New Opportunities for System Architecture Measurement

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Background

- **The United States Government Accountability Office, the United States Department of Defense ((Carter, 2010) and (Thompson 2010)), and industry (NDIA 2010) have all made the case for better measurement in support of program success.**

- **ISO/IEC/IEEE 15288 and INCOSE SE Handbook define architecture**
  - Defines elements of the architecture
  - No guidance on how to measure

- **INCOSE Handbook**
  - Defines processes for developing an architecture

- **INCOSE System Engineering Leading Indicators (SELI)**
  - Defines base measures and an indicator
  - Measures trends in architecture and related resources and processes
  - Does not directly measure the quality of an architecture or its description

Previous Activity

- **Outgrowth of a NDIA/PSM study[1]**
  - Identify a set of leading indicators that provide insight into technical performance
  - Build upon objective measures in common practice in industry, government, and accepted standards.
  - Select objective measures based on essential attributes (e.g., relevance, completeness, timeliness, simplicity, cost effectiveness, repeatability, and accuracy).
  - Measures should be commonly and readily available
- **Results published as NDIA System Development Performance Measurement Report, December 2011**
  - Architecture was a high priority area but no indicators were identified that met criteria
- **PSM Workshop[2] July 2012 to obtain support for base measures and measurable concepts as basis for indicators**

[1]NDIA System Development Performance Measurement Report, December 2011
[2]System and Software Architecture Measurement, July 2012

What is an Architecture?

- **ISO/IEC/IEEE 42010-2011 - IEEE Systems and software engineering – Architecture description**
  - **Architecture** (system) – fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution

  - **Elements**
    - **Structure**
    - **Behavior**
    - **Data**
    - **Procedures**
  - **Relationships**
    - **Internal**
    - **External**
  - **Principles**
    - **Architecture Rules and Overarching Guidance**

- **These outcomes are all objectively measurable**

Traditional Architecture Measurement

- **Traditionally architecture quality was determined at the milestone reviews and was a lagging indicator at a milestone review**
  - Design was briefed
  - Didn't always address requirements satisfaction
  - Text documentation made it difficult to see full picture or determine consistency (MIL STDs 2167A & 498B)
  - Assessment was subjective by "experts"

- **INCOSE SELI Indicator measures trends in architecture and related resources and processes but doesn't directly measure the quality of the architecture or its description**

- **PSM focus has been on the needs of the Program Manager (PM)**

Model based architecting brings new opportunities for measurement

Architecture Measurement Needs

- **Architecture measurement requires a set of measures to fully address the needs of Technical Leaders as well as the PM**
- **Measures may be:**
  - Objective (Quantitative) where discrete elements can be counted or otherwise measured or
  - Subjective (Quality) where human judgment is needed to fully evaluate an aspect of the architecture
- **Measures should be:**
  - Based on common practice and standards
  - Readily obtainable
  - Reflect essential attributes of architecture

Quantitative measures are preferred and easier to obtain with model based architecting

Quantitative Measurement

- **Goal is to measure whether an architecture is complete and consistent and is the "best" at satisfying the requirements**

- **Easier with model-based architecting**
  - Anticipated artifacts / completed artifacts
  - Internal reports showing missing data and inconsistencies between artifacts
    - Empty data field counts
    - Other reports from the modeling tool database that address consistency
    - Requirements trace reports
  - Supported by many of the architecture tools but requires effort on the part of the program to create and customize
  - Models help visualize heuristics as well

July 2012 PSM Workshop Results

- **Results:**
  - Achieved consensus that architecture is measureable
  - Agreed on a set of measurable concepts
  - A preferred set of measures was voted on and captured in ICM table (Information Category-Measurable Concept-Prospective Measures) format

- **Measurable Concepts**
  - Size
  - Complexity
  - Degree of completeness (more than work unit progress)
  - Quality of solution
  - Quality of representation
  - Cost or effort of the architecture

