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New Opportunities for System Architecture Measurement

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Outline

- State of architecture measurement
- Recent activity
- PSM Workshop Results
- Proposed Architecture Measures
- Means of Measuring
- Summary

State of Architecture Measurement

- **Architecture has been measured at the milestone reviews as a lagging indicator**
  - Design was briefed; often referenced to satisfying requirements
  - Documentation made it difficult to see full picture or determine consistency (MIL STDs 2167A & 498B)
  - Assessment was subjective; sometimes focused on "views"
- **ISO/IEC/IEEE 15288 and INCOSE SE Handbook define architecture**
  - Define elements of and processes for developing an architecture
  - Discuss measurement; not specific to 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
- **PSM (Practical Software and Systems Measurement) focus has been on the needs of the Program Manager**

Model-based architecting brings new opportunities for measurement

Recent 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[1] December 2011**
  - Architecture was a focus area for more effort: "Evaluates the architecture from the perspectives of quality, flexibility, and robustness. Stability. Adequacy of design rules. No recommendation at this time; see "Future Directions"."
  - Interface definition status identified as a separate quantitative measure
- **PSM Workshop[2] July 2012 conducted to identify 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

Post-Workshop Activities

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- **Added additional enterprise perspectives and related questions to that of the PM**
  - Technical Leadership (e.g. Chief Architect)
  - Cost / Engineering Effectiveness Analysts
  - Enterprise Measurement Team
- **Normalized the questions to determine common needs**
- **Merged workshop preferred measures into PSM ICM Tables** (***I***nformation Category-Measurable ***C***oncept-Prospective ***M***easures)

Reminder: What is an Architecture?

- **ISO/IEC/IEEE 42010:2011 – 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
- **Measure the architecture: applying INCOSE SE Measurement Primer:**
  - Measure to answer questions (information needs) to achieve goals
  - Measure the products of the process, and correlate to the process

Architecture Measurement

- **Goals**
  - **Measure whether an architecture is *sufficient* (adequate to the needs)**
  - **Measure whether an architecture is *optimal* (the "best" architecture)**
- **Model-based architecting creates opportunities for measurement**
  - **Anticipated artifacts / completed artifacts**
  - **Reports show missing data and inconsistencies between artifacts, e.g., empty data field counts, requirements trace reports**
  - **Additional architecting measures must be defined**
  - **Measurement can quantify heuristics (coupling, etc.)**

Normalized Questions (Information Needs)

