Systems Knowledge Framework

Procter & Gamble: “Canonical, Enterprise Scale MBSE”

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Acknowledgements:

- Foundational Canonical Systems Model : “Systematica” Method : ICTT (William Schindel)
- Key Enabling Technology & Services: Tom Sawyer (Josh Feingold, Margers Kietis), IBM
- Key Services: 321gang (Tim McKemy, Kevin Johnson, Jerry Romanek), InterCAX (Dirk Zwemmer)
Agenda

• Business Objectives

• Strategy: Systems Model
  • Canonical Systems Model (Systematica)
  • Leverage Today’s MBSE Infrastructure to Realize Canonical Model

• Strategy: Requirements
  • Standard, Structured Requirement Statements
  • Requirements Authoring Tool embedded in SysML Tool

• PLM Design Perspective

• Phased Transformation Plan
CPG vs. Aero, Auto, Mil

Organizational Differences:
- One engineer for multiple projects vs. concurrent engineering
- One engineer wearing multiple hats vs. one or more engineers for each discipline

Initiative Differences:
New product lifecycle = 18 months vs. 10+ years

Similarities:
- Simple goals:
  - Deliver troops (or bomb)
  - Keep baby dry
- Complicated delivery
  - # of parts & lines of code on Paper
  - Machine = the same on Transport Airplane
  - Multi-physics
  - Information intensive operations
  - Build & operate machines in 70 countries
Engineering Tools and Environments

Manufacturing Co. Objective

Digital Engineering Design
- Digital System Model/Digital Thread
- Education
- Policy & Guidance
- Data Rights

Engineered Resilient Systems
- Trade Space Analysis
- SERC
- CREATE/HPCMO

Modular Open Systems Architecture
- BBP 3.0
- Technical Standards
- Curriculum Development

Outreach: INCOSE/JPL, NDIA, MBE Summit, AMSWG

Engineering processes, tools and techniques incorporating the latest digital practices for making informed decisions throughout the acquisition lifecycle.
Better Buying Power 3.0 (Draft)
Achieving Dominant Capabilities Through Technical Excellence and Innovation

Achieve Affordable Programs
- Continue to set and enforce affordability caps

Achieve Dominant Capabilities While Controlling Lifecycle Costs
- Strengthen and expand “should cost” based cost management
- Build stronger partnerships between the acquisition, requirements, and intelligence communities
- Anticipate and plan for responsive and emerging threats
- Institutionalize stronger DoD level Long Range R&D Planning

Incentivize Productivity in Industry and Government
- Align profitability more tightly with Department goals
- Employ appropriate contract types, but increase the use of incentive type contracts
- Expand the superior supplier incentive program across DoD
- Increase effective use of Performance-Based Logistics
- Remove barriers to commercial technology utilization
  - Improve the return on investment in DoD laboratories
  - Increase the productivity of IR&D and CR&D

Incentivize Innovation in Industry and Government
- Increase the use of prototyping and experimentation
- Emphasize technology insertion and refresh in program planning
- Use Modular Open Systems Architecture to stimulate innovation
- Increase the return on Small Business Innovation Research (SBIR)
- Provide draft technical requirements to industry early and engage industry in funded concept definition to support requirements definition

Highlight items are key opportunities for engineering community engagement

Eliminate Unproductive Processes and Bureaucracy
- Emphasize Acquisition Executive, Program Executive Office and Program Manager responsibility, authority, and accountability
- Reduce cycle times while ensuring sound investments
- Streamline documentation requirements and staff reviews

Promote Effective Competition
- Create and maintain competitive environments
- Improve technology search and outreach in global markets

Improve Tradecraft in Acquisition of Services
- Increase small business participation, including more effective use of market research
- Strengthen contract management outside the normal acquisition chain
- Improve requirements definition
- Improve the effectiveness and productivity of contract engineering and technical services

Improve the Professionalism of the Total Acquisition Workforce
- Establish higher standards for key leadership positions
- Establish stronger professional qualification requirements for all acquisition specialties
- Strengthen organic engineering capabilities
- Ensure the DoD leadership for development programs is technically qualified to manage R&D activities
- Improve our leaders’ ability to understand and mitigate technical risk
- Increase DoD support for Science, Technology, Engineering and Mathematics (STEM) education
Multi-Discipline System of Innovation

Idea
Stakeholder Requirements

Residuals

Design  Tests  Financials

Unmet Need: Increased Innovation Productivity
The Obstacle: “Activity” Centric
Transformation Needed

- Decision models not designed for emergent behavior
- Translation errors
- Too many people developing & revising “the plan”.

