APPLYING MODEL-BASED SYSTEM ENGINEERING IN SEARCH OF QUALITY BY DESIGN

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Overview

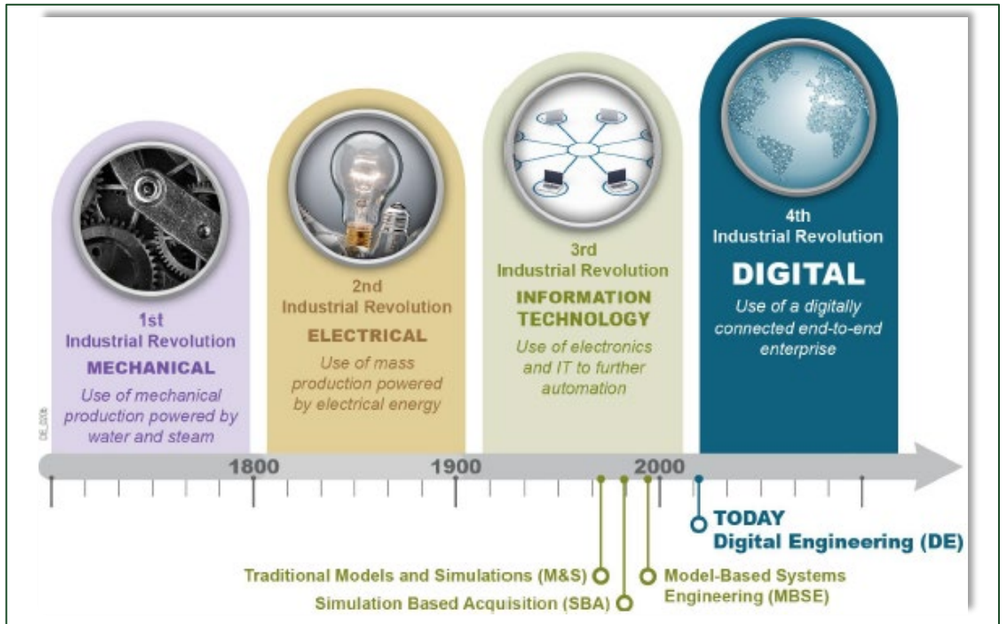
1. Brief Introduction and Problem Statement
2. Research Overview
3. Proposed Solution Methodology
4. Applied Solution to Case Studies Analysis
5. Recommendations/ Reviews
6. Additional Publications and Efforts

Introduction

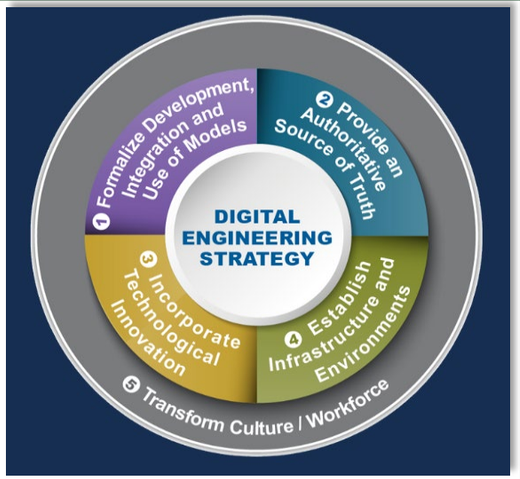
Dollars to Seconds for Perspective						
Dollars ($)	Years	Months	Days	Hours	Min	Sec
1						1
10						10
100					1	40
1,000				2	46	40
10,000			1	3	46	40
100,000			11	13	46	40
1,000,000		3	23	17	46	40
1,000,000,000	31	8	9	1	46	40

Introduction

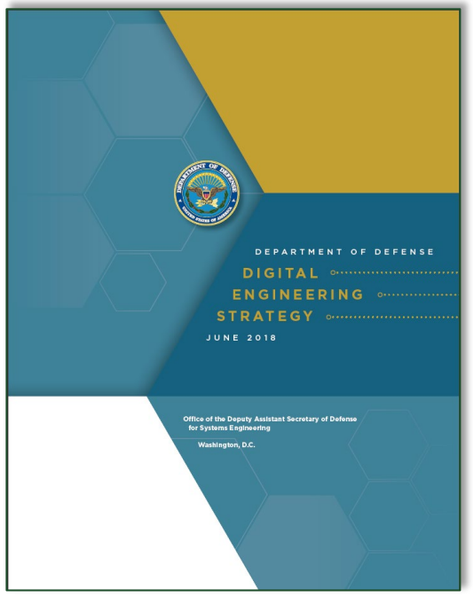
- Model Based System Engineering (MBSE) and Digital Engineering (DE) **has become the standard tool for system engineering**
  - MBSE and DE are considered by industry leader to be the **4th Industrial Revolution**
  - MBSE and DE have become a primary focus of the Defense Department for the foreseeable future
- For the purpose of this study, the **focus was placed on Department of Defense Architecture Framework (DoDAF)** specifically to address quality of models
  - Standards like DoDAF, typically **do not directly address quality**
  - **Quality is implied by simply stating "if we follow the standard, quality will be the inherited trait"**
  - **DoDAF is still in use today**, and its system description **methodologies continue to impact subsequent system description approaches** [72]
  - DoDAF still leads both government and industry practice as the most **widely mandated defense standard** for U.S. government acquisition [77]



Source: DoD Digital Engineering Strategy, 20thAnnual NDIA SE Conference, 10/25/2017

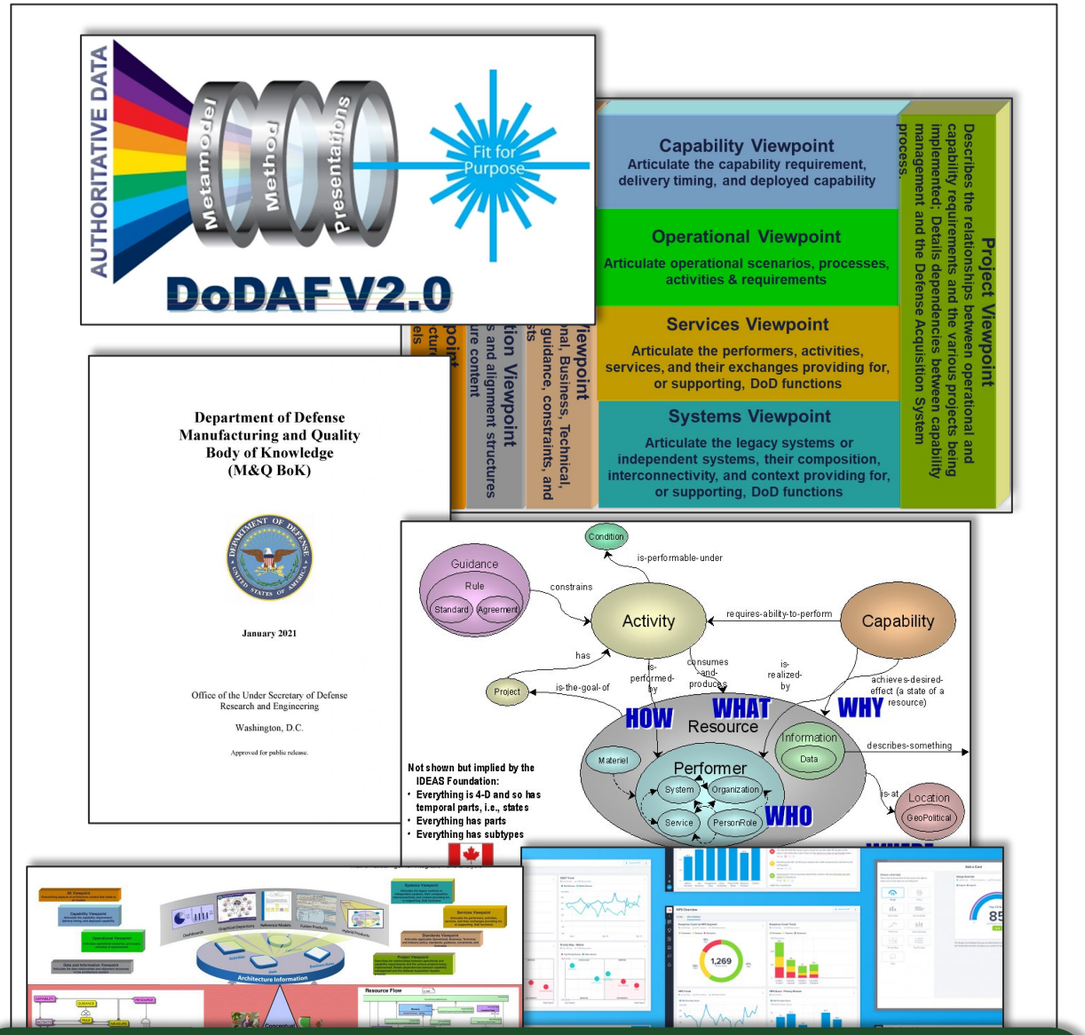


Robert P. Scheurer 11/15/2018, DE ME MBSE and the Like



Problem Being Addressed

- The following are taken from the Hawaii International Conference on System Sciences conducted an analysis of papers **over a 15 year period**:
  - Key sub-problems are: Business View Presence and Alignment, Modeling Tool Availability, and **Quality**, Stakeholders Perspectives, Handling Dynamics [1].
  - Use of **practices and procedures – formal or otherwise** – to develop the Architecture. A framework, such as described in TOGAF, **DoDAF**, etc., along with portfolio management processes, can guide the development. Key sub-problems are: Assessing Technical Architecture Maturity, Assessing Infrastructure Stress, The System Architect's Value Proposition, Virtual Enterprise, Scalability, **Metrics**, Best Practices [1]
  - **Modeling Quality Attributes**: **Modeling systems, including languages**, are required to facilitate assessment of architecture according to **quality attributes**. [1]
- **Evaluation and measurement of methodological practice[1]**
- **Modeling assessment encompasses two key areas: quality attributes and metrics [1]**



What are good methods or practices to extract meaningful Quality Metrics to understand quality of the architectures?

Research

Research Objectives Literary Review

- The review process followed a **pre-established protocol for analyzing each document or material** to provide a broad scientific basis of the current state of academia and industry around model-based system engineering within the context of quality.
- The Literary Review attempted to answer research questions using a **formulated step process through the collection of data sources, a selection evaluation process, a data recording template, and a results area** where the details of the literature review could be integrated in to the dissertation
  - **Research Question 1:** How does DoDAF **relate to system engineering methods** of analysis for a quality-based design for a weapon system?
  - **Research Question 2:** What are the **main factors in developing an MBSE conceptual framework that provides good system engineering** analysis?
  - **Research Question 3:** What are **the metrics that are significant in assessing an approach that correlates quality** of design with an MBSE

Literary Review Steps

Step Number	Description
Step 1	Formulation of research questions. Guiding research questions were formulated. (Section 1.2.1)
Step 2	Selection of data sources. A set of reference materials were selected from various DoD sources, Libraries, and Databases were selected for the search. (Section 1.2.1)
Step 3	Selection and evaluation of literature. An initial evaluation to confirm that the selected material met the inclusion criteria was performed. (Section 1.2.1)
Step 4	Data recording. Relevant papers identified in Step 3 were evaluated, extracting and recording data addressing MBSE benefits and the potential benefits provided by quality metrics. (Section 1.2.1)
Step 5	Reporting of results to contextualize the Problem Statement. (Section 1.2.2)

Document

30th Annual INCOSE International Symposium
Virtual Event
July 20 - 22, 2020

Models as enablers of agility in complex systems engineering

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Abstract. Complex systems engineering programs not only deal with the inherent complexity of the systems they develop, they also face shorter time-to-market, increasing changes in environments and usages, and more sophisticated industrial schemes. The ability to adapt to new circumstances, or agility, becomes mandatory. In this paper we present how Model-Based Systems Engineering (MBSE) approaches can be enablers of the implementation of agility in complex systems engineering programs. Known to provide additional engineering rigor and quality, MBSE also brings key concepts favoring agility and co-engineering.

Introduction

Agility, defined as the ability to adapt to new circumstances, is intrinsic to systems engineering. The systems approach highlights the interactions between the system parts and between the system and the entities external to it, in order to better understand, analyze and develop solutions that satisfy the expectations and the constraints of the stakeholders. Such an approach is well suited to address the cases in which these expectations and constraints evolve in time, as the elements of the system are not isolated single entities, but as parts of a whole which environment and content of scope may evolve in time.

Nevertheless, the way systems engineering has been traditionally implemented in organizations developing complex systems, struggle to address situations in which expectations and constraints change at a very fast pace. As the pressure for developing new products and services even faster and cheaper increases, agility becomes mandatory for organizations developing such systems[1].

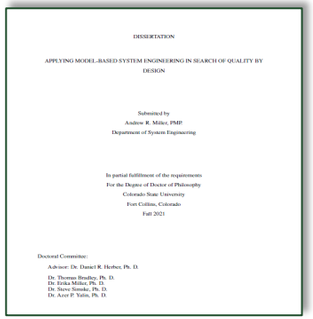
In more recent years, the agile approaches originated in software engineering have been extended and tailored to complex systems engineering, claiming similar outcomes on speed of development and on efficiency of the use of resources. These applicability is not straightforward though, as software engineering, contrary to systems engineering, almost exclusively involves virtual objects that can be evolved rapidly. Also, these approaches introduce new concepts and practices which are not always consistent with well-proven systems engineering ones. Finally, complex systems engineering

[1] As an example, the number of Internet of Things (IoT) connected devices installed base worldwide will increase up to 75 to 100 billion in 2025, depending on the estimations. This is 7 to 4 times the number in 2018. The providers of offering services by orchestrating these objects are countless, and the competition to win market shares will be rude.

Data Capture

Research Article *(Provide proper Reference and Title of published article)*	Navas, Juan, Stéphane Bonnet, Jean-Luc Voirin, and Guillaume Journaux. "Models as Enablers of Agility in Complex Systems Engineering." INCOSE International Symposium 30, no. 1 (2020): 339–355.
Problem Addressed / Identified	we present how Model-Based Systems Engineering (MBSE) approaches can be enablers of the implementation of agility in complex systems engineering programs
Research Contribution	Agile implementation for MBSE to drive quality
Aim & Objectives	Agility with user stories for example and MBSE with Functional Chains share the common objective of making operational need the primary citizen of engineering practices
Novelty/Rationale and Significance: *The key reasons for undertaking the research, with a focus on why the research was worth undertaking*	subset of the Arcadia concepts that are key for implementing agility Good Images on what happens during these finer increments paper we presented how the use of models is an enabler for a successful implementation of agility in the context of complex systems engineering. The methodological approach was illustrated with a case study inspired by current engineering practices in our organization. Agility with user stories for example and MBSE with Functional Chains share the common objective
Limitations and Weaknesses	
Findings and Conclusions	First, the fast access, consistency and the integration of data produced by different sources, and particularly those issued from technical and technical management process (e.g., integrate Capability increments and releases management with configuration management and business strategies): this not only demands an effort on the integration of tools, but also on organizations' processes and mindsets. Second, agility requires the development and maintenance of multiple architectural alternatives until one of them is selected to be further developed to fulfill the expectations of the stakeholders: this requires developing means to early-evaluate architectural alter-natives and to efficiently reuse existing building blocks. Last, agility requires the continuous integration and validation at the system level to ensure that global optimums are reached.
Future Work	Integrate into a Model

Data synthesis into Dissertation Document



DISSERTATION

APPLYING MODEL-BASED SYSTEM ENGINEERING IN SEARCH OF QUALITY BY DESIGN

Submitted by
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In partial fulfillment of the requirements
For the Degree of Doctor of Philosophy
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Literary Review High Points and Synopsis

- **Quality of Models**
  - MBSE methodologies being able to connect disparate data in a digital engineering environment has improved but, **quality understanding still needs to be addressed within academia and industry** [2]
- **MBSE Benefits That Drive Quality**
  - MBSE provides **struggles with quality within modeling paradigms** that needs to be addressed to meet the need of all stakeholders [3]
- **MBSE Quality in Defense**
  - The translation of architectural standards and **traditional system engineering documentation into the digital engineering model elements introduces ambiguity and programmatic risk to quality of the model** is not emphasized [4]
- **MBSE Architecture Frameworks and Quality**
  - **Quality is simply a byproduct and relies heavily on subjectivity, influence decisions in the application, or the expertise** of the team applying the standard [5] [7]
- **MBSE Quality Role In DoDAF Application**
  - Understanding the **quality competencies are required of system engineers and the MBSE implementation approach, without a quality design framework application of DoDAF architecture may lead to ambiguous data or lost context** [6]
- **MBSE Metrics and Quality**
  - Concepts of verification and validation approaches are not possible of MBSE descriptive models as **there is no output data to compare with actual data** [8]
- **MBSE Modularity Addressing Quality**
  - Even with the bucketing of data into specific views within DoDAF architecture, considering modularization or **understanding what level of granularity is needed is a difficult task in the representation of quality in the architecture** [9]
- **MBSE Quality Architecture**
  - From functional to non-functional requirements, the MBSE approaches to **quality deal with the overall System of Systems approach to quality of MBSE models focusing on the SysML and less on parts of defense aspects** of the model quality [10]
  - While the **Quality Attribute Balancing (QAb) method addresses the quality of the SoS architecture, it fails to address the DoDAF specific framework** and instead focuses on the SysML stereotypes [11]

The Literary Review has shown that quality is difficult to address and is a ever growing problem within the DoDAF architecture

Why DoDAF Quality Conceptual Framework (DQCF)?