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

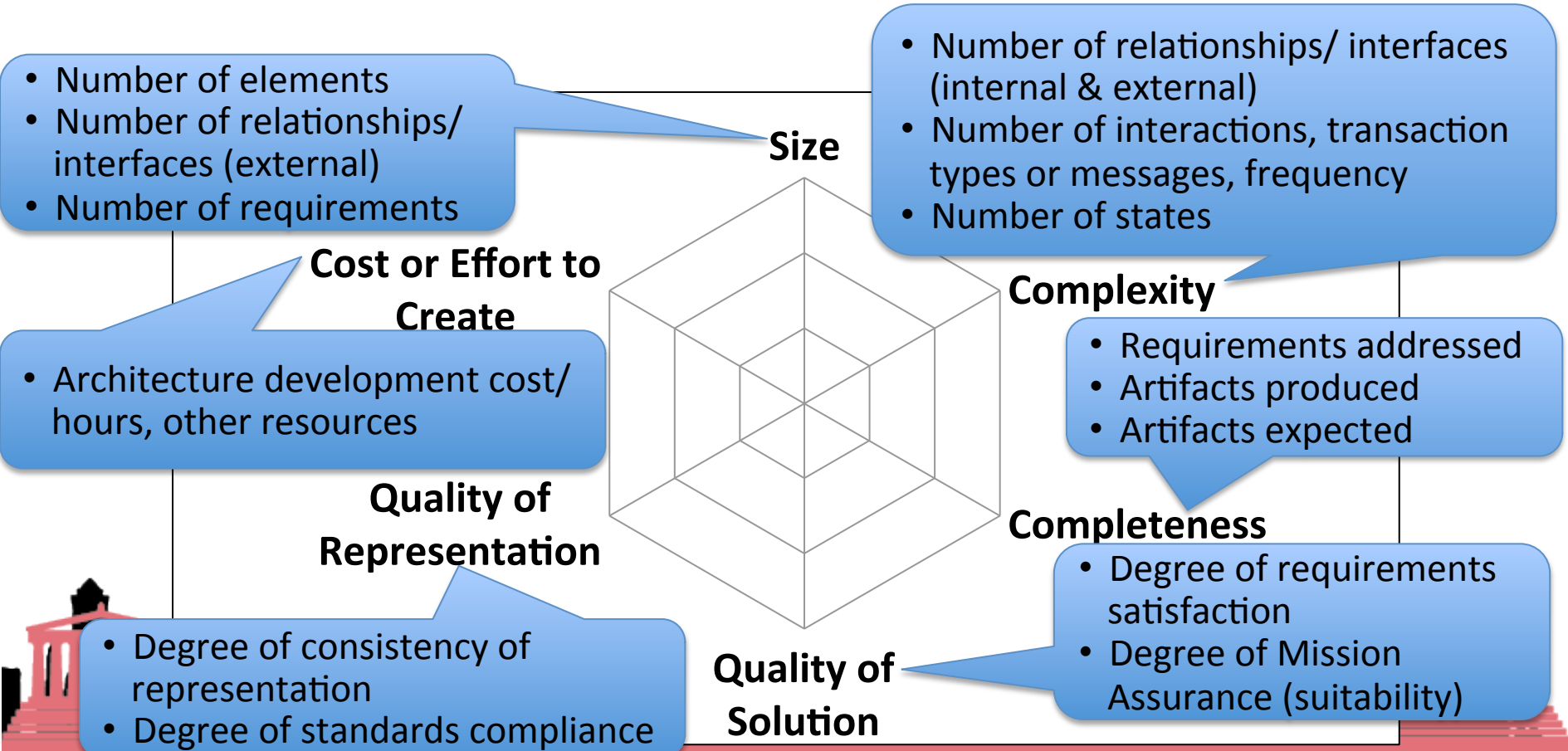
Prospective / Leading

Retrospective / Lagging

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

July 2012 PSM Workshop Results

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



Mapping Categories

Architecture Measurement Categories *	PSM Category
Size Complexity	Product Size & Stability
Quality of Solution Quality of Representation	Product Quality
Size Completeness	Schedule & Progress
Quality of Solution Quality of Representation Cost or Effort to Create	Process & Performance
Cost or Effort to Create	Resources & Cost
*Derived from Olson (2008)	

ICM Table for 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? How did it change during development?	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? How is it changing over time?	Element count, Internal interface and transaction counts	# of system elements # of external interfaces # of internal interfaces # of requirements # of messages # of transactions
Product Size and Stability	Functional Size and Stability	Is the design stable?	% of change at each architecture level	# of objects in model, # of changes to elements in time frame

ICM Table for Product Quality

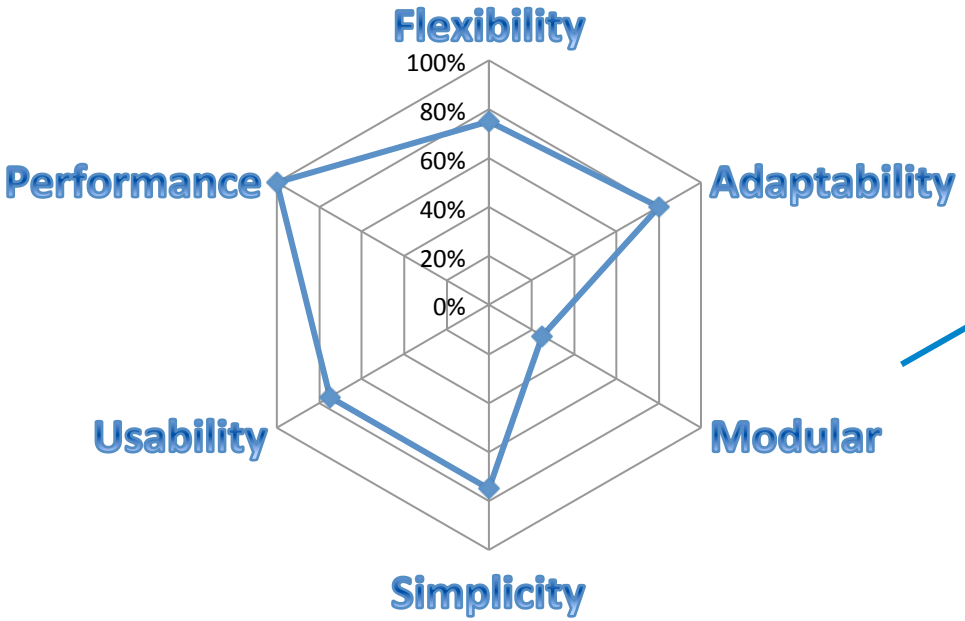
PSM Info Category	Measurable Concept	Questions Addressed	Prospective Indicators	Sample Measures
Product Quality (Solution)	Functional Correctness, Suitability Degree of Requirements Satisfaction Degree of Mission Assurance (Suitability)	Does the architecture meet the requirements? Will we be successful (will it work)?	Multivariate function of the driving requirements or TPM. Multivariate function of 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 # defects including inconsistencies