Preferred Measures (from multi-voting)

- **Size**
  - **Number of elements**
    - **Constituent parts to be bought or developed**
  - **Number of relationships/interfaces (external)**
    - **Logical and physical interfaces, organizational relationships**
  - **Number of requirements**
  - Number of mission / system scenarios / use cases
  - Number of artifacts produced
  - Number Data points
  - Number of Function points
  - Number of Use Case points

- **Complexity**
  - **Number of relationships/interfaces (internal & external)**
  - **Number of interactions**
    - **Transaction types or messages, frequency**
  - **Number of states**
  - Number of functions/methods

Preferred Measures

- **Completeness**
  - **Requirements addressed**
  - **Artifacts produced**
  - **Artifacts total expected**

- **Quality of Solution**
  - **Degree of requirements satisfaction**
  - **Degree of Mission Assurance (the 'ilities)**
  - Number of defects in the baseline
  - Degree of coupling
  - Cost of the solution (@some confidence level)
  - # of open TBx

- **Quality of representation**
  - **Degree of consistency of representation**
  - **Degree of standards compliance**
  - Number of defects

Post-Workshop Activities

- **Added additional enterprise perspectives to that of the PM**
  - Technical Leadership (e.g. Chief Architect)
  - Cost / Engineering Effectiveness Analysts
  - Enterprise Measurement Team
- **Added questions for these additional perspectives**
- **Normalized the questions to determine common needs**
  - Validation of preferred measures
  - Identify any missing measures
- **Merged workshop preferred measures into PSM ICM Tables**

Normalized Questions (Info Need)

Information Needs	Viewpoints	PSM Information Category
Can we do the work better?	TL	Process Performance
Does the architecture contain all the data required?	TL	Product Quality
Have we removed all the defects?	TL	Product Quality
Does the architecture meet the requirements? Will we be successful?	PM, TL	Product Quality, Customer Satisfaction
What is/was the cost (effort) needed for the architecture?	PM, TL, CA, EM	Resources and Cost
Will the architecture be done on time?	PM, TL	Schedule and Progress
Are process changes providing a benefit?	EM	Process Performance
Are there trends across the business? (Defects, durations, success, size and complexity)	EM	Process Performance
Can we predict future costs?	EM	Resources and Cost
How big was it and can we compare it other programs?	CA, EM	Product Size and Stability
How long did it take?	CA, EM	Schedule and Progress
How many defects were there?	CA	Product Quality

PM- Program Mgr, TL- Technical Leadership, CA- Cost Analysts, EM- Enterprise Measurement Tm