- Based on research and experience, the following observations have been noted through many different Societies:
  - Even with the combination of Digital Engineering (DE) integrated activities and increased design rigor, **adequate model quality can still be lost** in the complexity of architecture. [2]
  - Further investigation or **research is needed to fully understand the implications of quality in the system engineering of model based approaches**. [3]
  - Even with standardization and simplification for model architecture development, the **translation from textual context of document in system engineering into digital engineering often introduces ambiguity and programmatic risk effecting quality of models developed**. [4]
  - Some methods exist that **address the quality of the SoS architecture, but fail to address the DoDAF specific framework** and instead focus on the SysML stereotypes
- The average cost of rework for increase of a project quality is around **2-20%** of the **total contract amount** [12]
- The Government Accountability Office (GAO) found that United States Defense Acquisition Programs are either **over budget or have schedule delays** [13]
  - 61 of 86 programs evaluated showed cost growth of **62.4% or $542.1 Billion and schedule overruns of 35 months** on an average [13]

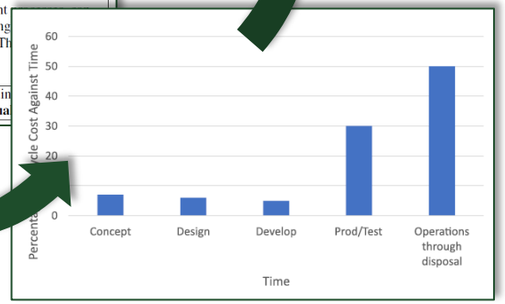
INCOSE

Sandia National Laboratories

HICSS

Problem	Description
Modeling	Use of formal models and/or tools to describe and analyze the EA. EAs must be modeled to present a clear, coherent, and concise picture of the baseline and target EAs and to communicate this picture to the stakeholders. The EA must be good enough, but does not have to be perfect. Key sub-problems are: Business View Presence and Alignment, Modeling Tool Availability and **Quality**, Stakeholders Perspectives, Handling Dynamics
Managing	Use of practices and procedures – formal or otherwise – to develop the EA and manage the EA team. An EA framework, such as described in, TOGAF, **DoDAF**, etc., along with portfolio management guide the development. Key sub-problems are: Assessing Architecture Maturity, Assessing Infrastructure Stress, Th Architect's Value Proposition, Virtual rise, Scalability, **EA Metrics**, Best Practi
Challenge	Modeling Quality Attributes: Mod ystems, includin required to facilitate assessment o according to **qua**

Poor Quality = Cost and Schedule Growth



"DoD will implement rigorous processes to support cost-effective technology development and selection decisions"- DoD Digital Engineering Strategy 2018

Cost of Quality (CoQ) is usually around 15 – 20% of product development[69]

Proposed Solution

package Quality Logical Model for DoDAF [Quality Logical Model for DoDAF]

Logical Model for DoDAF Quality By Design

Situation

Need to know that the quality of the DoDAF architecture produce is of substantial quality to address the customer needs for the system of interest.

Priorities

- Quality of DoDAF
- Quality of Product
- Modularity
- Analysis
- Ease of Implementation
- Useability

INPUTS

- DoDAF Model
- Quality By Design Concept
- Quality By Design Analysis Profile
- Cameo Enterprise Architecture
- MBSE Conceptual Understanding
- DoDAF Programmatic Application Understanding

ACTIVITIES

- Identify Area of DoDAF Architecture analyze
- Integrate DoDAF Quality Analysis Profile and Plugin into the Model
- Identify Viewpoints of DoDAF Architecture for Analysis
- Select Desired Element as well and the Necessary Element
- Stereotype Elements
- Evaluate the DoDAF Elements based on the Quality Criteria
- Run Quality Analysis Plugin to generate Data

OUTPUTS

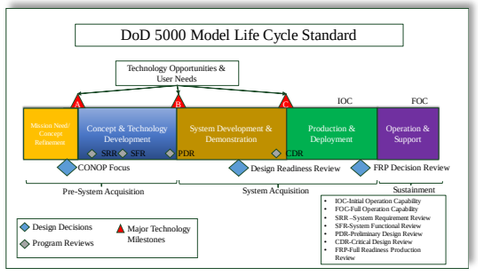
- Individual DoDAF Element Quality
- DoDAF Element Quality by Category
- Average DoDAF Element Quality
- DoDAF View Quality
- Statically Analyzed Quality of DoDAF Elements

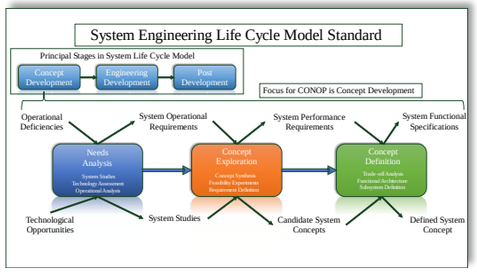
RESULTS

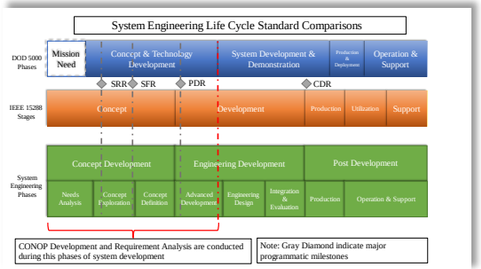
- Identification of any individual DoDAF Elements that need [redacted]ents
- Programmatic understanding of DoDAF Elements with Record, understanding, and where risk exists
- Ability to focus program efforts to increase quality of DoDAF Elements
- Modular Framework that can be applied to any number of Elements for evaluation

Critical Theory Understanding

- System Engineering (SE)
  - Due to the **<u>importance of the Concept Development Stage</u>** in multiple System Engineering lifecycle models, focus was put on this stage and its quality
  - In the Concept Development stage, the **<u>functional performance or operational requirements</u>** analysis can be instantiated in an architecture
- Model Based System Engineering (MBSE)
  - **<u>The extensible customization capability that MBSE brings</u>** was used to develop a profile to capture criterion related to quality
- Department of Defense Architecture Framework (DoDAF)
  - Viewpoints and View
    - Views or viewpoints allow for data-centric elements to **<u>provide an ontology and taxonomy through an architecture profile</u>** to capture technical information for a system
  - CONOP Design Process
    - CONOP architecture development in conjunction with **<u>operational performance requirements</u>** goes to an ever-increasing level of detail in identifying mission performance assumptions, constraints, deficiencies, and enhancements needed for the system operation to enable mission success [16][17]

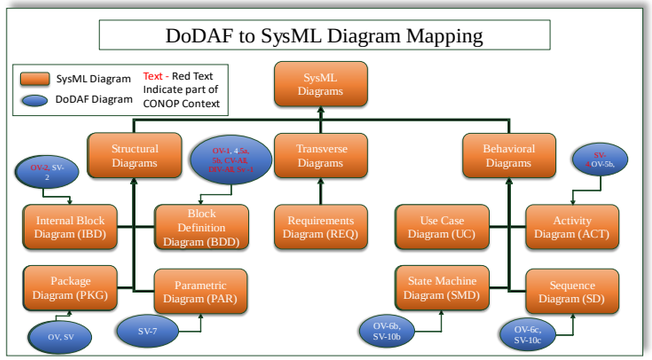






Concept Development Stage

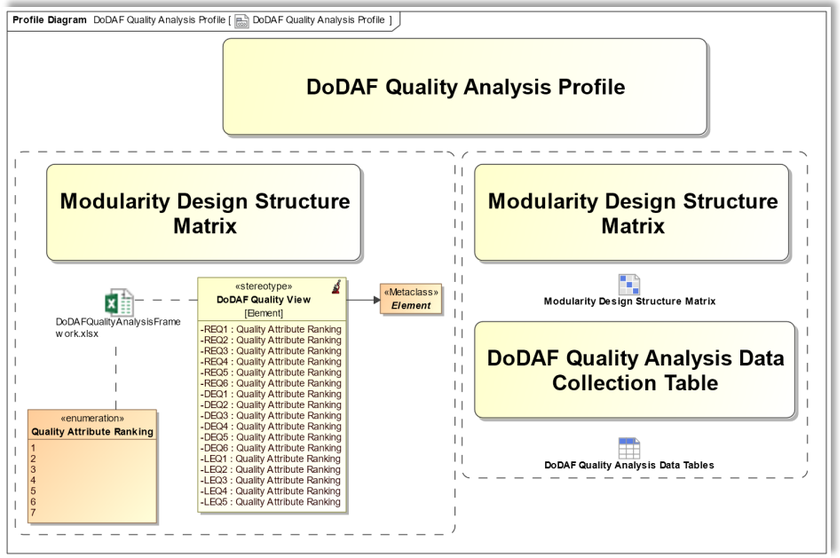
Viewpoint Types	Descriptions
All or AV	The All Viewpoint provides data that is relevant to the entire architecture description [3] [4]. The All Viewpoint is comprised of two views the AV-1 and AV-2.
Capability or CV	The Capability viewpoint captures any taxonomy or capability data as well as capability evolution data [3] [4]. The Capability viewpoint is comprised of seven views CV-1, CV-2, CV-3, CV-4, CV-5, CV-6 and CV-7.
Data and Information or DIV	The Data and Information Viewpoint show operational and business information requirements or rules for system design [3] [4]. The Data and Information Viewpoint consist of three views DIV-1, DIV-2, and DIV-3.
Operational or OV	The Operational Viewpoint describe tasks, activities, operational elements, and resource exchanges and is material independent [3] [4]. The Operational Viewpoint has eight views OV-1, OV-2, OV-3, OV-4, OV-5a, OV-5b, OV-6a, OV-6b, and OV-6c.
Project or PV	The Project Viewpoint identifies how programs, projects, portfolios, or initiatives deliver capabilities, the organizations contributing to them, and dependencies between them [3] [4]. The Project Viewpoint consists of three views PV-1, PV-2, and PV-3.
Service or SvcV	The Service Viewpoint shows services and their interconnections providing or supporting the program or project [3] [4]. The Service Viewpoint consist of thirteen views SvcV-1, SvcV-2, SvcV-3a, SvcV-3b, SvcV-4, SvcV-5, SvcV-6, SvcV-7, SvcV-8, SvcV-9, SvcV-10a, SvcV-10b, and SvcV-10c.
Standards or StdV	The Standards Viewpoint maintains a set of rules governing the arrangement, interaction, and interdependence of parts or elements of the Architectural Description [3] [4]. The Standards Viewpoint consists of two views StdV-1 and StdV-2.
System or SV	The System Viewpoint describes systems and interconnections providing for, or supporting, DoD functions [3] [4]. The System Viewpoint consists of thirteen views SV-1, SV-2, SV-3, SV-4, SV-5a, SV-5b, SV-6, SV-7, SV-8, SV-9, SV-10a, SV-10b, and SV-10c.

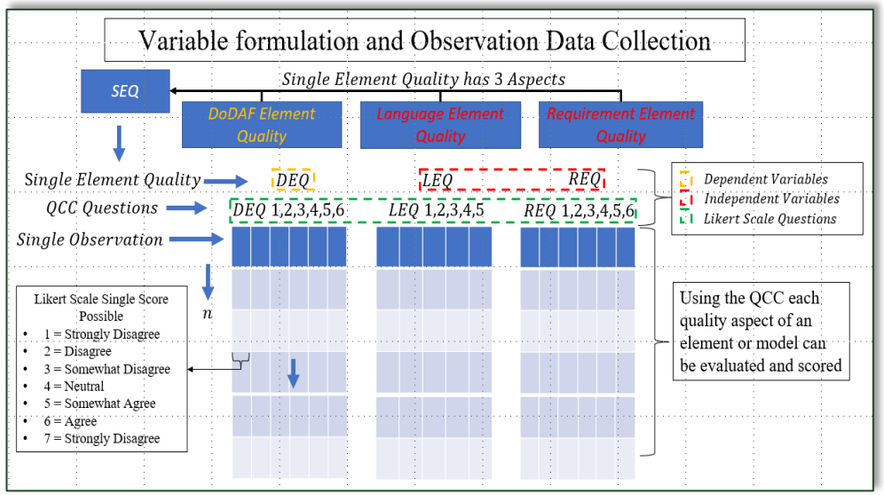


Extensible and Customization Capability of MBSE

Quality Characteristic Categories (QCC)

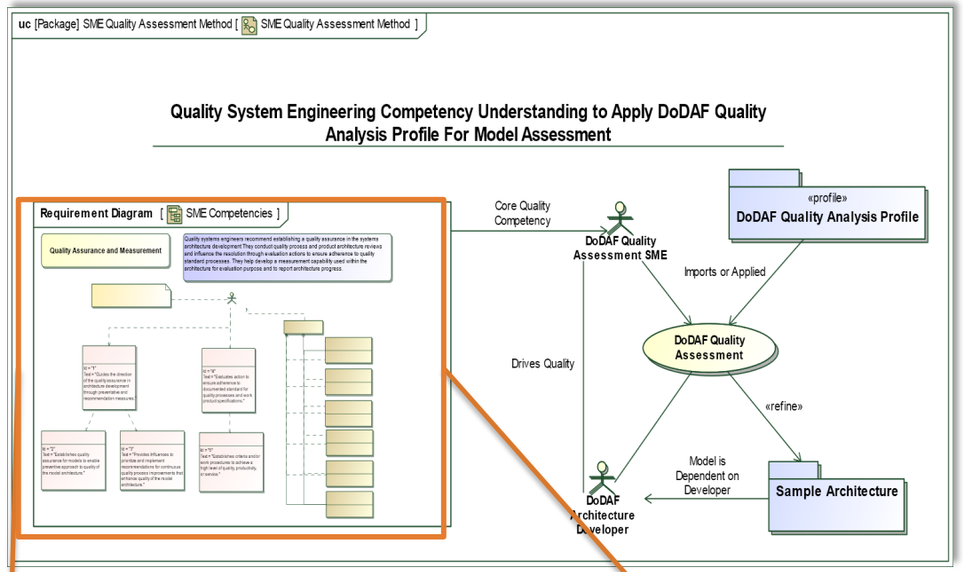
- **DoDAF Element Quality (DEQ) – 6 Factors**
  - Deals with the aspect of the **DoDAF element that meet standard** and establishes elements in the architecture.
- **Language Element Quality (LEQ) – 5 Factors**
  - Deals with the aspect of the **UML/SysML element that meet standards** and establishes elements in the architecture
- **Requirement Element Quality (REQ) – 6 Factors**
  - Deals with the aspect of the r**equirement instantiation of an element to establish system contextual meaning** in the architecture to understand developed requirements or outline requirement development support
  - The criteria attempts to provide an understanding of the **functional coherent design for the system**
- **DEQ, LEQ, and REQ constitute 17 category parameters to assess each element during the evaluation process**
- **DEQ 2, 6 and REQ 1-6 deal with consistency and continuity** for element data which are important considerations **when addressing modularity within an architecture**, and this part of assessment addresses these considerations
- A **neutral value is acceptable because some elements might not require a rating under specific category given contextual meaning** of the element

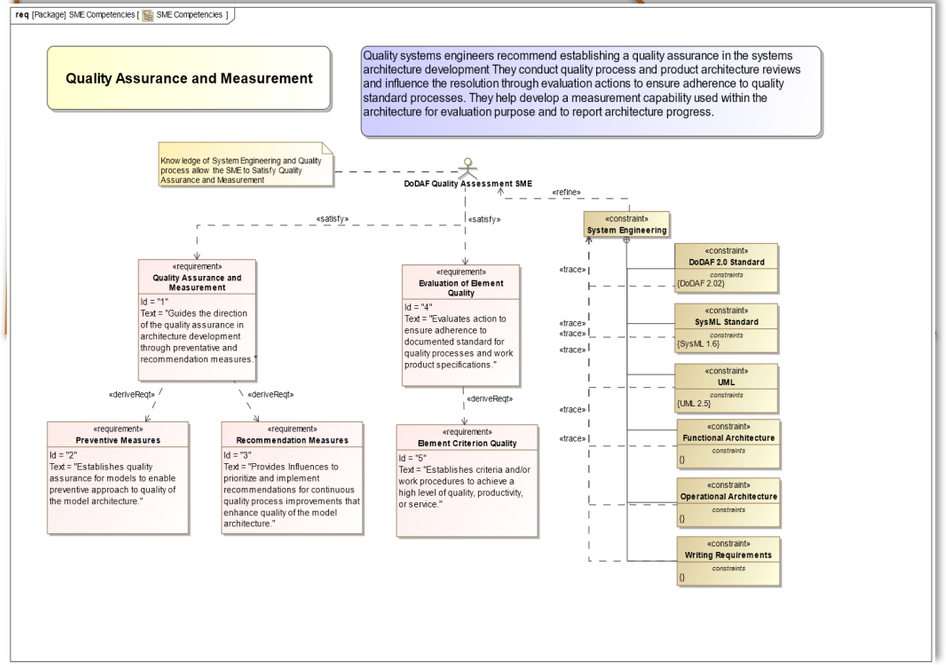




Addressing Subjectivity and Quality SME Engineer

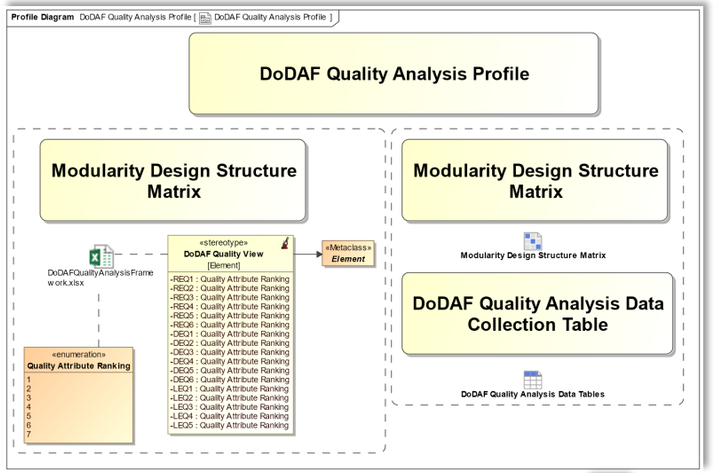
- Subjectivity
  - **When introducing a human making a multi-attributed choice, such as for the Likert scale evaluation of the QCC variables**, introducing bias into the analysis is almost a certainty [23][24]
  - By using a **Likert scale to survey a sample of model elements, system models, elements, and content can be evaluated through the application of numerical ratings, providing a promising approach for quantifying deterministic values of quality** [25] [26] [27]
  - Additionally, a **Likert scale format may effectively reduce Acquiescence Bias meaning the agreement with research statements,** without lowering quality of the data produced from the evaluation to determine the quality [28] [29] [30]
  - The **reliability of the seven point Likert scale has been shown empirically to be approximately ~90\% reliable and approximately ~89\% valid** [71]
- Quality SME Engineer
  - Role of **SME quality engineer is key** to effectively assessing the quality of model [70]
  - **INCOSE, NSAS, and MITRE Competencies evaluated** and arrived at these for Quality
  - Subject **skills and experience** are still essential [70]