• Knowledge Re-Use
  - about customer needs
  - technical knowledge about products, manufacturing, distribution, etc.

• Requirements Mgmt
  - improved awareness & visibility of requirements trade space
  - avoid incorrect, excessive and/or overlooked requirements
  - avoid overly constrained requirements (i.e. pre-mature convergence on solution)
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The Solution: Recognizing “System-ness”
The Solution: Cross-Discipline “Pattern”

• A “systems pattern” is a re-usable, functional and architectural model of a “set of things” whose behaviors (individually & collectively) must be manipulated to meet the objectives of stakeholders.
  • There is no limit on the types of (or number of) “things” in a “systems” pattern.
    • They can be roles/organizations, chemicals/parts, machines/computers, information/perceptions, etc.
  • Accordingly, there is no limit on the purposes (stakeholder needs) for creating systems patterns.
    • E.g. they could be used to manage economics, logistics, machine dynamics or physics phenomena.

• Patterns are, in essence, the encoding of useful, re-usable knowledge about the nature of and the manipulation of things.
The Transformation to: “Systems Thinking”

Current State

Systems Pattern
Work Process: for Systems Thinking


**Enterprise Mgmt Processes**
- Environment
- Investment
- System Life Cycle
- Resource
- Quality

**Project Processes**
- Project Planning
- Project Assessment
- Project Control
- Decision Making
- Risk Mgmt
- Configuration Mgmt
- Information Mgmt

**Technical Processes**
- Stakeholder Requirements Definition
- Requirements Analysis
- Architectural Design
- Implementation
- Integration
- Verification
- Transition
- Validation
- Operation
- Maintenance
- Disposal

**Agreement Processes**
- Acquisition
- Supply

Need Analysis

Architecture (Interactions)

Design

Detailed Design

Unit Test

Integration Test

System Test

Acceptance Test

Fabricate Construct

Need Analysis

Architecture (Interactions)

Design

Detailed Design

Unit Test

Integration Test

System Test

Acceptance Test

Fabricate Construct

4/11/2018
Bob Sherman (sherman.rf@pg.com)
Data/Metamodel: for Systems Thinking

Triple Store for “Linked Data”

<table>
<thead>
<tr>
<th>Subject</th>
<th>Predicate</th>
<th>Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td>Assigned To</td>
<td>Design Component</td>
</tr>
<tr>
<td>Requirement</td>
<td>Verified By</td>
<td>Test</td>
</tr>
<tr>
<td>etc</td>
<td>etc</td>
<td>etc</td>
</tr>
</tbody>
</table>

Metamodel Complexity Continuum

Reduce adoption activation energy
Data: Concurrent Elaboration

Current State

Architecture (Interactions)

Design

Detailed Design

Integration Test

Unit Test

System Test

Acceptance Test

Fabricate Construct

PLM & Discipline Specific Design Tools

4/11/2018

Bob Sherman (sherman.rf@pg.com)
V-Model: Unstructured Documentation

Unstructured, document based Requirements Mgmt

FUTURE INITIATIVE QUESTIONS:
• What will this change impact?
• Why did they do this?

PLM & Discipline Specific Design Tools

4/11/2018

Bob Sherman (sherman.rf@pg.com)
William Schindel (of ICTT) is the creator of this canonical model called “Systematica” (S*).
Canonical Systems Model: Fractal
What should be known about a system?