ICM Tables for Schedule & Progress

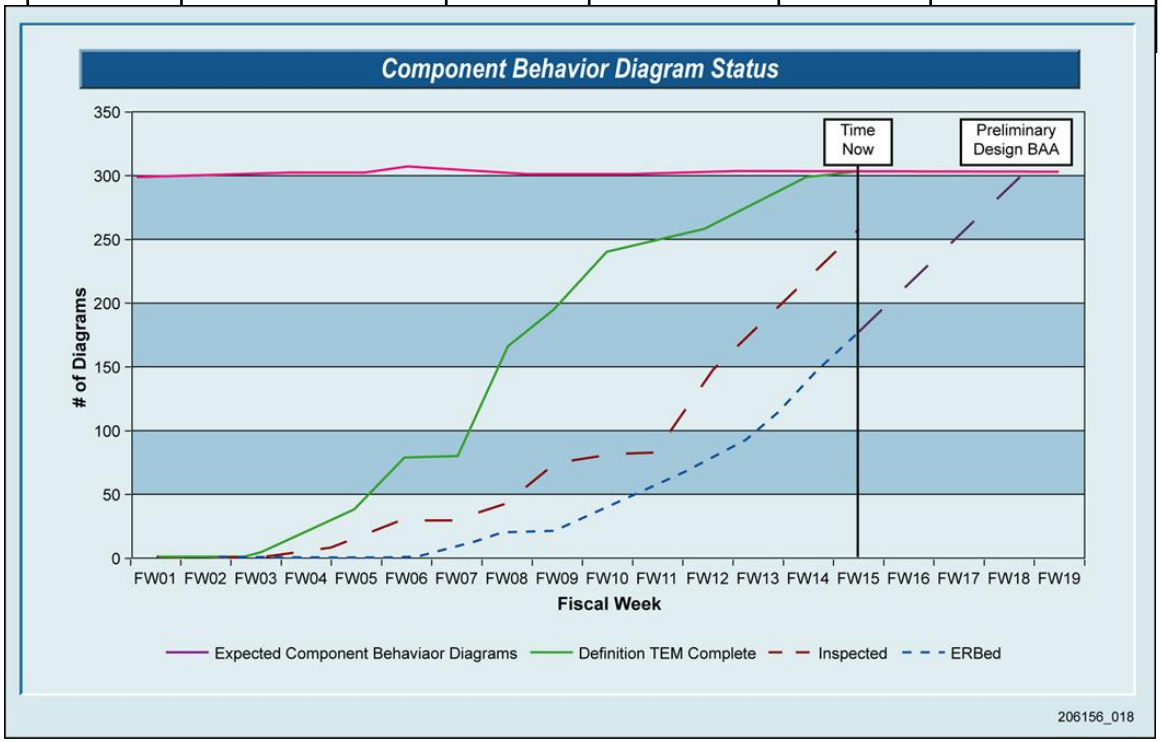
PSM Info Category	Measurable Concept	Questions Addressed	Prospective Indicators	Sample Measures
Schedule and Progress	Work Unit Progress Milestone Completion Degree of Completion	Will the architecture be done on time?	EVMS (SPI), Artifacts produced versus the plan[1]	EVMS data Artifact completed Artifacts planned # of requirements addressed[2]
Schedule and Progress	Duration	How long did it take?	N/A Historical	Planned Schedule Actual Schedule

[1] To avoid subjectivity measurement of "Produced" artifacts must align with a verifiable event such as an inspection or baseline acceptance.

[2] Requirements addressed is measured by number of requirements traced to architecture element or artifact.

Example Progress Table/Chart

Estimated # of diagrams	Started	Definition TEM Complete	Drawn	Inspected	ERBed	% Complete
System Behavior Diagrams	26	26	26	26	26	100%
Subsystem Behavior Diagrams	175	175	170	160	150	86%
Component Behavior Diagrams	300	25	25	20	15	5%



ICM Table for Product Quality

PSM Info Category	Measurable Concept	Questions Addressed	Prospective Indicators	Sample Measures
Product Quality (Solution)	Functional Correctness, 'illities Degree of Requirements Satisfaction, Degree of Mission Assurance	Does the architecture meet the requirements? Will we be successful (will it work)?	Multi-variate function against the driving requirements or TPM[1]. Multi-variate function against the 'illities.	Degree of requirements satisfaction (Threshold, Objective), # of requirements satisfied, # of defect traceable to architecture
Product Quality (Representation)	Functional Correctness	Does the architecture contain all required data? Have we removed all the defects? How many defects were there?	Artifacts produced versus the plan, #/ % of null data elements in model, # of defects that reach the baseline	Artifacts completed, artifacts planned, null data elements[2], defects including inconsistencies

[1]Construct radar chart (Kiviat) rather than defining equation. Requirements satisfied is a true/false evaluation of each requirement which must be traced to an architecture element .

[2]Null data elements must be life-cycle appropriate. Some elements may not be required until later in the life-cycle.