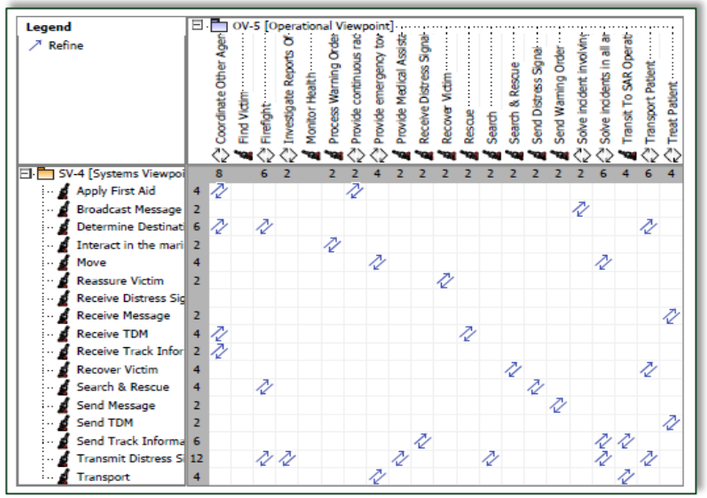
Degree of Modularity

- For purpose of modularity evaluation the DoDAF CONOP architecture specified **mission threads in each of the case studies and was considered the end product** [34][35][36]
- The degree of modularity assessment is used in order to **grasp functional reusability understanding of architecture aspects** to support future development of system design
- The more **modular a designed system is, the easier it is to upgrade, replace, or reuse design aspects**[35][38]
- A modified version of YuTian's equation for **Minimum Description Length (MDL)** was used for describing the Degree of Modularity using human clustering [38] [39]



Modularity Design Structure Matrix Template

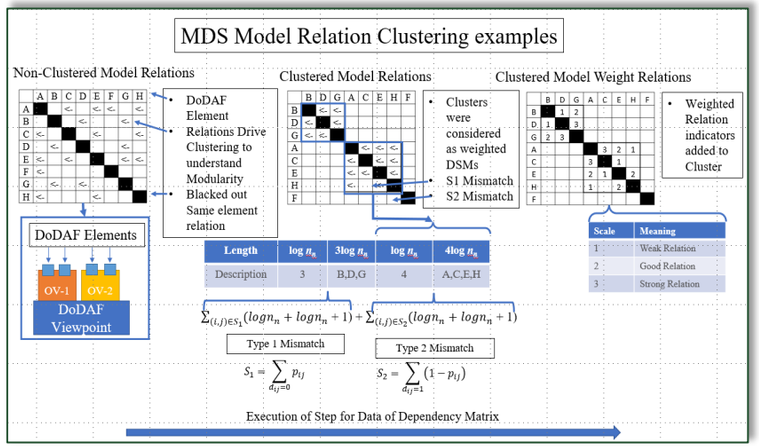
Clustering Method Applied



Score	Definitions
10	Highest possible order of affirmation for the Model and DoDAF View is much more important than the other
8	Strongly Important and is absolutely more important that other DoDAF Views
6	The DoDAF View is more important that another DoDAF View
4	The DoDAF View is slightly more important than another DoDAF View
2	The DoDAF View is not practically important
9,7,5,3,1	Intermediate values between two adjacent judgments

DoDAF Views Weight Table

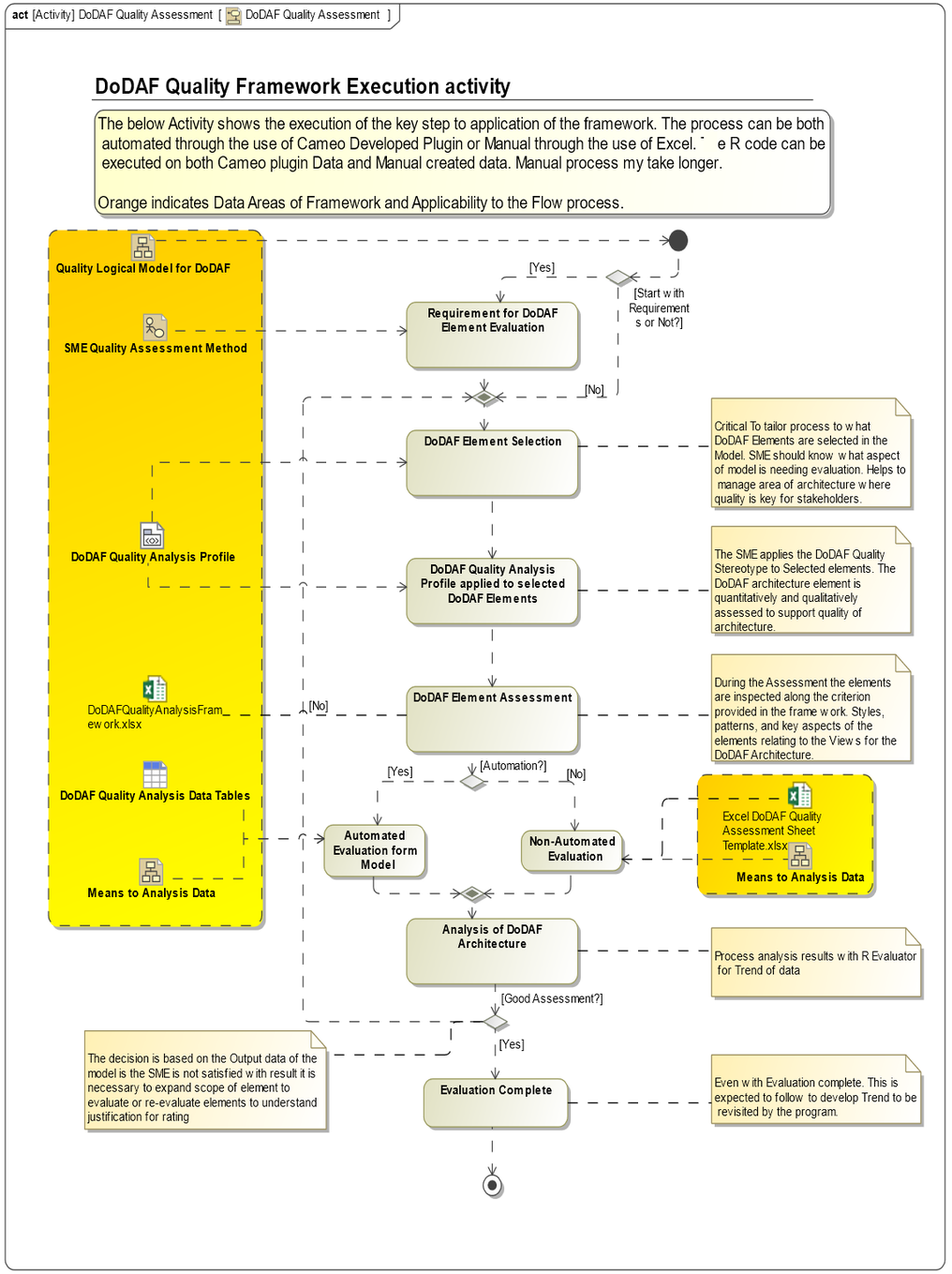
		OV-1	CV-2	OV-2	SV-1	DIV-1	OV-5	SV-4	DIV-2	CV-1	Total	Weights
DoDAF Views	OV-1	1.00	0.25	0.13	0.17	0.25	0.13	0.14	0.20	0.50	2.75952	0.014
	CV-2	4.00	1.00	0.13	0.20	6.00	7.00	7.00	1.00	2.00	28.325	0.148
	OV-2	8.00	8.00	1.00	3.00	8.00	7.00	6.00	4.00	2.00	47	0.246
	SV-1	6.00	5.00	0.33	1.00	2.00	4.00	1.00	5.00	4.00	28.3333	0.148
	DIV-1	4.00	0.17	0.13	0.50	1.00	0.25	0.20	0.33	2.00	8.575	0.045
	OV-5	8.00	0.14	0.14	0.25	4.00	1.00	3.00	6.00	8.00	30.5357	0.160
	SV-4	7.00	0.14	0.17	1.00	5.00	0.33	1.00	4.00	7.00	25.6429	0.134
	DIV-2	5.00	1.00	0.25	0.20	3.00	0.17	0.25	1.00	4.00	14.8667	0.078
	CV-1	2.00	0.50	0.50	0.25	0.50	0.13	0.14	0.25	1.00	5.26786	0.028
										Total	191.306	



$$MDL = \frac{1}{3}\left(n_c log(n_n) + log(n_n)\sum_{i-1}^{n_c} cl_i w\right) + \frac{1}{3}S_1 + \frac{1}{3}S_2$$

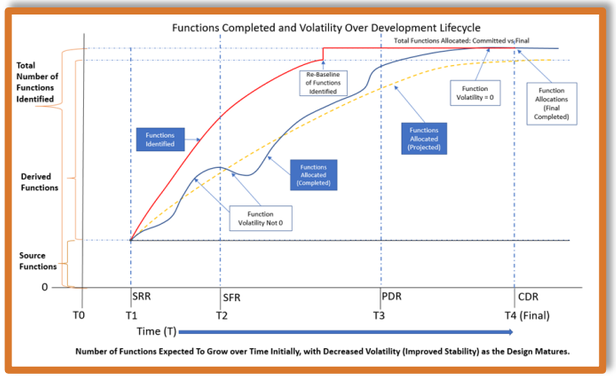
Presentation Simple Execution Activity

- The Activity shows the **simple execution** of the key steps to application of the framework
- DoDAF Element Section
  - **Critical to the tailoring process** is what DoDAF Elements are selected in the Model
  - Helps to manage area of architecture **where quality is key for stakeholders**
- **DoDAF Quality Analysis Profile Applied** to Selected DoDAF Elements
  - The DoDAF architecture element is assessed using the 17 factors to support quality of architecture
- DoDAF Element Assessment
  - **Becomes data set** for analysis extracted from the model
  - **Automated** Evaluation From Model vs **Non-Automated** Evaluation
- Analysis of DoDAF Architecture



Digital Transformation - Published work

D. Miller and R. Scheurer, "Functional completeness and stability," Practical Software and Systems Measurement Continuous Iterative Development Measurement Specifications, vol. 1, no. 1, 2021.



Practical Software and Systems Measurement
Continuous Iterative Development
Measurement Specifications
Functional Completeness and Stability

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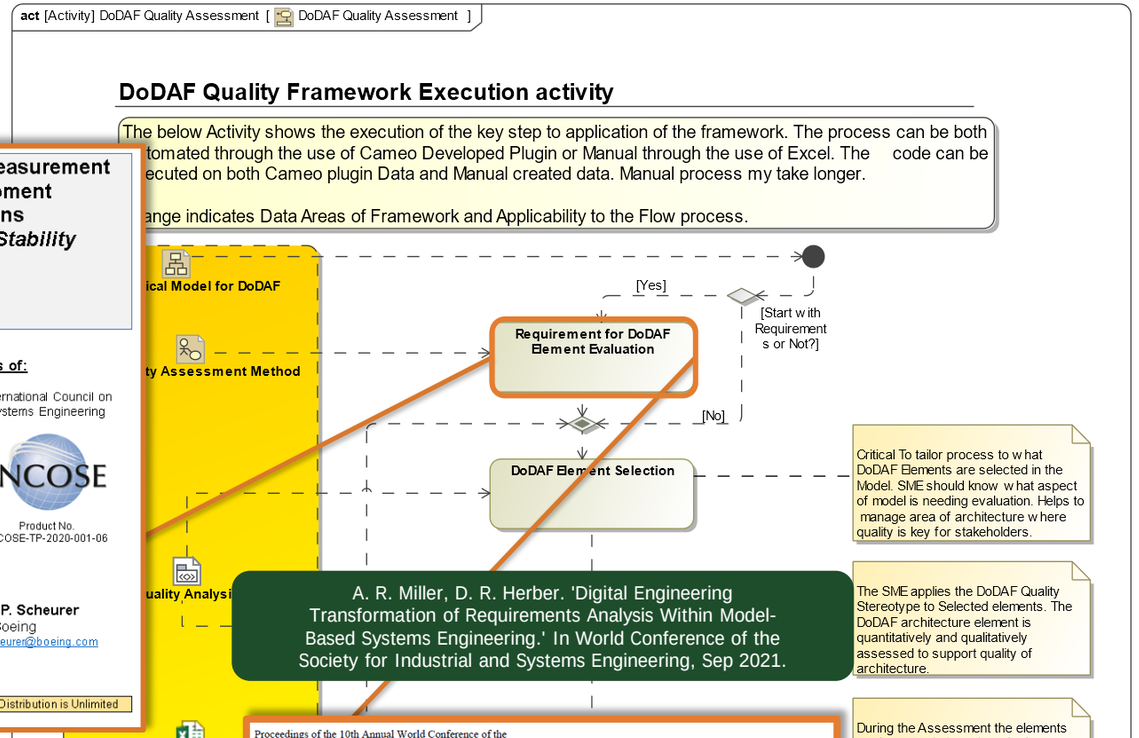


A. R. Miller, D. R. Herber. 'Digital Engineering Transformation of Requirements Analysis Within Model-Based Systems Engineering.' In World Conference of the Society for Industrial and Systems Engineering, Sep 2021.

Critical To tailor process to what DoDAF Elements are selected in the Model. SME should know what aspect of model is needing evaluation. Helps to manage area of architecture where quality is key for stakeholders.

The SME applies the DoDAF Quality Stereotype to Selected elements. The DoDAF architecture element is quantitatively and qualitatively assessed to support quality of architecture.

During the Assessment the elements are inspected along the criterion provided in the framework. Styles, patterns, and key aspects of the elements relating to the Views for the DoDAF Architecture.

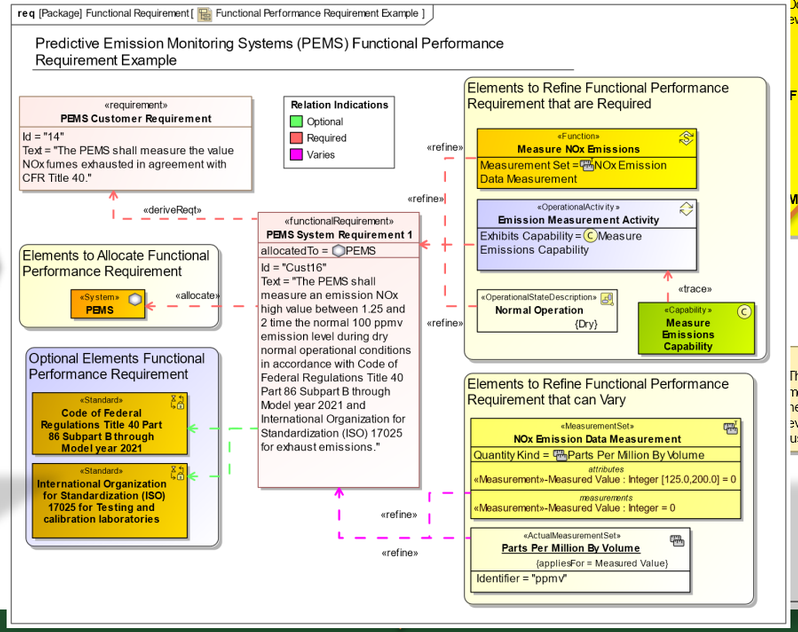
Excel DoDAF Quality Assessment Sheet Template.xlsx
Means to Analysis Data

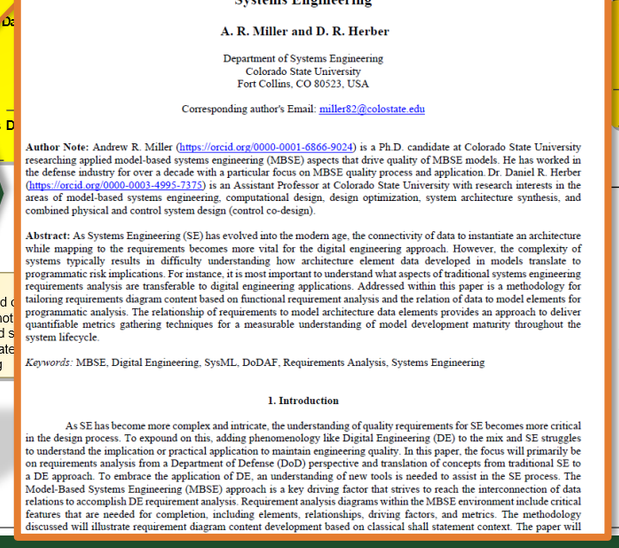
Process analysis results with R Evaluator for Trend of data

Even with Evaluation complete. This is expected to follow to develop Trend to be revisited by the program.

Translates Requirement

Method Step	Element Stereotype Created	Relations Created
1	«requirement»	
2	«functionalRequirement»	«deriveReq»
2.a	«System»	
2.a.1		«allocate»
2.b	«function»	
2.b.1		«refine»
2.c	«MeasurementSet» «ActualMeasurementSet»	
2.c.1		«refine»
2.c.2	«Standard»	
2.d	«OperationalAction» «OperationalActivity»	
2.d.1		«refine»
2.e.1		«dependency»
2.e.2	«OperationalStateDescription»	«refine»
2.e.3	«OperationalConstraint»	
3	«Capability»	
3.a		«trace»
4	Complete	Complete





Proceedings of the 10th Annual World Conference of the Society for Industrial and Systems Engineering, 2021 SISE Virtual Conference, September 23-24, 2021

Digital Engineering Transformation of Requirements Analysis within Model-Based Systems Engineering

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Author Note: Andrew R. Miller (https://orcid.org/0000-0001-6866-9024) is a Ph.D. candidate at Colorado State University researching applied model-based systems engineering (MBSE) aspects that drive quality of MBSE models. He has worked in the defense industry for over a decade with a particular focus on MBSE quality process and application. Dr. Daniel R. Herber (https://orcid.org/0000-0003-4995-7375) is an Assistant Professor at Colorado State University with research interests in the areas of model-based systems engineering, computational design, design optimization, system architecture synthesis, and combined physical and control system design (control co-design).