Example Architecture "Radar" Chart

Key attributes

- ***Requirements*** **are evaluated as compliant/ non-compliant**
- **Example: Threshold performance**
- **Other characteristics: weighted utility function**

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



$$Suitability = \sum_i W_i \frac{|V_i - T_i|}{|O_i - T_i|}$$

Use of Architecture Frameworks

- "Quality of Representation" can be based on architecture frameworks
  - Architecture Frameworks have defined stable sets of process activities (TOGAF) or viewpoint/models (DoDAF & FEAF)
  - These identify items which may be used as a standard for measurement
- Example measures
  - % Complete (viewpoints, data)
    - Adequacy: do we have the right viewpoints?
  - Degree of conformance to standard (viewpoints and standard data elements)

ICM Table 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	EVMS data Artifact completed / planned # of requirements addressed
Schedule and Progress	Duration	How long did it take?	N/A Historical	Planned Schedule Actual Schedule

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	Hours per artifact, # of defects
Process and Performance	Process Effectiveness	Are process changes providing benefits?	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)?	Trends of selected architecture measures on multiple programs	All architecture measures

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 counts, ACWP, Staff experience, budget, cost
Resources and Cost	Support environment resources	What is/was the cost (effort) needed to develop the architecture?	Cost of development environment tools and on-going maintenance	Dollars/Euros
Resources and Cost	Financial Performance	Can we predict future costs?	N/A Historical	Architecture development cost

Means of Measuring in a Model-based Environment

- Model-based architecting 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

Proposed Measures and Means – 1

Measurement Category	Proposed Measures	Definition/Description	Means
Size / Stability	Number of elements	Count of constituent parts to be bought or developed, at each architectural level vs. time (stability)	Report of number of classes, objects, logical elements vs. time
Size / Stability / Complexity	Number of external interfaces	Count of logical and physical interfaces vs. time	Report of number of external interfaces to each element vs. time.
Size / Stability / Complexity	Number of external relationships	Count of organizational relationships (stakeholders) vs. time	Report of number of program interfaces vs. time.
Size / Stability	Number of requirements	Count of requirements at each architectural level vs. time	Report of number of requirements by element and/or architectural level vs. time.

Proposed Measures and Means – 2

Measurement Category	Proposed Measures	Definition/Description	Means
Completeness	Requirements addressed	Count of number of top-level requirements addressed by the architecture	Report of number of top-level requirements that are addressed by the architecture (traced to architecture element)
Completeness	Artifacts produced	Count of number of architecture artifacts (e.g., viewpoints) produced vs. time	Report of number of architecture artifacts completed, by type
Completeness	Artifacts expected	Count of number of architecture artifacts (e.g., viewpoints) needed vs. time	Report of number of architecture artifacts needed, by type

Proposed Measures and Means – 3

Measurement Category	Proposed Measures	Definition/Description	Means
Quality of solution	Degree of requirements satisfaction	Count of number of requirements satisfied, normalized by the number of requirements	Report of ratio of number of requirements that are satisfied by the architecture to number of requirements (derived measure)
Quality of solution	Degree of Mission Assurance (suitability)	User/program-defined multivariate function of weighted suitability attributes.	Derived measure from base measures of individual attributes or surrogates above required thresholds.
Quality of representation	Degree of consistency of representation	User/program defined measure of adherence to internal standards or templates (data content and format), by artifact vs. time	Report of missing data per artifact; analysis of format conformance to templates
Quality of representation	Degree of standards compliance	Measures of adherence to external standards(data content and format), by artifact vs. time	Report of missing data per artifact; analysis of format conformation to standards

Next Steps

- Community review and validation
  - NDIA Architecture Working Group
  - NDIA and INCOSE member companies and organizations
- Review to determine and ensure effectiveness
  - Ongoing validation of preferred measures
  - Identify any missing measures
- Incorporate validated measures in SELI

Summary

- **Model-based architecting has made it easier to objectively measure architecture**
  - **Information needs of the PM, technical leadership and other stakeholders addressed**
  - **Potential measures and means identified**
  - **Thresholds remain to be established for these measures based on correlation to program results**
- **Quality of Solution (Suitability) remains somewhat subjective as each stakeholder in the architecture has a different perspective**
  - **Standardization of measurement can be achieved but requires top-down direction, including definition of thresholds**
- **Frameworks can support standardization for Quality of Solution (Representation)**