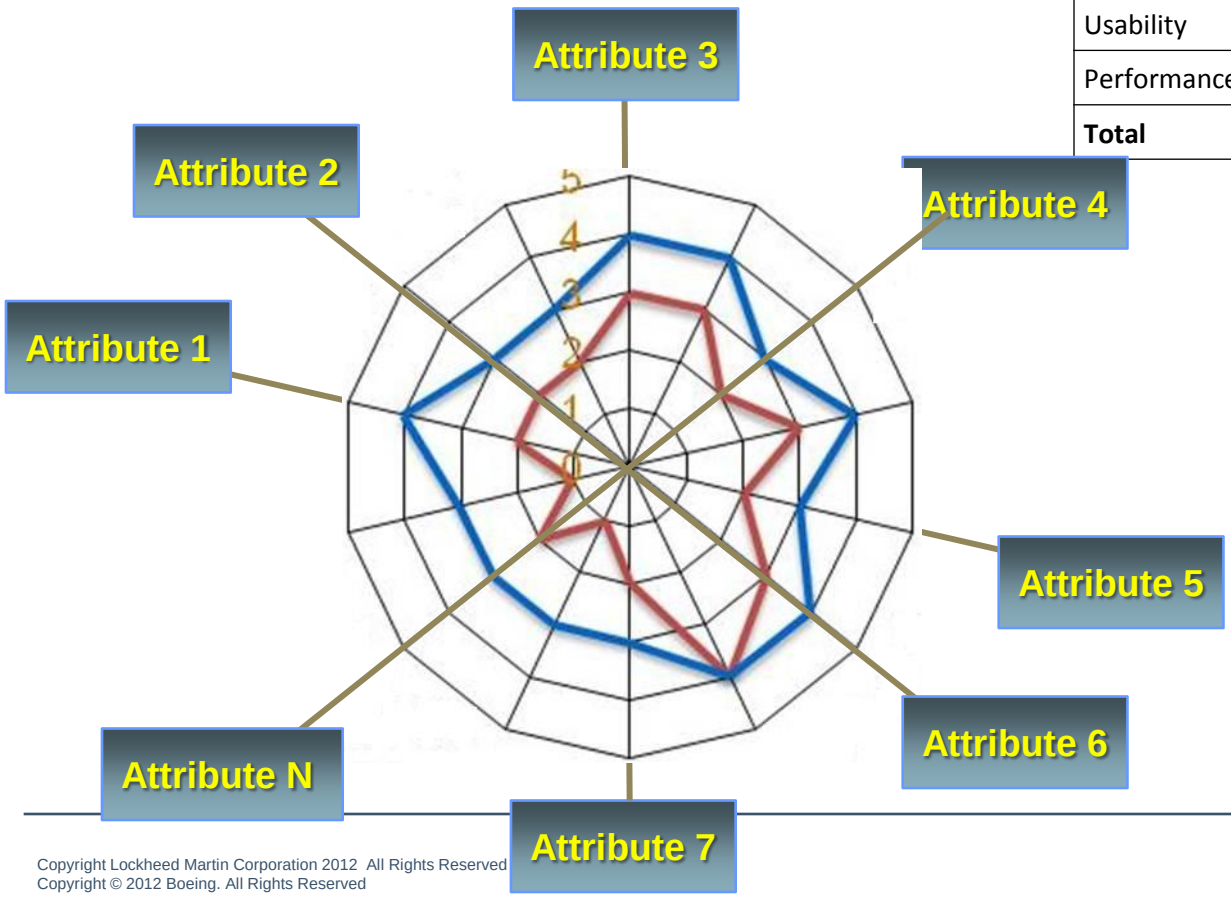
Example Architecture "Radar" Chart / Table

Key attributes

Must haves
- Evaluate as true/false

Examples:
- Completeness of requirements coverage
- Threshold performance

Attribute	Weight	Value	Weighted Value
Flexibility	25%	75%	19%
Adaptability	10%	80%	8%
Modular	15%	25%	4%
Simplicity	10%	75%	8%
Usability	10%	75%	8%
Performance	30%	100%	30%
Total	**100%**		**77%**



"Utility Function" for the architecture assessment is a simple weighted sum of the assessed attribute values… repeat for each candidate architecture!