Abstract: As Systems Engineering (SE) has evolved into the modern age, the connectivity of data to instantiate an architecture while mapping to the requirements becomes more vital for the digital engineering approach. However, the complexity of systems typically results in difficulty understanding how architecture element data developed in models translate to programmatic risk implications. For instance, it is most important to understand what aspects of traditional systems engineering requirements analysis are transferable to digital engineering applications. Addressed within this paper is a methodology for tailoring requirements diagram content based on functional requirement analysis and the relation of data to model elements for programmatic analysis. The relationship of requirements to model architecture data elements provides an approach to deliver quantifiable metrics gathering techniques for a measurable understanding of model development maturity throughout the system lifecycle.

Keywords: MBSE, Digital Engineering, SysML, DoDAF, Requirements Analysis, Systems Engineering

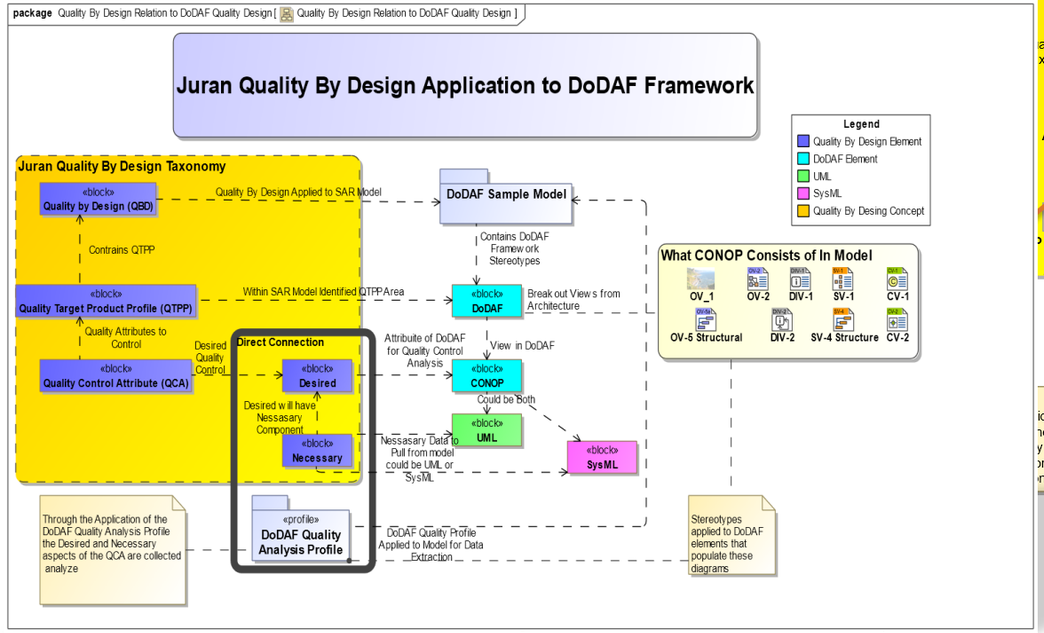
1. Introduction

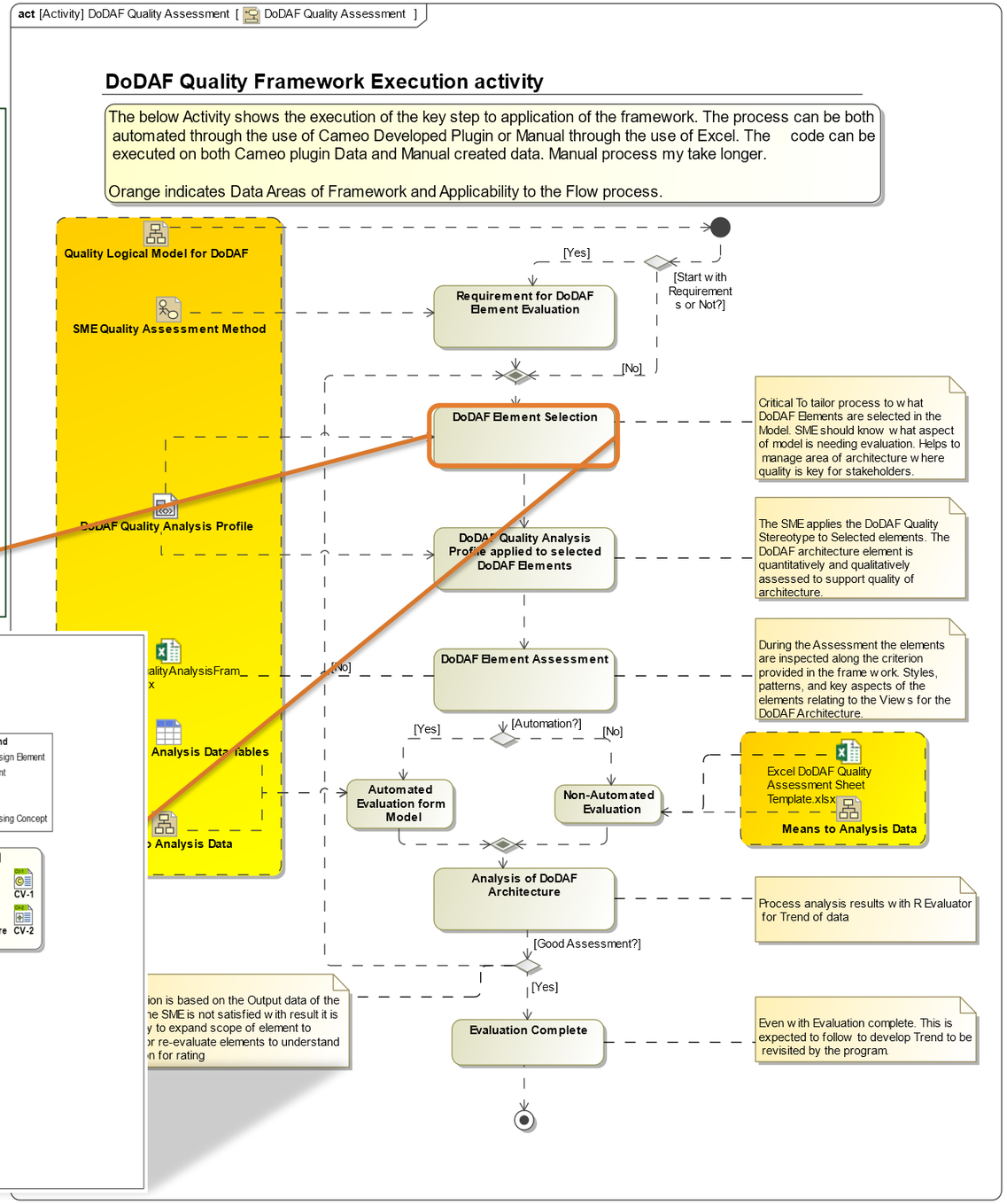
As SE has become more complex and intricate, the understanding of quality requirements for SE becomes more critical in the design process. To expound on this, adding phenomenology like Digital Engineering (DE) to the mix and SE struggles to understand the implication or practical application to maintain engineering quality. In this paper, the focus will primarily be on requirements analysis from a Department of Defense (DoD) perspective and translation of concepts from traditional SE to a DE approach. To embrace the application of DE, an understanding of new tools is needed to assist in the SE process. The Model-Based Systems Engineering (MBSE) approach is a key driving factor that strives to reach the interconnection of data relations to accomplish DE requirement analysis. Requirement analysis diagrams within the MBSE environment include critical features that are needed for completion, including elements, relationships, driving factors, and metrics. The methodology discussed will illustrate requirement diagram content development based on classical shall statement context. The paper will

Element Selection

- The **Quality Target Product Profile (QTPP)** has selected the DoDAF CONOP architecture with specific views
  - Additional refinement can be applied to get the specific quality attribute or **Quality Control Attribute (QCA)**
- The process can be tailored to what DoDAF Elements are selected using the **QCA identification on the model architecture**
- It is **critical to identify what aspect of model is in need of evaluation**
  - The QCA identification drives the focus area of quality understanding on critical areas of DoDAF architecture model

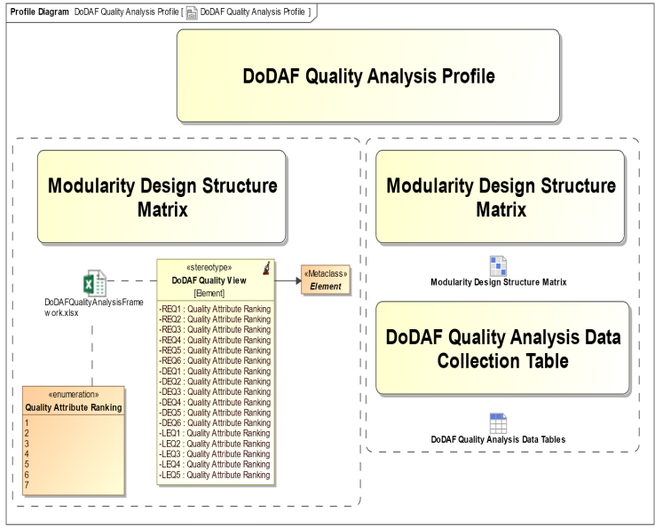
The Case Studies focused on **DoDAF CONOP Mission Thread** to tailor the scope of what element were collected for evaluation

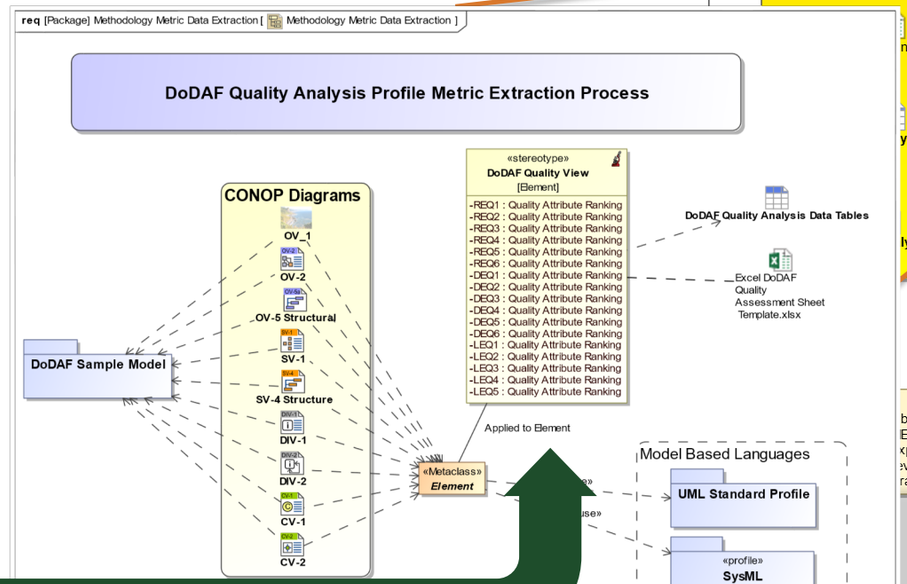


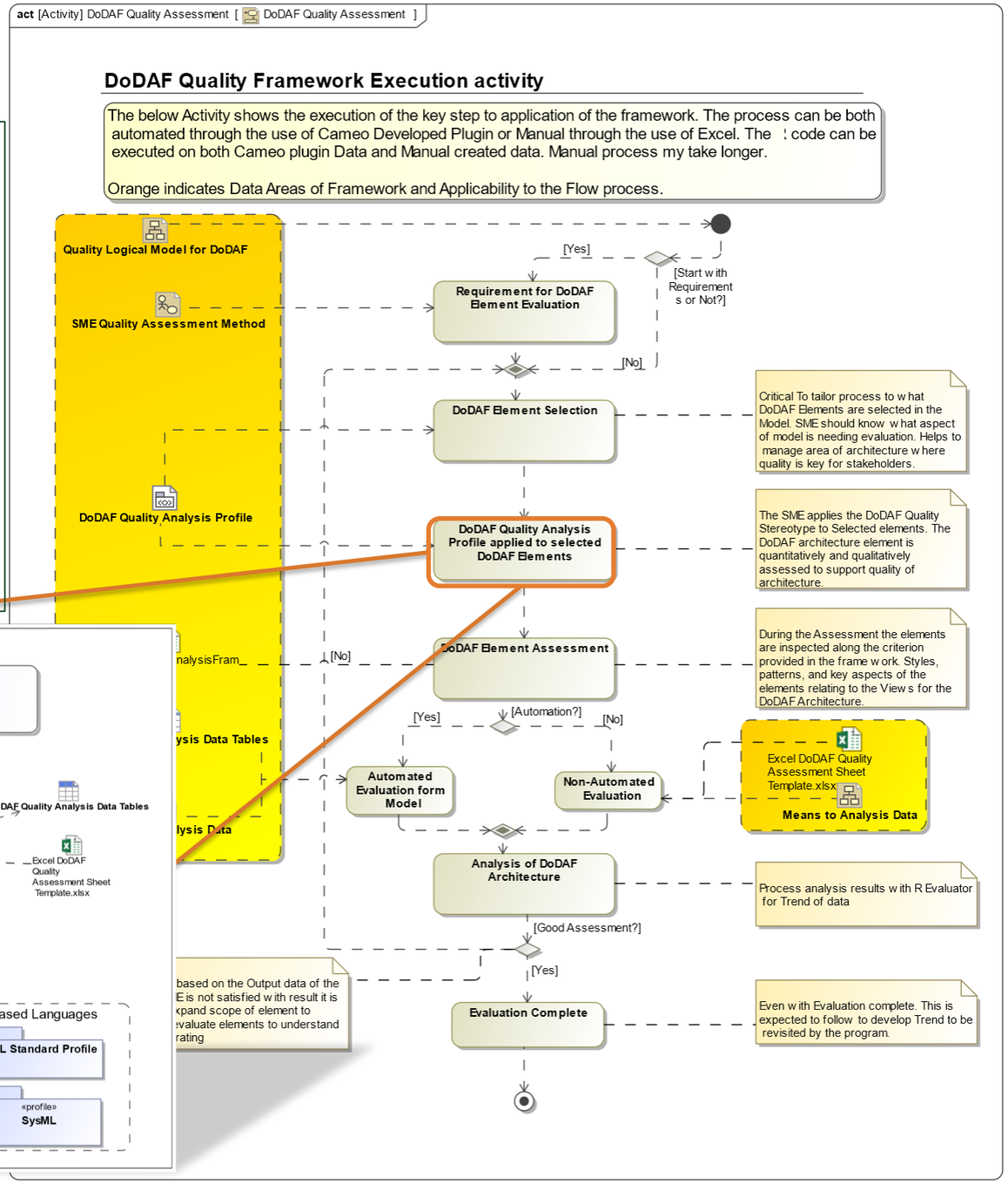


Profile Application to Element

- The DQCF contains the **DoDAF Quality Analysis Profile (DQAP)** and was built using a built-in profiling capability
- UML falls **under two approaches to development with profiles** [32]
  - The first is based on **Domain Specific Language (DSL) which is how a complete new language is developed** for use in a model that would be as extensive as UML or SysML [32] [33].
  - The **second is based on particularization of a UML specializing elements or stereotypes with tag definitions** with respect to the UML base language [32]