<table>
<thead>
<tr>
<th>Component</th>
<th>Question</th>
<th>Content Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ontology</td>
<td>What exists?</td>
<td>Theory about what exists most fundamentally</td>
</tr>
<tr>
<td>Metaphysics</td>
<td>What is its nature?</td>
<td>Theory about the nature of what exists (and hence what is possible given the ontology)</td>
</tr>
<tr>
<td>Cosmology</td>
<td>What is its story?</td>
<td>High-level theory of the origin, history, organisation and destiny</td>
</tr>
<tr>
<td>Epistemology</td>
<td>What/how can we know?</td>
<td>Theory about what kinds of knowledge are possible and how to gain knowledge</td>
</tr>
<tr>
<td>Axiology</td>
<td>What is important?</td>
<td>Value system and theories about what is important and why</td>
</tr>
</tbody>
</table>

Source of table (above): 2c.2_Modeling+ComparingSysWVs IW18 - System Sciences- David Rousseau.pptx

4/11/2018

Bob Sherman (sherman.rf@pg.com)

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The Transformation to: “Systems Thinking”

Current State

Transformation

Data
Work Process

Systems Thinking

Improvement

Systems Pattern

4/11/2018

Bob Sherman (sherman.rf@pg.com)
A Landscape for Business Strategy Development

Knowledge Gaps and/or Competitive Activity and/or Simulations Needed

Current activities and/or Strengths To Exploit
DEMO: Systems Knowledge Framework
(Systematica on SysML)
Rhapsody
SysML Profile of Systematica
Let's see what is required to deliver this feature.
Zoom to Logical Systems
Zoom to Physical Design Components
Change in cardboard material surface roughness
Initiate Impact Analysis on Changing Attribute

Here is the "Carton" system object and its "Surface Roughness" attribute.
Impact Analysis from Physical Component to Feature

System "Roles"

Dependency Coupling

Manufacturing Equipment Reliability

Change in cardboard material surface roughness
Summary of Systems Knowledge Framework

• Product Line Engineering
  • Cross Discipline Architecture & Strategic Variation Management

• Traceability from Features to Physical Design explicates:
  • trade-spaces
  • change impact analysis

• Simple, Common Systems Language
  • clarity and economy of expression
Forensics: Digital Evolution

Benefits
- Intentional Innovation
- Asset Re-Use

Platforming
- Digital Twins
- “Pattern Based” Systems Engineering (PBSE)
- Product Line Engineering (Strategic Variation Management)

Life Cycle Management
- Version Mgmt
- Work Flow

Systems Engineering
- Functional decomposition

Abstraction & Integration
- Common Systems Modeling Language (SysML)
  - Semantic Framework/Ontology (S*)
  - Model to Model Referencing (OSLC)

Centralization of Information
- Shared drives -> SharePoint (VCS) -> PLM

Big Data
- Cross discipline Knowledge and Work Process Integration
- Communication Efficacy & Efficiency

S*
- Cross discipline Knowledge and Work Process Integration
- Communication Efficacy & Efficiency

Modeling
- Model Based Design (e.g. mCAD/eCAD)
  - Simulation
  - Master Data

Accessibility
- Basic Version Mgmt
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A “requirement” describes a system’s behavior in response to a stimulation from its environment.

William Schindel INCOSE 2005 white paper: “Requirements are Transfer Functions”
Enabling Requirements for “Travel”

Systems Engineering

<table>
<thead>
<tr>
<th>Feature</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logical System 1</td>
<td>Attribute</td>
<td>Attribute</td>
</tr>
<tr>
<td>Logical System 2</td>
<td>Attribute</td>
<td>Attribute</td>
</tr>
<tr>
<td>Requirement 2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Thing A</td>
<td>Attribute</td>
<td>Attribute</td>
</tr>
<tr>
<td>Physical Thing B</td>
<td>Attribute</td>
<td>Attribute</td>
</tr>
</tbody>
</table>

Simulation

<table>
<thead>
<tr>
<th>Requirements Monitor</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logical System 1</td>
<td>Attribute</td>
</tr>
<tr>
<td>Logical System 2</td>
<td>Attribute</td>
</tr>
<tr>
<td>Physical Thing A</td>
<td>Attribute</td>
</tr>
<tr>
<td>Physical Thing B</td>
<td>Attribute</td>
</tr>
</tbody>
</table>

Test Orchestrator

Requirements Verdict Mgr

4/11/2018

Bob Sherman (sherman.rf@pg.com)
Example System

Behavior failure leads to...