ICM Table for Process & Performance

PSM Info Category	Measurable Concept	Questions Addressed	Prospective Indicators	Sample Measures
Process and Performance	Process Efficiency	Can we do the work better?	Hours per artifact and trends Defects at process steps[1]	Hours per artifact, # of defects
Process and Performance	Process Effectiveness	Are process changes providing benefits?[2]	Hours per artifact and trends Defects at process steps	Hours per artifact, # of defects
Process and Performance	Process Compliance	Are there trends across the business (Defects, durations, success, size and complexity)?[3]	Trends of selected architecture measures on multiple programs	All architecture measures[4]

[1]Defects and trends should be captured at internal reviews (e.g. Inspections or baseline approval reviews)
[2]This question must be measured against a known baseline or in comparing two programs
[3]This question must be measured across multiple programs and does not directly benefit the program
[4] All measures being collected across the enterprise are options. Measures should be chosen to provide value to the enterprise.

ICM Table for Resources & Cost

PSM Info Category	Measurable Concept	Questions Addressed	Prospective Indicators	Sample Measures
Resources and Cost	Personnel Effort	What is/was the cost (effort) needed to develop the architecture?	EVMS (CPI)	Labor hours, staff heads, ACWP, staff experience, budget, cost
Resources and Cost	Support environment resources	What is/was the cost (effort) needed to develop the architecture? [1]	Cost of development environment tools and on-going maintenance	Dollars
Resources and Cost	Financial Performance	Can we predict future costs?	N/A Historical	Architecture development cost

[1]Useful to compare cost of different tool suites and as part of Business Case analysis. See Process Effectiveness.

ICM Table for Product Size & Stability

PSM Info Category	Measurable Concept	Questions Addressed	Prospective Indicators	Sample Measures
Product Size and Stability	Functional Size and Stability Size	How big was it?	N/A Historical	# of system elements, # of interfaces, # of requirements
Product Size and Stability	Functional Size and Stability Size, Complexity	How big is it? How hard is the job?	Element count, Internal interface and transaction counts	# of system elements, # of external interfaces, # of internal interfaces, # of requirements, # of transactions/ message types
Product Size and Stability	Functional Size and Stability	Is the design stable?	% of change at each architecture level[1]	# of objects in model, # of changes in time frame to objects

[1]Must measure the right changes. Don't measure stability of preliminary design at SRR.

Impact of Architecture Frameworks on Measurement

- **Architecture Frameworks have defined stable sets of process activities (TOGAF) or viewpoint/models (DoDAF & FEAF)**
- **The latter provide items which may be measured**
- **When combined with the advances in modeling tools we have a standard set of products which may be measured with relative ease**
  - Size (number of elements and interface)
  - % Complete (artifacts/diagram)
  - Conformance to standard (diagram types and standard data elements)
  - Adequacy of representation (right viewpoints & well represented)

