented in an automated tool, and simulated.

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Models

Models are abstractions of reality constructed for a (useful) purpose consisting of:

- Formal notations and rules for representations
- Model components or building blocks
- Ways to model interfaces, interdependencies, and other relationships among the model components

There are numerous modeling languages and tools.

A Few Modeling Examples:

- Behavioral Models (e.g., timing, states)
- Structural Models (e.g., hierarchy, order)
- Functional Models (e.g., input, function, output)
- Process Models (e.g., the 5 W's)

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What is a Process Model?

Process Model:

- An abstraction of a process typically characterized by formal notations for representing roles, activities, and/or work products, and the relationships (e.g., events, transformations) among them.

Types of process models:

- Descriptive (as-is): describes what is actually done
- Prescriptive (to-be): prescribes what to do (e.g., by new policies, standards, process guidelines, etc.)
- Mixed (both): most process models are a mixture of prescriptive and descriptive processes

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Popular Process Models: CMM/CMMI

SADT: Structured Analysis and Design Technique (SADT) is a graphical systems modeling language developed at Softech/MIT by Doug Ross in early 1970's. Used extensively to document all manner of systems including manufacturing processes. Has automated tool support (e.g., IDEF).

ETVX: Entry criteria/Tasks/Verification/eXit criteria (ETVX). Developed at IBM in the mid 1980's. Simple to use, but no automated tool support.

Role/Flow or Swim-Lane Models: Like flow charts, but have swim-lanes for roles and are formal process models. Have become very popular in the last decade. [Example Handout].

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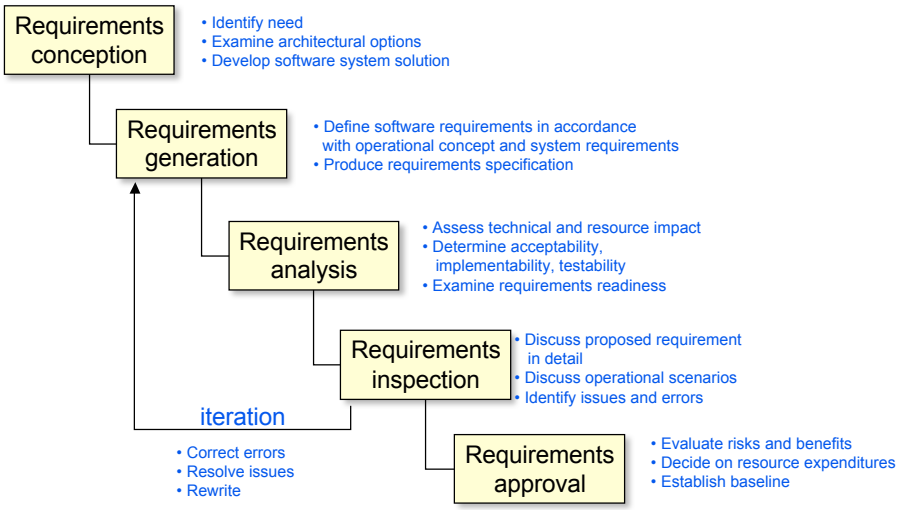
Example Requirements Process: NASA Onboard Shuttle Project



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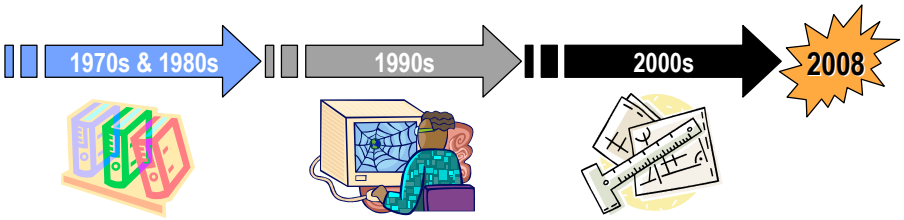
State of the Industry – Process Management



Three-Ring Binders
- Demonstrated organization commitment
- Often became shelfware

Websites
- More accessible by practitioners
- Often difficult to navigate and maintain

Model-Driven
- Access to industry standard frameworks
- Integration of multiple lifecycles
- Formal process asset management

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Benefits of a Standards-Based Approach

Increased sustainability:
- **Lower cost and shorter time of initial adoption**
- **Widespread availability of knowledgeable employee, contractor, and vendors**
- **Lower cost of maintenance**

Lower risk:
- **Apply proven best practices**
- **Widespread adoption across industry**

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Some Industry Standards

OMG: Object Management Group

UML: Unified Modeling Language

SysML: Systems Modeling Language

SPEM: Software and Systems Process Engineering Metamodel

Eclipse Process Framework (EPF) Composer: Open Source based on SPEM: www.eclipse.org/epf.

OpenUP: Open Unified Process - process framework

TOGAF: The Open Group Architecture Framework

DoDAF: DoD Architecture Framework

IEEE 1471: Recommended Practice for Architecture Description of Software Intensive Systems

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Summary

There are many industry engineering problems.

Systems engineering needs to focus on improving those engineering problems.

Organizations need lean measurable results (e.g., 7:1 ROI).

Architectures and models are powerful tools to help improve engineering and obtain measurable results.

The future of architectures and models is industry standards and tools. Architectures can also be represented with models.

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