Waterfall Failure
"When subject to a" <force> |condition| ",,"
"the/The" <system> "shall" <key word> "a"
<flow or attribute> "in accordance with the"
<constraint> "constraint".

When subject to a Carton_Flow_Force force, > 5Nm
Carton_Escapement_Top shall exert a minimum
Friction_Dynamic force in accordance with the
Dynamic_Friction_Resistance constraint.
Multi-Trigger/Multi-Behavior Formats

| “When subject to a” <flow> | condition| “,” | “the/The” <system> “shall” <key word> “a” <flow or attribute> | “in accordance with the” <constraint> “constraint.” |

| “When subject to the following conditions,” | “the/The” <system> “shall” <key word> “a” <flow or attribute> “in accordance with the” <constraint> “constraint.” |
- <flow> | condition|
- <flow> | condition|

| “When subject to a” <flow> | condition| “,” | “the/The” <system> “shall” <key word> “a” <flow or attribute> | “in accordance with the following constraints:” |
- <constraint>
- <constraint>

| “When subject to the following conditions,” |
- <flow> | condition|
- <flow> | condition|
“the/The” <system> “shall” <key word> “a” <flow or attribute> | “in accordance with the following constraints:” |
- <constraint>
- <constraint>
DEMO:

“Executable Requirements”

Single, Standard Requirements Statement
managed via embedding

“The ReUse Company” Requirement Authoring Tool (RAT) in Rhapsody
Zoom here
When subject to a Carton Flow Force, the Carton Escapement Top shall exhibit a Carton to Top Escapement Friction Dynamic in accordance with the Dynamic Friction Resistance constraint.
Standard, structured, linked, almost “executable” requirement statement
Summary of Executable Requirements

- Embedding requirements in system models improves context
- Transfer function approach explicates assumptions about conditions under which systems must exhibit specific behaviors
- Standard syntax (and semantics) for “requirements” will enable requirements to travel to simulations (and eventually to operations) where monitoring can occur.
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Implementation Architecture

Project/Program Processes

"Systems" Model

SysML (Rhapsody)

OSLC

OSLC (FMI)

Discipline Specific Technical Work Processes

Mechanical

Electrical

First Principles Simulation

Patterns

Force, Mass, Energy or Information

Behavior Requirement

Functional Role

Stakeholder Feature Satisfies Attribute

Delivers Coupling

Design Component

Design Component

Design Component

Design Component

Design Component

Design Component

OSLC

OSLC

OSLC

OSLC

Project Mgmt

Procurement

Regulatory

Facilities Engineering

Cost Engineering

Reliability Engineering

Operations
Requirements are visible (not copied)

SE diagrams accessible in PLM

Rhapsody + Jazz

OSLC Repository

Position in Architecture

Instance of Position

Instance of Position

Sys 1

Sys 2

Sys 3

Sys 4

Sys 5

Requirement

Requirement

Requirement

Requirement

Requirement 1

Requirement 2

Requirement 3
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Phase 1: Capture the Knowledge
Phase 2: Harness Models to Support Decisions
Phase 3: Re-use
Phase 4: Drive “Discovery”
Phase 5: Support Prediction
Phase 6: PLM Through Platforming
Recap: Altitude 100,000 ft

INTEGRATION OF MBSE & KNOWLEDGE MGMT

Alignment on the problem
Systems Knowledge Model (SKM)
Applicability to Traverse Left Side of V-Model

Missing steps in the digital evolution of MBSE & KM

Forensic Discussion:
Why didn’t we spot this earlier?

IT Architecture Implications
Questions

Hyperlink to canonical systems modeling video demo viewing: http://www.screencast.com/t/Wt74garOk
Hyperlink to canonical systems modeling video demo download: https://app.box.com/s/m09zner7pefaen5dc3yzp7354idsprv7

Hyperlink to canonical requirements modeling video viewing: http://www.screencast.com/t/nmC4iWC0UxoU
Hyperlink to canonical requirements modeling video download: https://app.box.com/s/kxx13b0o4zbkv1w4mq8i4hkqd1ql9jnu