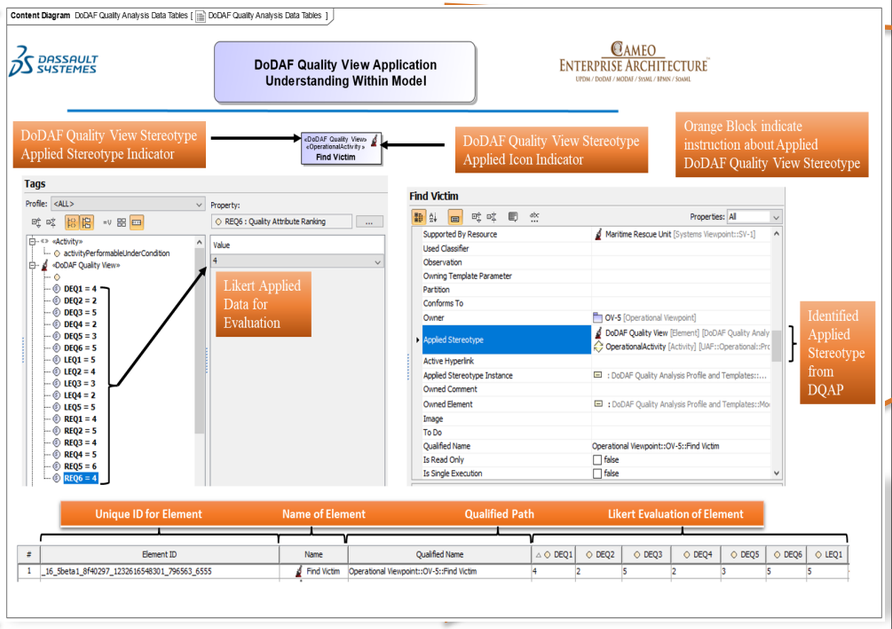
<<DoDAF Quality View>>

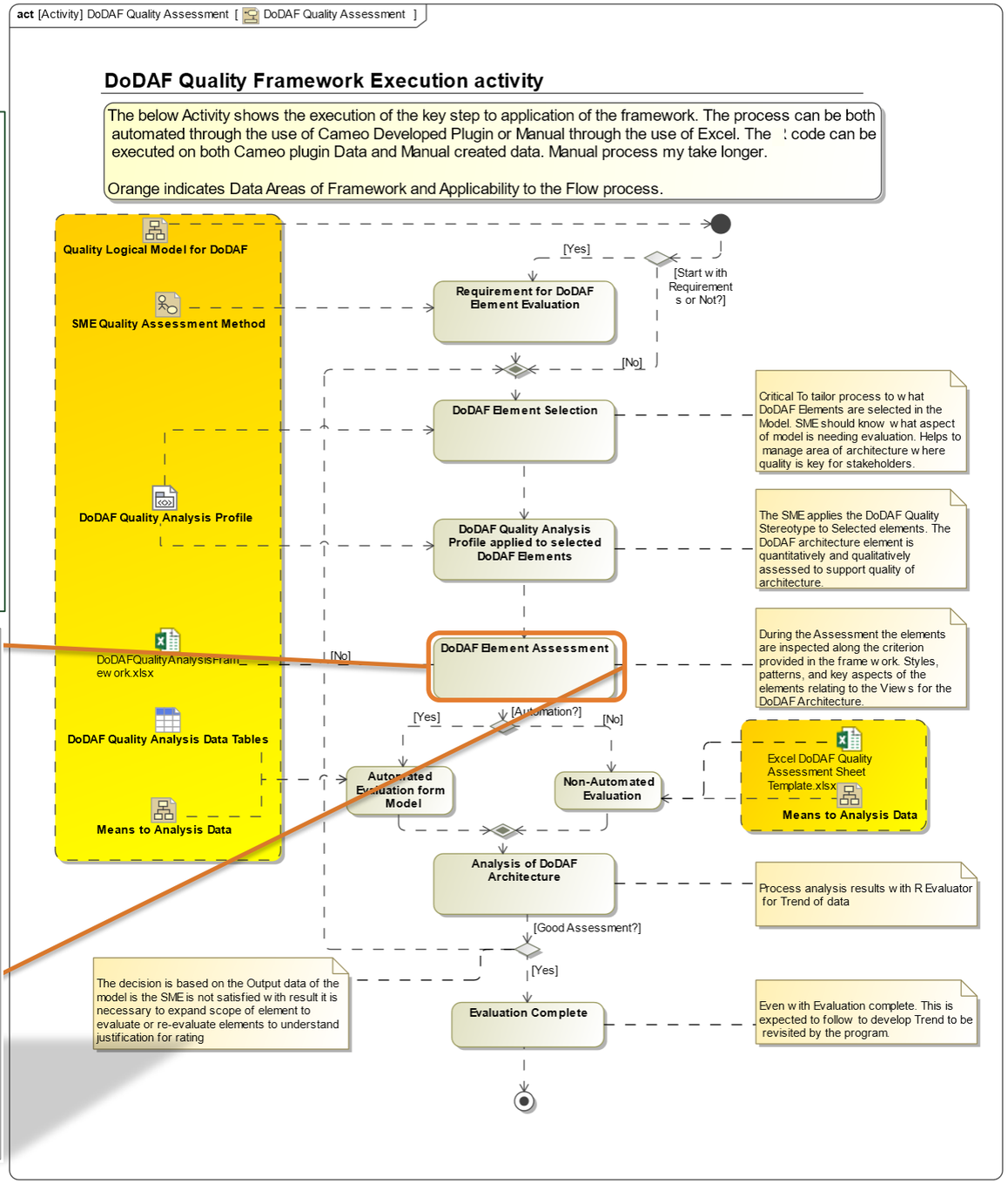
Element Assessment Data

- The ***«DoDAF Quality View»*** **icon appears at the right upper corner of the element indicating application**
- The Specification window displayed to the right of the figure shows the **applied stereotype section of data**
- The window to the left in the figure shows the *«tag definition»* area of the element and is populated with the ***«DoDAF Quality View»*** **Likert scale data for QCC evaluation of the element**

«DoDAF Quality View»
«OperationalActivity»
Find Victim

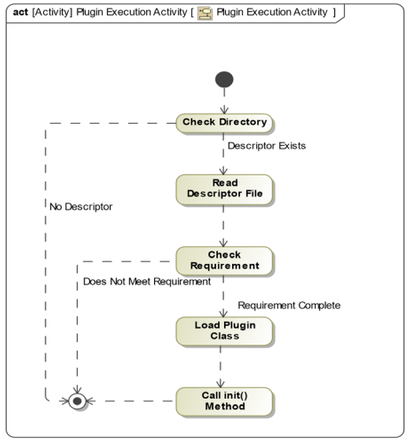
Each Identified Element is Evaluated based on the QCC

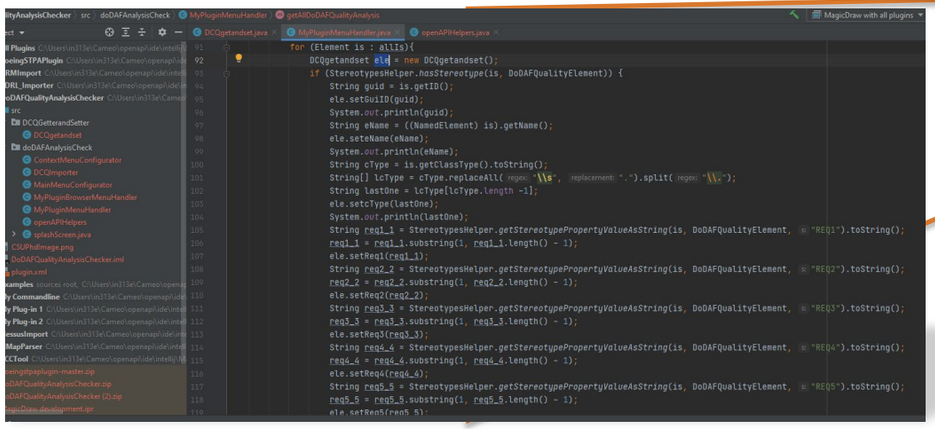


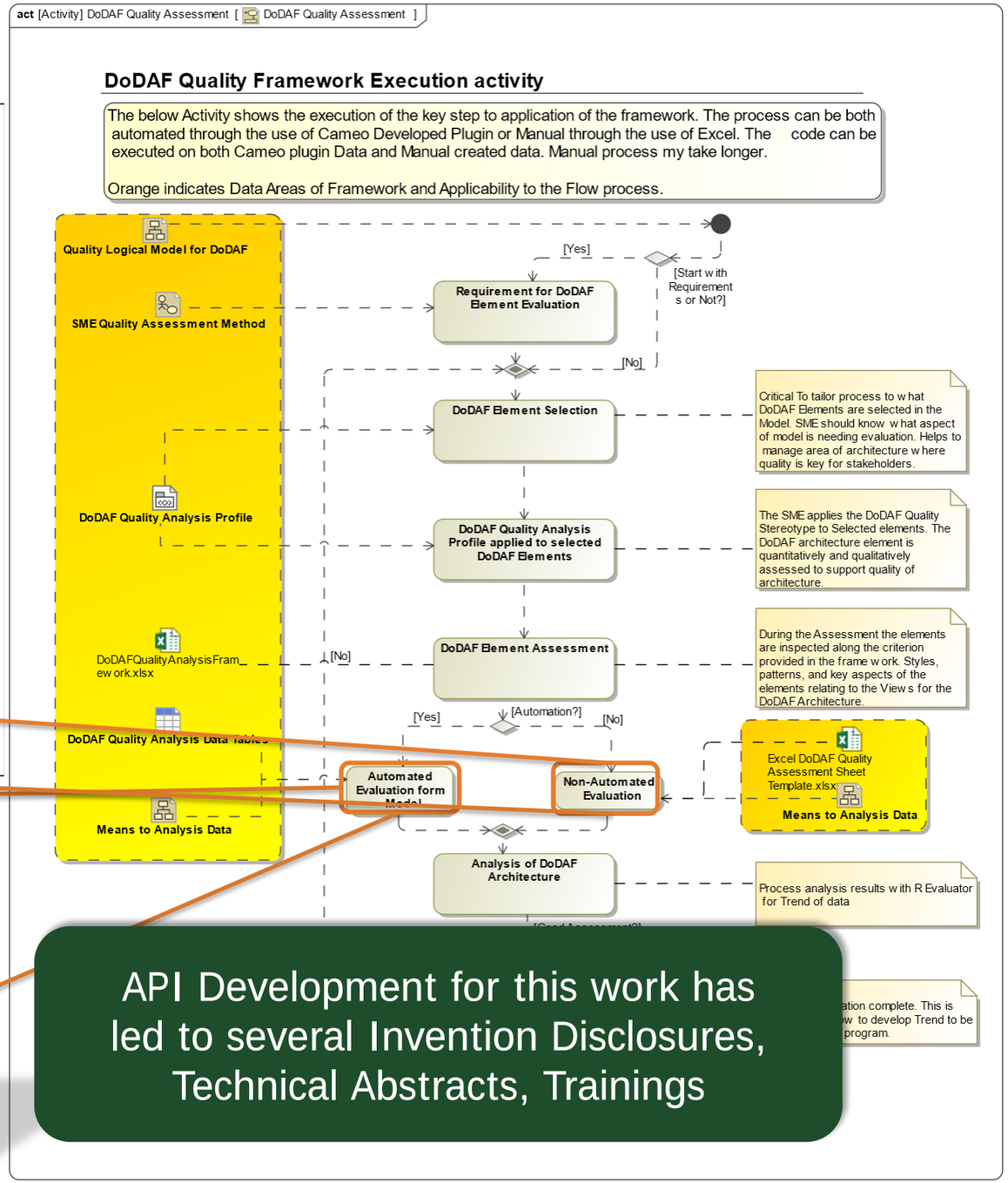


Automation and Non-Automation Collection

- Both Case study models are contained in Cameo Enterprise Architecture 19.0 Service Pack 3 Model Based System Engineering (MBSE) tool
- The tool for automation is Cameo Enterprise Architecture 19.0 Service Pack 3 with Unified Profile for DoDAF/MODAF (UPDM) DoDAF profile
- The Java based plugin is designed specifically to work with Cameo Enterprise Architecture 19.0 Service Pack 3
- The Java base library for API calls is the jdk1.8.0_231 (64x) version
- Intellij IDEA ideaIC-2021.2.3 is the Java Integrated Development Environment (IDE) for automated data extraction
- Microsoft Office Excel 2013 or later is used for the template of data collection



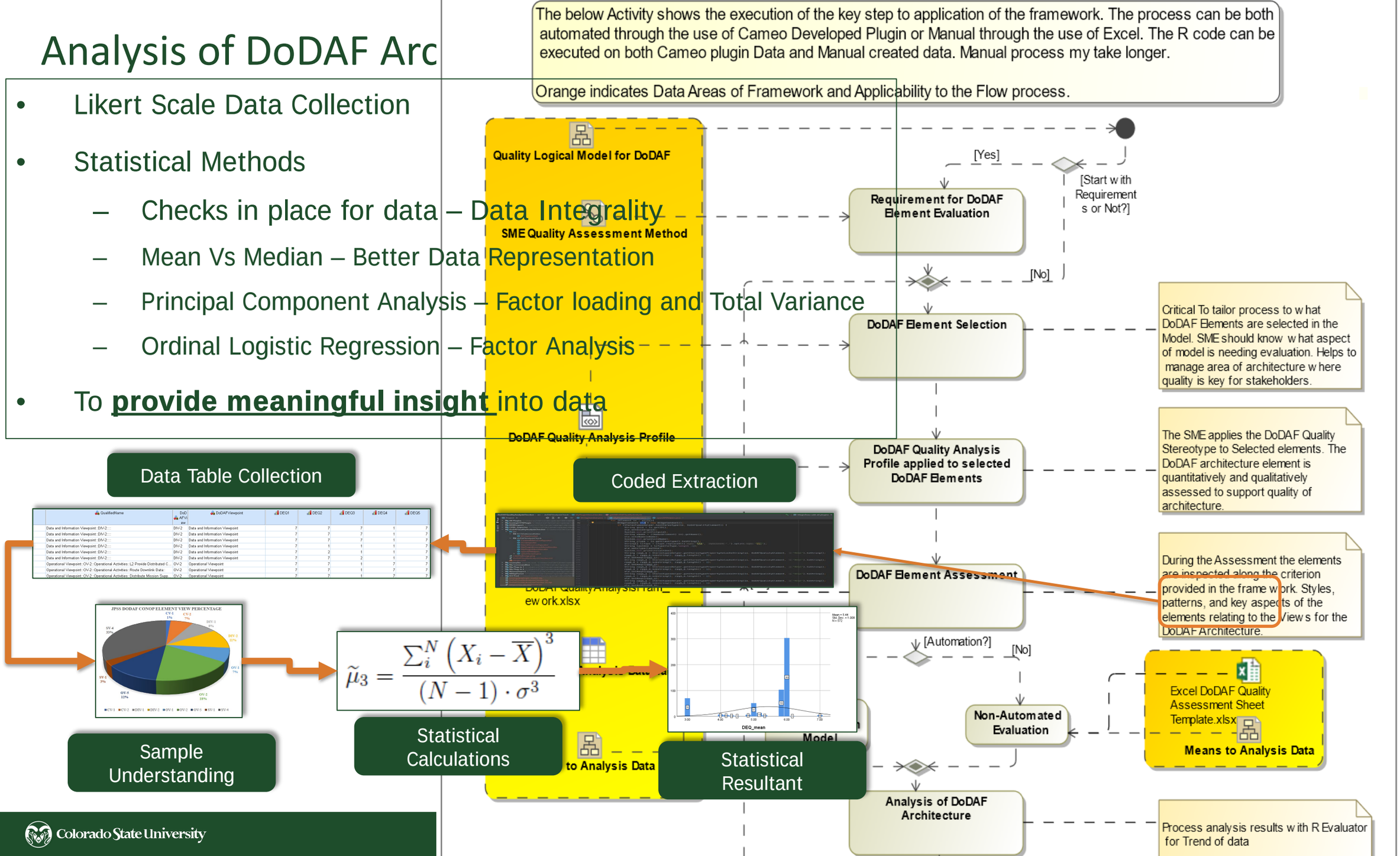




API Development for this work has led to several Invention Disclosures, Technical Abstracts, Trainings

Analysis of DoDAF Arc

- Likert Scale Data Collection
- Statistical Methods
  - Checks in place for data – Data Integrality
  - Mean Vs Median – Better Data Representation
  - Principal Component Analysis – Factor loading and Total Variance
  - Ordinal Logistic Regression – Factor Analysis
- To **provide meaningful insight** into data



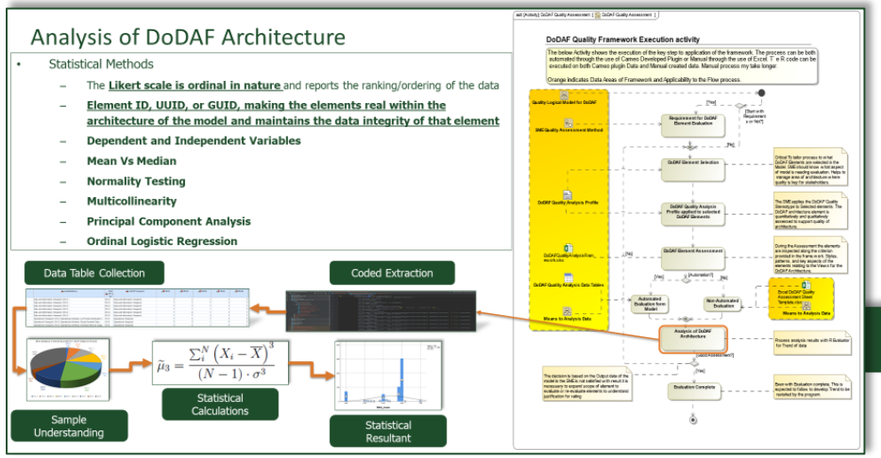
$$\tilde{\mu}_3 = \frac{\sum_i^N \left(X_i - \overline{X}\right)^3}{(N-1)\cdot\sigma^3}$$

Final Quality and Degree of Modularity Determination

- The culmination of the analysis was to transform the final mean values for DEQ, LEQ, and REQ in to an overall rating for quality of the model
- The **variables providing insight of the coherent design of the system** model as well as **application of standards**
- The variables rating can provide insight into **sensitivities of the system design that could be used to identify risks** to the system design
- The degree of modularity assessment is used in order to **grasp functional reusability understanding of architecture aspects** to support future development of system design

Overall Quality Scale

1. "= Very Poor"
2. "= Poor"
3. "= Acceptable"
4. "= Good"
5. "= Very Good"

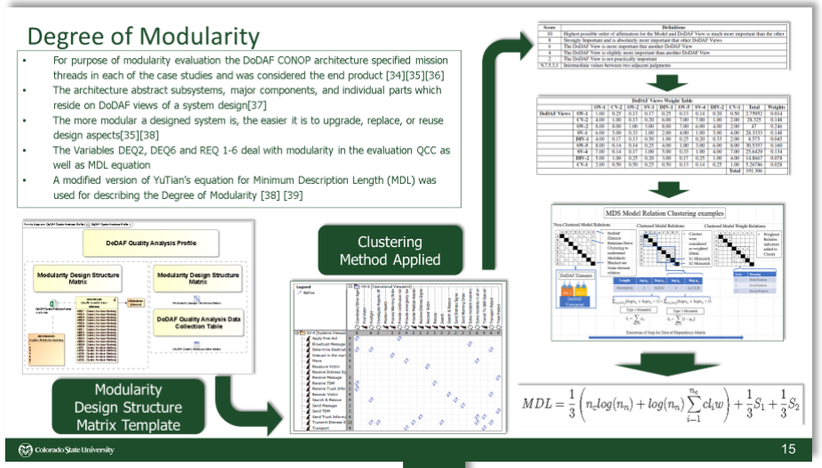


$$Y_5 = (X_7 - 1)\left(\frac{4}{6}\right) + 1$$

Overall Quality and Degree of Modularity

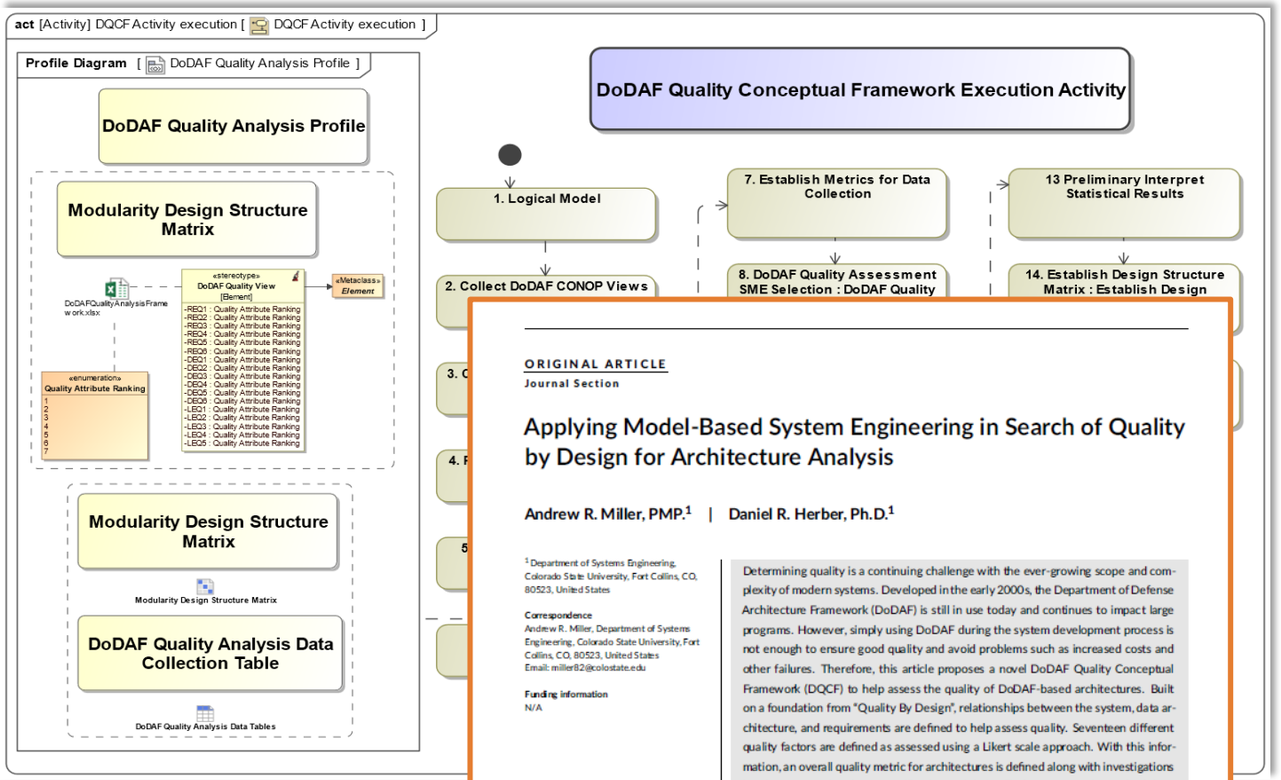
Overall Model Quality		
	Mean Value	Quality Score
DEQ	5.435	3.96
LEQ	5.9056	4.27
REQ	3.437	2.62
Total		3.62