Heuristics

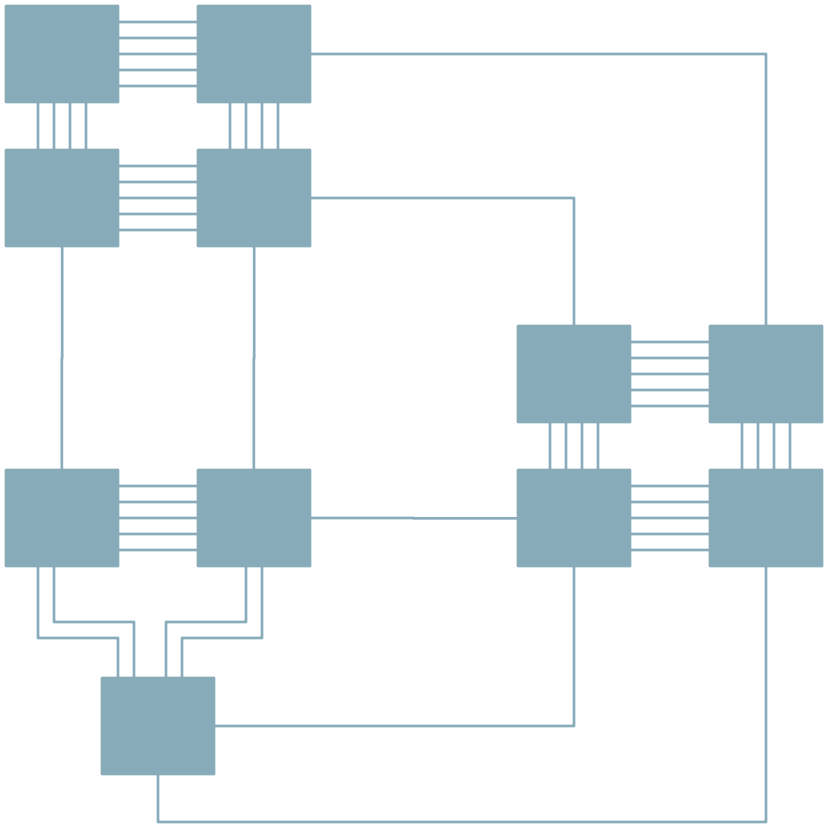
- **"Does it look right"**
  - Heuristics are experience based
  - Review of the model artifacts can sometimes indicate if an architecture exhibits good / bad characteristics such as low cohesion or high levels of coupling
  - Not generally directly measurable using quantitative means
- **Internal metrics**
  - Number of internal interfaces
  - Number of requirements per architecture element can indicate an imbalance
  - Coupling counts
- **Heuristics must be applied within the architecture team to be effective**
  - Utilized as part of artifact/product inspections
  - Required application prior to baselining of products

Otherwise

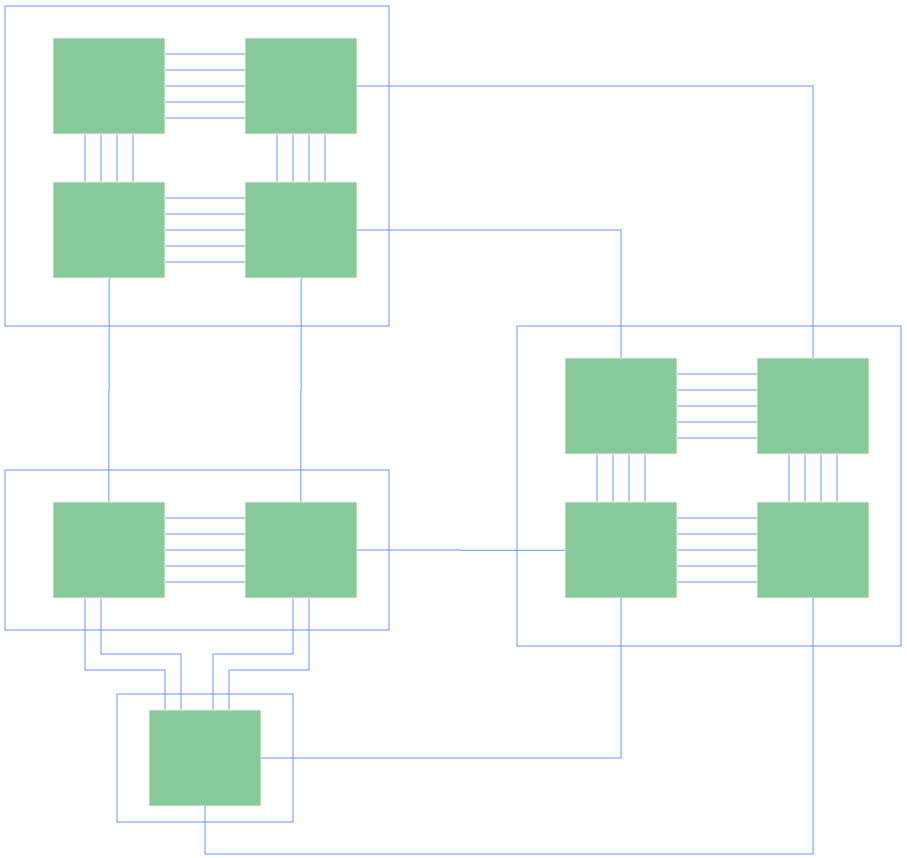
- **Heuristics become a lagging indicator**
  - Found at milestone reviews
  - Become defects