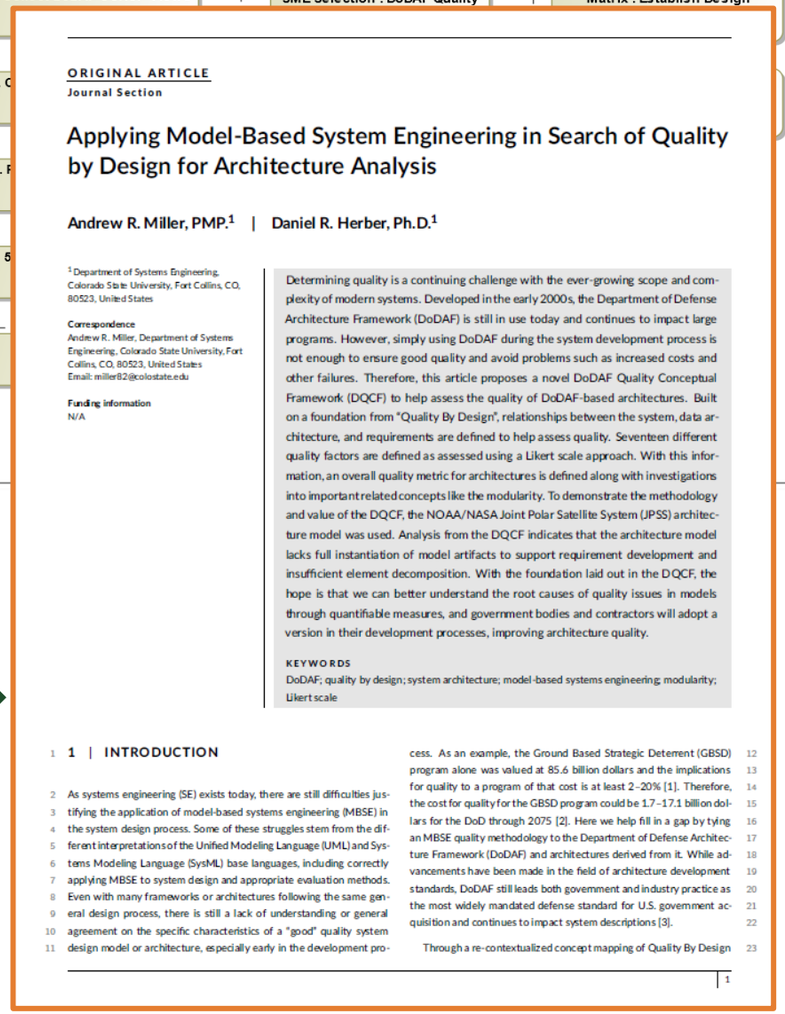
Degree of Modulairty	
Model	196.42
Type I	32350.71
Type II	1827.04
Total MDL	34374.17



DQCF Conceptual Framework Execution

- DoDAF Quality Conceptual Framework (DQCF) to help assess the quality of DoDAF-based architectures
- **17 different quality factors are defined as assessed** using a Likert scale approach
- Variables providing insight of the **coherent design of the system model as well as application of standards**
- Specifically, the variables **rating can provide insight into sensitivities of the system design that could be used to identify risks to the system design**
- The profile **is exportable to XML 1.0** and can be imported to other tools making the profile useable in many other tools
- The degree of modularity assessment is used in order to **grasp functional reusability understanding of architecture aspects** to support future developme system design





ORIGINAL ARTICLE
Journal Section

Applying Model-Based System Engineering in Search of Quality by Design for Architecture Analysis

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Funding information
N/A

Determining quality is a continuing challenge with the ever-growing scope and complexity of modern systems. Developed in the early 2000s, the Department of Defense Architecture Framework (DoDAF) is still in use today and continues to impact large programs. However, simply using DoDAF during the system development process is not enough to ensure good quality and avoid problems such as increased costs and other failures. Therefore, this article proposes a novel DoDAF Quality Conceptual Framework (DQCF) to help assess the quality of DoDAF-based architectures. Built on a foundation from "Quality By Design", relationships between the system, data architecture, and requirements are defined to help assess quality. Seventeen different quality factors are defined as assessed using a Likert scale approach. With this information, an overall quality metric for architectures is defined along with investigations into important related concepts like the modularity. To demonstrate the methodology and value of the DQCF, the NOAA/NASA Joint Polar Satellite System (JPSS) architecture model was used. Analysis from the DQCF indicates that the architecture model lacks full instantiation of model artifacts to support requirement development and insufficient element decomposition. With the foundation laid out in the DQCF, the hope is that we can better understand the root causes of quality issues in models through quantifiable measures, and government bodies and contractors will adopt a version in their development processes, improving architecture quality.

KEYWORDS
DoDAF; quality by design; system architecture; model-based systems engineering; modularity; Likert scale

1 | INTRODUCTION

As systems engineering (SE) exists today, there are still difficulties justifying the application of model-based systems engineering (MBSE) in the system design process. Some of these struggles stem from the different interpretations of the Unified Modeling Language (UML) and Systems Modeling Language (SysML) base languages, including correctly applying MBSE to system design and appropriate evaluation methods. Even with many frameworks or architectures following the same general design process, there is still a lack of understanding or general agreement on the specific characteristics of a "good" quality system design model or architecture, especially early in the development process. As an example, the Ground Based Strategic Deterrent (GBSD) program alone was valued at 85.6 billion dollars and the implications for quality to a program of that cost is at least 2–20% [1]. Therefore, the cost for quality for the GBSD program could be 1.7–17.1 billion dollars for the DoD through 2075 [2]. Here we help fill in a gap by tying an MBSE quality methodology to the Department of Defense Architecture Framework (DoDAF) and architectures derived from it. While advancements have been made in the field of architecture development standards, DoDAF still leads both government and industry practice as the most widely mandated defense standard for U.S. government acquisition and continues to impact system descriptions [3].

Through a re-contextualized concept mapping of Quality By Design

A. R. Miller, D. R. Herber. 'Applying Model-Based System Engineering in Search of Quality by Design for Architecture Analysis.' Wiley System Engineering Journal, TBD, 2022
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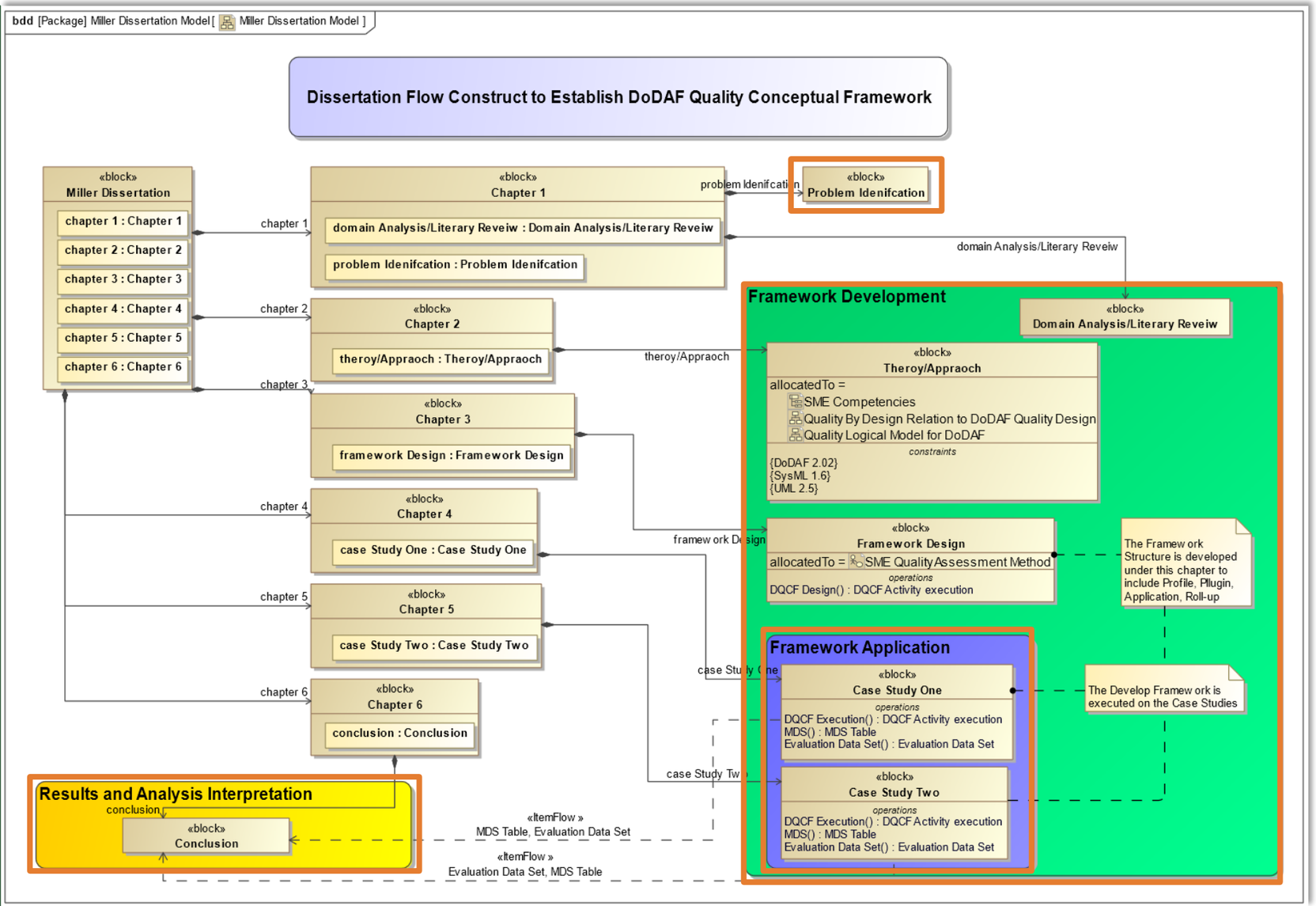
Dissertation Flow Construct to Establish DoDAF Quality Conceptual Framework (DQCF)

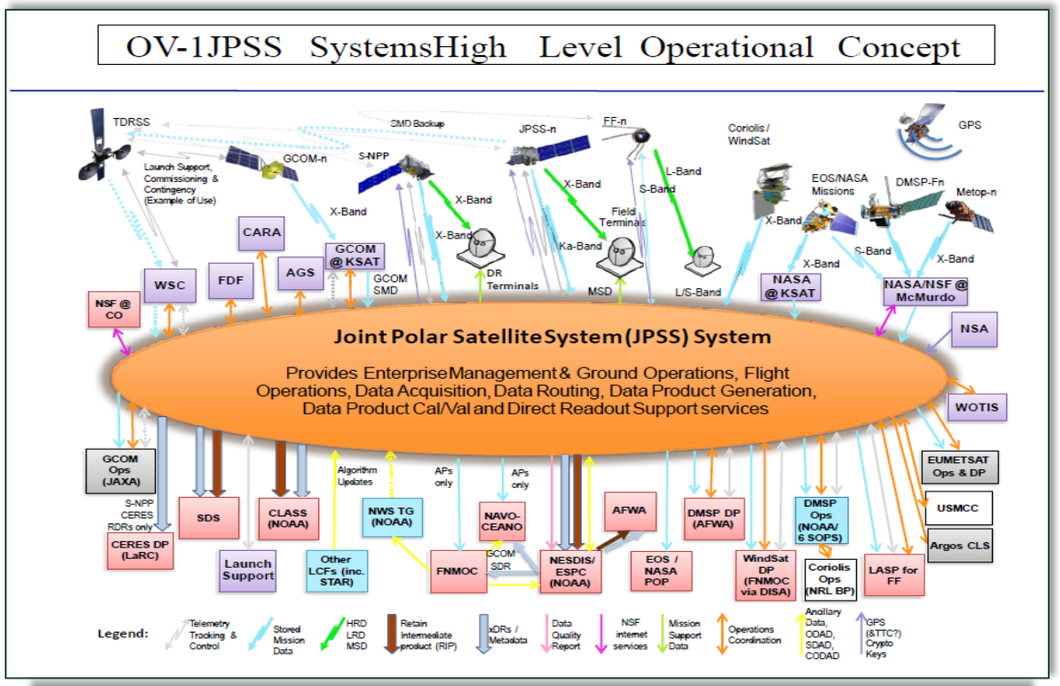
- The figure to the right shows the DQCF Framework Development Model
  - The idea was that the Chapter developments drive the content to form the overall framework
- The green area represents the development area of the DQCF framework
  - The development area is covers both the theory/approach and critical constraints on the development
- The blue area represents the application phase of the DQCF for generation of results
  - The blue is smaller but drives the activity execution in the case study model to preform analysis and generate results
  - The «activity» execution becomes the «operation» within the «block» Chapters case studies that must be performed
- The orange area is the conclusion analysis were the interpretation will occur for the case studies analysis
  - The «ItemFlow»s coming into the conclusion are the data «object» from the executed «operation» generated by the DQCF «activity» in the case study «block»

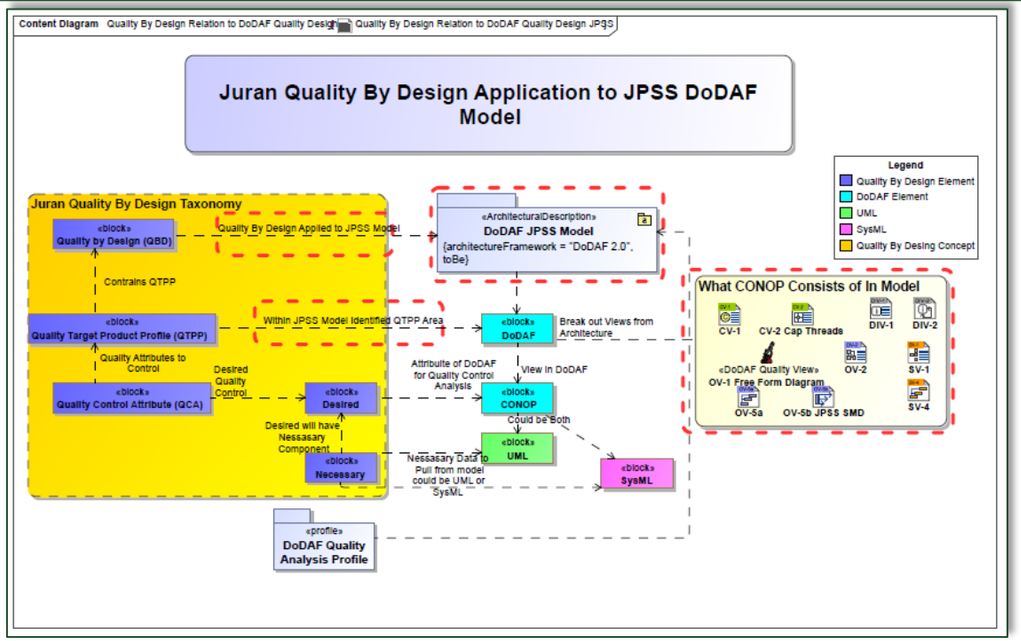


Case Study Analysis Results

Joint Polar Satellite System (JPSS) Case Study One

- **National Oceanic and Atmospheric Administration (NOAA) / National Aeronautics and Space Administration (NASA) Joint Polar Satellite System (JPSS) DoDAF CONOP architecture with focus on the Stored Mission Data (SMD) mission thread**
- JPSS is a next generation earth observation program that collects and communicates global environmental data via polar-orbiting satellites [41]
- The primary mission of the JPSS system is to understand/predict changes in weather, climate, oceans, coasts, and space environment [41]
- The OV-1 shows the corresponding missions, activities, organizations, and high-level operations of the JPSS system [42]
- The JPSS CONOP contained all corresponding views for the **SMD Mission Thread including the CV-1, CV-2, DIV-1, DIV-2, OV-1, OV-2, OV-5, SV-1, and SV-4**
  - The **OV-5 includes the OV-5a and OV-5b**
  - Major system components and the interconnection among those components
  - Interfaces to external systems or procedures [43]
  - Capabilities, functions, and features of the current system [43]
  - Charts and accompanying descriptions depicting inputs, outputs, data flows, control flows, and manual and automated processes sufficient to understand the current system or situation from the users point of view [43]
  - Performance characteristics, such as speed, throughput, volume, frequency
  - Provisions for safety, security, privacy, integrity, and continuity of operations in emergencies [43]





JPSS Element Sampling

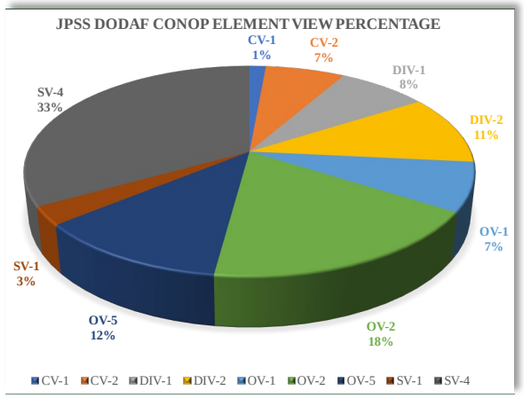
- **572 elements of the JPSS model**, which represents the JPSS DoDAF CONOP, are **roughly 5.46%** of the total JPSS DoDAF CONOP architecture
- Bulk of the elements are **concentrated in the OV-2 ~18%, OV-5 ~12%, and SV-4 ~33%** views for the CONOP
- The DoDAF standard states that the **OV-2 is the backbone to which all other DoDAF elements**
- **OV-2 integrates the corresponding *«OperationalActivity»* of OV-5a Operational Activity Decomposition Tree or OV-5b Operational Activity Model to display interactions of behaviors in the architectural model**
- 572 elements are evaluated against the **17 Quality Characteristic Categories (QCC)**, a total of **9,742 data points are present for the evaluation process**

Cameo Project Statistics	Count
Project Diagrams	228
All Diagrams	667
Project Elements	10481
All Elements	291158
Project Symbol Styles	5
All Symbol Styles	47

SMD Mission Thread

DoDAF CONOP View	Element Count
CV-1	8
CV-2	39
DIV-1	44
DIV-2	61
OV-1	43
OV-2	103
OV-5	68
SV-1	16
SV-4	190
Total	572

% View Makeup



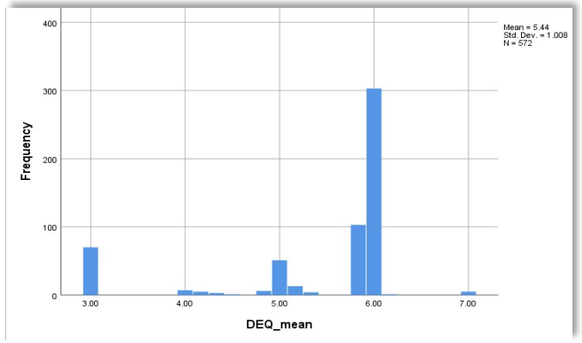
JPSS Statistical Analysis - Descriptives, Skewness, and Kurtosis

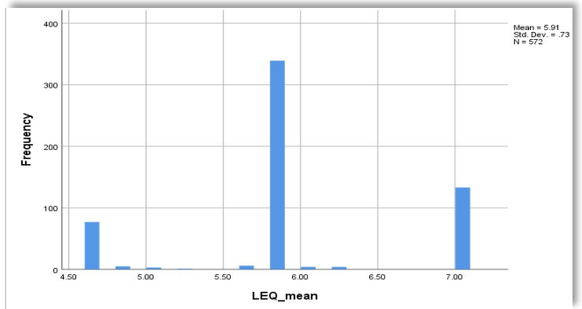
- Mean Vs Median
  - Median value can give you a better interpretation of the **consolidated rating variables for each of the individual element**, when consolidated across **all elements evaluated a problem is presented**
  - Standard errors are small for the mean values, **mean values are more representative of overall population** [45]
- Skewness and Kurtosis
  - Skewness and Kurtosis can provide **some interpretation about the model results** [46] [47]
  - More values are on the **right-handed for *DEQ* and *LEQ* on the right-hand side of graph with negative values**
  - For ***REQ*, this indicates a larger spread between values**, which reflect an **impact on the quality of the JPSS model**

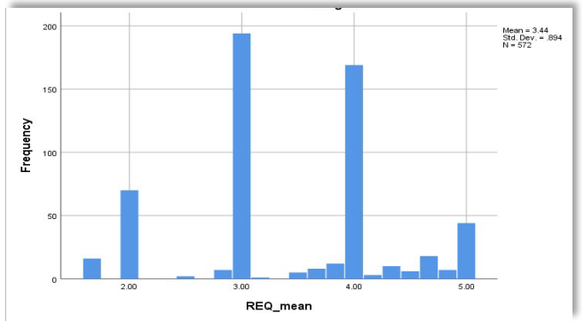
JPSS Descriptives

		Mean		Median	
		Statistic	Std. Error	Statistic	Std. Error
DEQ	Mean	5.4350	0.04216	6.1853	0.08303
	Median	6.0000		7.0000	
	Variance	1.017		3.944	
	Std. Deviation	1.00843		1.98588	
	Minimum	3.00		1.00	
	Maximum	7.00		7.00	
	Range	4.00		6.00	
	Skewness	-1.665	0.102	-2.155	0.102
	Kurtosis	1.391	0.204	2.791	0.204
LEQ	Mean	5.9056	0.03053	7.0000	0.00000
	Median	5.8000		7.0000	
	Variance	0.533		0.000	
	Std. Deviation	0.73007		0.00000	
	Minimum	4.60		7.00	
	Maximum	7.00		7.00	
	Range	2.40		0.00	
	Skewness	-0.031	0.102	.	.
	Kurtosis	-0.372	0.204	.	.
REQ	Mean	3.4374	0.03740	2.8024	0.08474
	Median	3.0000		1.0000	
	Variance	0.800		4.107	
	Std. Deviation	0.89441		2.02661	
	Minimum	1.67		1.00	
	Maximum	5.00		7.00	
	Range	3.33		6.00	
	Skewness	-0.121	0.102	0.641	0.102
	Kurtosis	-0.726	0.204	-0.83	0.204

***DEQ, LEQ* and *REQ* Plot Data**







JPSS Statistical Analysis – Multicollinearity

- Multicollinearity is where two or more variables in the **JPSS evaluation data set are highly linearly related**
- Each factor including a correlation coefficient and significance on for each observation was calculated to make a correlation determination [48]
- Multicollinearity needs to be addressed because the **standard errors of the coefficients for variables could cause false indicators and become non-significant or significant** [49]
- Analysis of the Variance Inflation Factors (VIF) values for each factor was used to determine elimination [49]
- Spearman's rho can both be positive and negative, with **the goal is to have a value between 0.1 and -0.1** [50]
- **Statistical significance does not always imply the strength of Spearman's correlation** between variables [51]
- Statistically significant Spearman correlation **indicates that there is less than a 5% chance that the strength of the association discovered occurred by coincidence** [51]

$$VIF_i = \frac{1}{1 - R_i^2}$$

Removed

Factors Eliminated due to VIF	
QCC Factor	VIF Value
DEQ1	11.684
DEQ2	21.112
DEQ5	18.235
DEQ6	13.521
LEQ2	11.442
LEQ5	16.348

11 Remaining Factors for Analysis

	Collinearity Statistics Tolerance	VIF
DEQ3	0.388	2.576
DEQ4	0.298	3.354
LEQ1	0.247	4.043
LEQ3	0.338	2.962
LEQ4	0.309	3.232
REQ1	0.581	1.721
REQ2	0.159	6.303
REQ3	0.274	3.652
REQ4	0.339	2.949
REQ5	0.479	2.088
REQ6	0.244	4.096

Spearman's Rho

$$\rho = 1 - \frac{6 \sum d_2^i}{n\left(n^2 - 1\right)}$$

JPSS Statistical Analysis - Principal Component Analysis (PCA)

- Accurately of the evaluation data set represents the **purposeful sampling adequacy** for the JPSS DoDAF CONOP architecture
- **KMO value** is considered on the lower end of the **suggested rating scale of 0.5 to 1.0** but adequate enough to proceed with the analysis [53] [54]

- Bartlett's Test of Sphericity showed that the **correlation matrix formed is not an identity matrix**
- Indicates that the **total variance is achieved between 72.986% and 82.507% for a total of four to five factors**
- When **it comes to statistical research**, where **extracted components often explain just 50% to 60% of the variance, the 70% to 80% of the variance approach may be unworkable** [57]
  - Because of this the **JPSS needed additional factor reduction**
- Adjusting for the **50% to 60% of the variance, the total variation for two to three components between 45.659% to 61.920% for two to three components**
- Oblique rotation or varimax rotation due to the **more realistic representation** for the data [55] [56]
- Simplicity of analysis only two factors are used for the eigenvalues giving a maximum of **49.077% of the total variance, which is still acceptable for the 50% to 60% of the variance**
- Evaluation of the **loadings aid in the identification of each component's characteristics in terms of the variables** [52]

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.592
Bartlett's Test of Sphericity	Approx. Chi-Square	3512.797
	df	55
	Sig.	0.000

Total Variance Explained						
Comp	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.500	31.817	31.817	3.414	31.041	31.041
2	1.899	17.260	49.077	1.984	18.037	49.077
3	1.413	12.842	61.920			
4	1.217	11.066	72.986			
5	1.047	9.521	82.507			
6	0.839	7.625	90.132			
7	0.414	3.761	93.893			
8	0.299	2.719	96.612			
9	0.183	1.665	98.277			
10	0.103	0.938	99.214			
11	0.086	0.786	100.000			
Extraction Method: Principal Component Analysis.						

JPSS Statistical Analysis – Ordinal Logistic Regression (OLR)

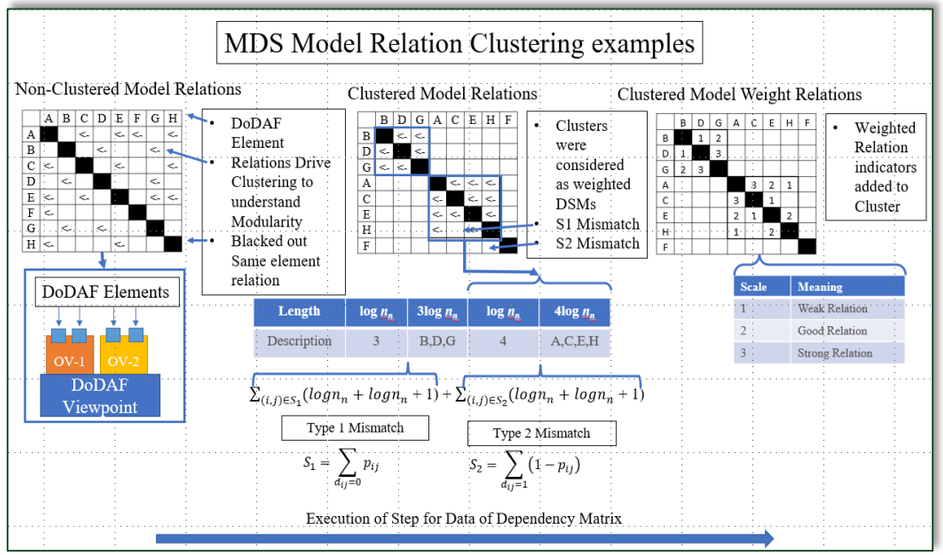
- ***DEQ3***: **Missing description to understand what element is representing** for the architecture were common place in the JPSS architecture.
- ***DEQ4***: Element types were used in the architecture **were missing *«ActualMeasurementTypes»* as well as *«ValueProperties»* to explain the data selection**.
- ***LEQ3***: The primary rating understanding for the model elements **did not always have some relation to some justification for need within the JPSS architecture**. In some cases **obsolete element type were used** which drove the quality of this QCC criteria to be rated as mostly "Disagree"
- ***LEQ4***: The JPSS model **contained orphaned elements existed** that often did not have relationships to parts of the DoDAF architecture.
- ***REQ4***: The Performance measurable **values are not completely specified** the **DIV-1 was not complete** which is a large contributing factor and **directly impacts test verification which effects the REQ6 variable**.
- ***REQ5***: DoDAF Element performance design attributes **which allow the verification for a system design, not all elements had performance design attributes associated** with them in the JPSS architecture and **the DIV-1 was not complete which is a contributing factor** and strictly impacting the JPSS overall ability to complete verification.
- ***REQ6***: While case can be conceived to assess all aspects of the DoDAF elements for a system design, the analysis **showed that non consistent decomposition from System to Sub-system** in the architecture for the JPSS SMD material.

Identify the Strength of effects

Location	DEQ3	3.170	0.308	106.176	1	0.000	2.567	3.773
	DEQ4	2.750	0.224	150.324	1	0.000	2.310	3.189
	LEQ1	0.082	0.142	0.335	1	0.563	-0.196	0.361
	LEQ3	2.085	0.235	78.440	1	0.000	1.624	2.547
	LEQ4	7.207	0.932	59.851	1	0.000	5.381	9.033
	REQ1	0.948	0.594	2.546	1	0.111	-0.217	2.113
	REQ2	-0.100	0.164	0.367	1	0.544	-0.422	0.222
	REQ3	-0.084	0.114	0.544	1	0.461	-0.308	0.140
	REQ4	-1.261	0.138	83.406	1	0.000	-1.531	-0.990
	REQ5	0.271	0.133	4.153	1	0.042	0.010	0.531
	REQ6	0.792	0.231	11.733	1	0.001	0.339	1.245
Link function: Logit.								

JPSS Degree of Modularity Determination

- ***DEQ2, 6*** and ***REQ1-6***: All of the element evaluated had some form of relationship to the JPSS DoDAF architecture being direct or indirect.
  - This means that **some degree of modularity is present**
  - ***DEQ6***: VIF calculated showed a value of 13.521
  - ***REQ1-6***: PCA and OLR analysis found key significance in the REQ criteria from the QCC for the JPSS architecture
- The **pairwise weighting each item** with the rest of the group and give a preferential level to the item
- If **the model description is simple, the model description is short** [39]
  - **Many data mismatches would exist, and the mismatched data description would become longer** [39]
  - A **complicated model reduces the description of mismatched data, but the model description would be longer** [39]



Clustering Arrangements				
	n_c	cl_i	$\lvert S_1 \rvert$	$\lvert S_2 \rvert$
JPSS Model	9	14, 28, 69, 76, 77, 107, 120, 181, 334	60108.33	8773.54

$$MDL = \frac{1}{3}\left(n_c log(n_n) + log(n_n)\sum_{i-1}^{n_c} cl_i w\right) + \frac{1}{3}S_1 + \frac{1}{3}S_2$$

	Description Length	Ratio
JPSS CONOP Model	196.42	0.333
Type I Mismatch	32350.71	0.333
Type II Mismatch	1827.04	0.333
Total MDL	33437.17	

JPSS Overall Results

- DEQ Findings:
  - **DEQ2 and DEQ6 showed some degree of modularity** is present in the architecture.
  - **Not all elements were located on correct diagram**, **deprecated element types** were used in the architecture.
  - The implications of **unjustified alternative behavior present** on the diagrams had no driving factor present.
  - Many elements had **missing description** difficulty understanding what elements were representing for the architecture was common place.
  - Element types were used in the architecture were **missing performance indication** or standard to explain the data selection.
- LEQ Findings:
  - Model **elements did not always have a need** within the architecture.
  - The model **contained orphaned elements** that often did not have relationships to parts of the architecture.
- REQ Findings:
  - Many of the element in the JPSS DoDAF CONOP architecture **did not have a sufficient requirement element instantiation** with in the architecture.
  - The p**erformance measurable values were not completely** specified directly impacts test verification.
  - **Not all elements had performance design attributes** associated with them and the DIV-1 was not complete strictly impacting overall ability to complete verification.
  - The **analysis showed that non consistent decomposition** from System to Sub-system in the architecture.
  - Analysis **found key significance in the REQ criteria from the QCC for the JPSS architecture**.