Heuristics Example

High External Complexity



Low External Complexity



Which Partitioning is Better? Why?

MEANS OF MEASURING

Measurement in a model based environment

- **Model based architecting (or architecture modeling) makes the evaluation of completeness and consistency feasible as a leading indicator)**
  - Architecture tools provide better insight into consistency and completeness via pre-defined reports or by directly accessing the underlying database
  - Makes it easy(ier) to count artifacts and determine change dates
  - Easier to determine missing information
  - Easier to make consistency checks between architecture artifacts (parent-child, peer-to-peer)

- **Quantitative measures are now available**

Measuring Size & Complexity

- **Size & Complexity measures available from architecture tools**
  - Number of elements (from model diagrams)
  - Number of external interfaces (from context diagram)
  - Number of requirements (from requirements tool)
  - Number of objects on diagrams / artifacts
  - Number of data elements / fields associated with artifacts and objects
  - Number of artifacts by type
  - Number of classes / objects
  - Number of functions/methods
  - Number of interactions
  - Number of functional requirements traced to an architecture element or artifact (e.g. scenario)

Measuring Completeness

- **Degree of Completeness measures available from architecture tools**
  - Size Measures
  - Empty required data fields
  - Number of {Size Measure} complete
  - % of {Size Measure} complete or at a given approval state
  - Quantity and trend (of closure) of empty required data fields (definition of required will change by milestone)
  - Number of functional requirements traced to an architecture element or artifact (e.g. scenario)
  - % of functional requirements traced to an architecture element or artifact (e.g. scenario)
  - Number & trend of closure of architecture TBx
  - Number & trend of closure of requirement TBx

Measuring Quality of Representation

- **Captured / reported from architecture or process tools**
  - # of Defects in baselined artifacts
    - External standards compliance
    - Consistency of representation (i.e. adherence to APS&C)
  - Quantity and trend (of closure) of empty required data fields (definition of required will change by milestone)
  - Stability of architecture artifacts (number of changes across time)

Measuring Solution Quality

- **Captured / reported from architecture or other tools**
  - # of Defects in baselined artifacts
    - Solution error (e.g. doesn't work)
  - Number of functional requirements traced to an architecture element or artifact (e.g. scenario)
  - % of functional requirements traced to an architecture element or artifact (e.g. scenario)
  - Number & trend of closure of architecture TBx
  - Number & trend of closure of requirement TBx
  - Degree of TPM satisfaction based on modeling or other method
  - Degree of satisfaction of 'ilities (could be based on checklist or other tools)
  - Stability of architecture artifacts (number of changes across time)
- **Reviewer comments**
  - Design Assessments before or at milestones

Measuring Cost or Effort

- **Captured / reported from architecture or process tools**
  - Size Measures
  - Experienced Productivity
  - CPI/SPI
  - Estimate at Completion (EAC)
  - Control Account charges

Summary

- **Model based architecting has made it possible to objectively architecture**
  - Easier answer information needs of the PM, technical leadership and other stakeholders
  - Potential measures and presentation methods provided in this presentation
  - Thresholds remain to be established for these measures

- **Quality of Solution remains somewhat subjective as each stakeholder in the architecture has a different perspective**

- **Standardization of measurement can be achieved but requires top-down (customer) direction**
  - Support definition of thresholds
  - Frameworks support this standardization

QUESTIONS?

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