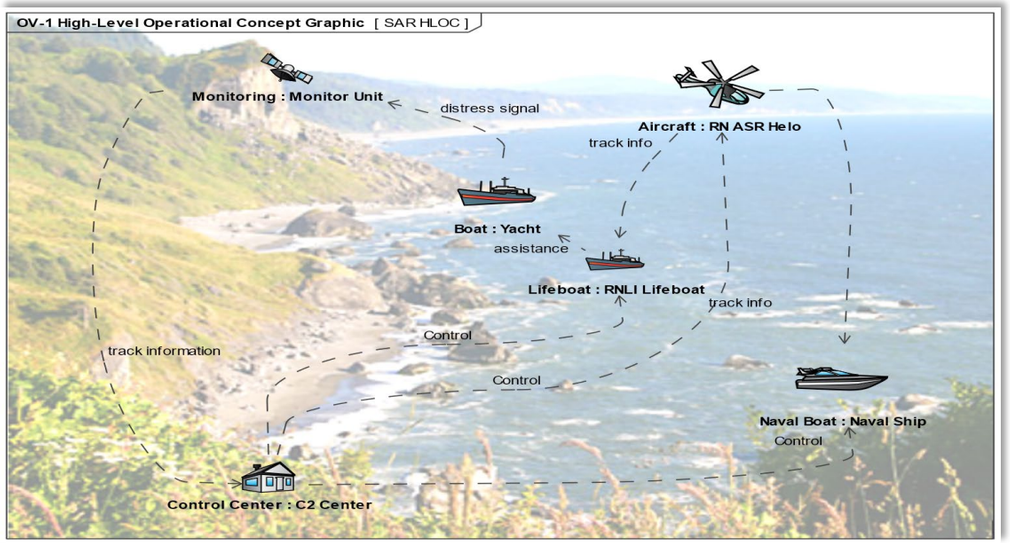
JPSS Rating was “Acceptable” to “Good” with sensitivity to *REQ* factors

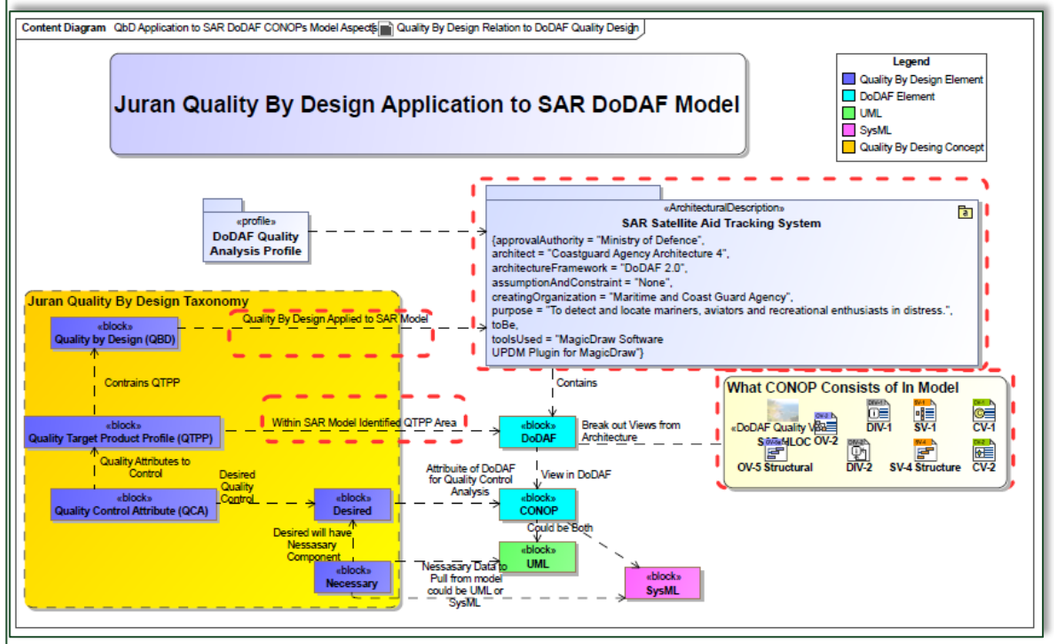
- DEQ was yellow to green but very close to a value of 3.96 or "Good" rating
- The LEQ was a green score of a value of 4.27 but still a "Good" rating
- The REQ was a red score of 2.62 in a "Poor" to "Acceptable" rating
- The JPSS Overall score is a 3.62 or "Acceptable" to "Good" rating

Overall Model Quality		
	Mean Value	Quality Score
DEQ	5.435	3.96
LEQ	5.9056	4.27
REQ	3.437	2.62
Total		3.62
Degree of Modulairty		
Model	196.42	
Type I	32350.71	
Type II	1827.04	
Total MDL	34374.17	

Search and Rescue (SAR) Case Study Two

- **Search and Rescue (SAR) DoDAF CONOP architecture with focus on the Command and Control (C2) signaling mission thread**
- SAR DoDAF architectural model consists of operations for locating and retrieving persons in distress, providing for their immediate needs and delivering them to a place of safety [64]
- Primary mission of the **SAR DoDAF architectural system is to capture all search and rescue capabilities, in conjunction with the Department for Transport and police**, while maintaining a United Kingdom military/civilian SAR capability to ensure the most effective and timely response available to assist people in hazardous situations [65] [66]
- The OV-1 shows the corresponding missions, activities, organizations, and high-level operations of the SAR system
- The SAR CONOP contained all corresponding views for the **Command and Control signaling mission thread the CV-1, CV-2, DIV-1, DIV-2, OV-1, OV-2, OV-5, SV-1, and SV-4**
  - The **OV-5 includes the OV-5a and OV-5b**
  - Major system components and the interconnection among those components
  - Interfaces to external systems or procedures [43]
  - Capabilities, functions, and features of the current system [43]
  - Charts and accompanying descriptions depicting inputs, outputs, data flows, control flows, and manual and automated processes sufficient to understand the current system or situation from the users point of view [43]
  - Performance characteristics, such as speed, throughput, volume, frequency
  - Provisions for safety, security, privacy, integrity, and continuity of operations in emergencies [43]





SAR Element Sampling

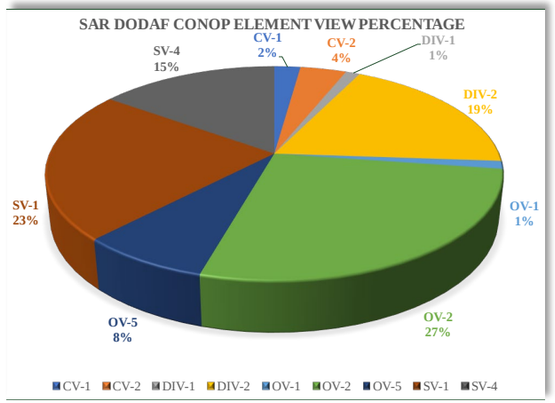
- **590 elements of the SAR model**, which represents the SAR DoDAF CONOP, are **roughly 6.34%** of the total SAR DoDAF CONOP architecture
- Bulk of the elements are **concentrated in the DIV-2 ~19%, OV-2 ~27%, OV-5 ~8%, SV-1 ~23%, and SV-4 ~15%** views for the CONOP
- The DoDAF standard states that the **OV-2 is the backbone to which all other DoDAF elements**
- **OV-2 integrates the corresponding *«OperationalActivity»* of OV-5a Operational Activity Decomposition Tree or OV-5b Operational Activity Model to display interactions of behaviors in the architectural model**
- 590 elements are evaluated against the **17 Quality Characteristic Categories (QCC)**, a total of **10,030 data points are present for the evaluation process**

Cameo Project Statistics	Count
Project Diagrams	197
All Diagrams	342
Project Elements	9303
All Elements	133473
Project Symbol Styles	7
All Symbol Styles	41

C2 Signaling Mission Thread

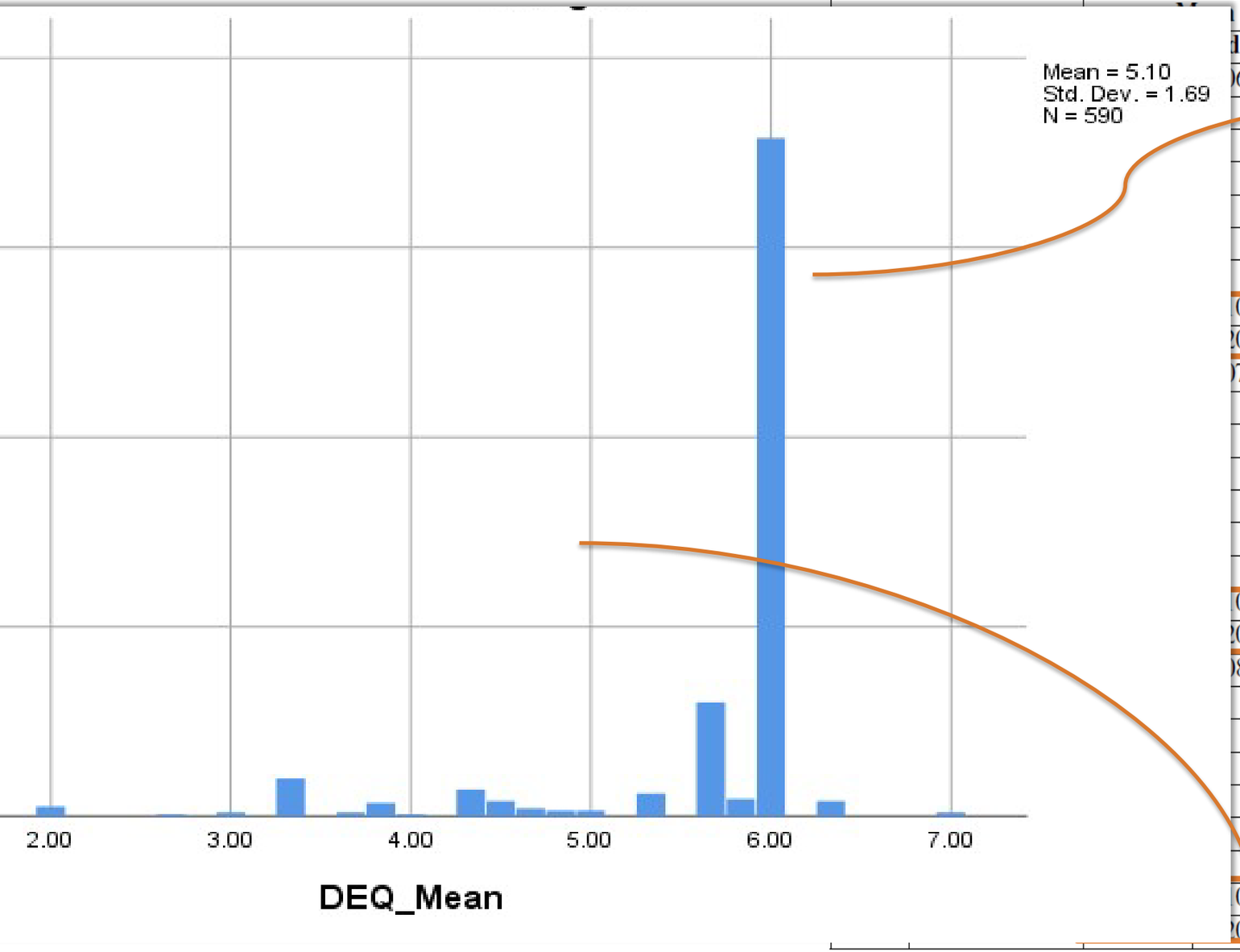
DoDAF CONOP View	Element Count
CV-1	13
CV-2	23
DIV-1	7
DIV-2	111
OV-1	7
OV-2	160
OV-5	46
SV-1	134
SV-4	89
Total	590

% View Makeup



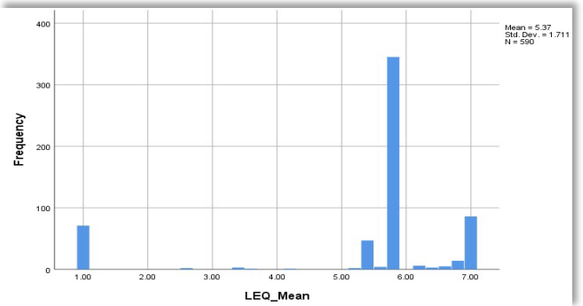
SAR Statistical Analysis - Descriptives, Skewness, and Kurtosis

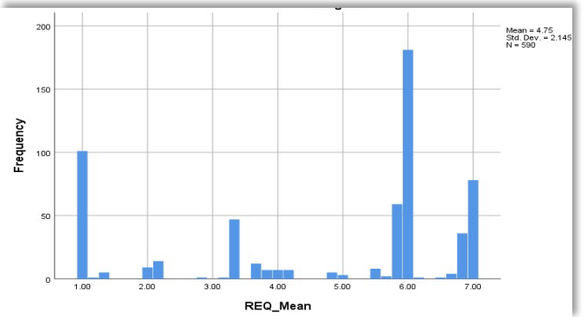
- Mean Vs Median



SAR Descriptives				
			Median	
		d. Error	Statistic	Std. Error
		06956	5.8890	0.8745
			7.0000	
			4.512	
			2.12411	
			1.00	
			7.00	
			6.00	
		01	-1.635	0.101
		201	0.946	0.201
		07042	6.2153	0.08279
			7.0000	
			4.044	
			2.01086	
			1.00	
			7.00	
			6.00	
		01	-2.195	0.101
		201	2.847	0.201
		08829	5.1932	0.10309
			7.0000	
			6.271	
			2.50415	
			1.00	
			7.00	
			6.00	
		01	-0.838	0.101
		201	-1.101	0.201

DEQ, LEQ and *REQ* Plot Data





SAR Statistical Analysis – Multicollinearity

- Multicollinearity is where two or more variables in the **SAR evaluation data set are highly linearly related**
- Each factor including a correlation coefficient and significance on for each observation was calculated to make a correlation determination [48]
- Multicollinearity needs to be addressed because the **standard errors of the coefficients for variables could cause false indicators and become non-significant or significant** [49]
- Analysis of the Variance Inflation Factors (VIF) values for each factor was used to determine elimination [49]
- Spearman's rho can both be positive and negative, with **the goal is to have a value between 0.1 and -0.1** [50]
- **Statistical significance does not always imply the strength of Spearman's correlation** between variables [51]
- Statistically significant Spearman correlation **indicates that there is less than a 5% chance that the strength of the association discovered occurred by coincidence** [51]

$$VIF_i = \frac{1}{1 - R_i^2}$$

Remaining

	Collinearity Statistics Tolerance	VIF
DEQ1	0.401	2.496
DEQ3	0.971	1.029
DEQ5	0.403	2.482
LEQ1	0.485	2.063
REQ5	0.485	2.061

Removed

Factors Eliminated due to VIF	
QCC Factor	VIF Value
DEQ2	17.143
DEQ4	11.052
DEQ6	16.504
LEQ2	38.105
LEQ3	39.008
LEQ4	54.958
LEQ5	60.373
REQ1	16.434
REQ2	28.595
REQ3	24.886
REQ4	22.476
REQ6	14.314

Spearman's Rho

$$\rho = 1 - \frac{6 \sum d_2^i}{n\left(n^2 - 1\right)}$$

SAR Statistical Analysis - Principal Component Analysis (PCA)

- Accurate evaluation of the data set represents the **purposeful sampling adequacy** for the SAR DoDAF CONOP architecture
- **KMO value** is considered on the lower end of the **suggested rating scale of 0.5 to 1.0** but adequate enough to proceed with the analysis [53] [54]

- Bartlett's Test of Sphericity showed that the **correlation matrix formed is not an identity matrix**
- When **it comes to statistical research**, where **extracted components often explain just 50% to 60% of the variance, the 70% to 80% of the variance approach may be unworkable** [57]
- No real adjustment is needed for the 50% to 60% of the variance, when the **total variance is achieved at 70.685% for a total of two factors**
- Oblique rotation or varimax rotation due to the **more realistic representation** for the data [55] [56]
- Evaluation of the **loadings aid in the identification of each component's characteristics in terms of the variables** [52]

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.546
Bartlett's Test of Sphericity	Approx. Chi-Square	994.027
	df	10
	Sig.	0.000

Total Variance Explained						
Comp	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.168	43.368	43.368	1.808	36.166	36.166
2	1.366	27.317	70.685	1.726	34.519	70.685
3	0.952	19.039	89.724			
4	0.286	5.727	95.451			
5	0.227	4.549	100.000			
Extraction Method: Principal Component Analysis.						

SAR Statistical Analysis – Ordinal Logistic Regression (OLR)

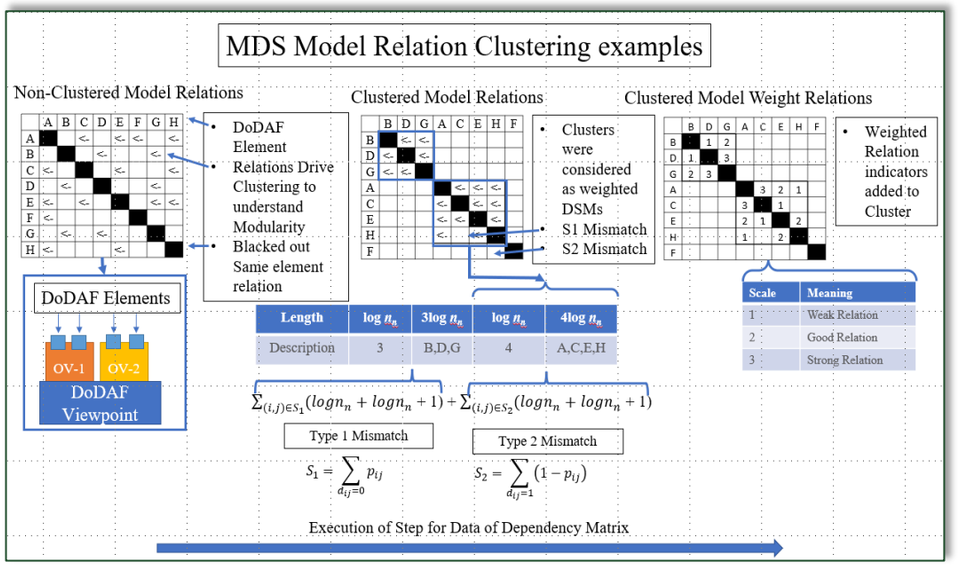
- ***DEQ1:*** The SAR model execution did not have a SysML termination to some of the *«ControlFlow»* functions.
  - Name were missing or improperly presented in **one case an element had a ";" semicolon as the** actual name element ID "_16_8beta_8f40297_1264755020203_887654_49788".
- ***DEQ3:*** Corresponding **descriptions were not always present** to tell what the element is representing for the architecture.
  - Without supporting documentation the terminology was lost or **redundant when names were used for two different stereotypes** on different diagrams.
- ***DEQ5:*** Several elements did not have instantiation for need in the architecture, this was consist **ratings presented "Neutral**".
  - The SV-4 specifically focused on the Command and Control signaling functionality for the SAR DoDAF CONOP and **had inconsistencies which were reflected in the correlation to DEQ 3.**
- ***LEQ1:*** Majority of elements presented most **elements with a "Strongly Disagree" and** had descriptions missing in nearly all SAR elements evaluated. LEQ 1 was also correlated to REQ 5 and was shown by significance in the correlation matrix
- ***REQ5:*** were DoDAF Element performance design attributes which allow the verification for a system design, not all elements had performance design attributes associated with them in the SAR architecture.
  - The element did have data that could be verified most of the element had string data type which presented as outside verification for the elements.
  - The element performance was not clear outside of the named data, What the data contained, structure, or measurement was not present.

Identify the Strength of effects

Location	DEQ1	1.014	0.093	118.118	1	0.000	0.831	1.197
	DEQ3	3.663	0.499	53.866	1	0.000	2.685	4.642
	DEQ5	1.315	0.099	175.668	1	0.000	1.121	1.510
	LEQ1	0.235	0.062	14.322	1	0.000	0.113	0.357
	REQ5	-0.292	0.055	28.025	1	0.000	-0.400	-0.184
Link function: Logit.								

SAR Degree of Modularity Determination

- ***DEQ2, 6*** and ***REQ1-6***: All of the elements evaluated had some form of relationship to the SAR DoDAF architecture being direct or indirect.
  - This means that **some degree of modularity is present**
  - ***DEQ6***: VIF calculated showed a value of 16.504
  - ***REQ1-6***: PCA and OLR analysis found key significance in the REQ criteria from the QCC for the SAR architecture
- The **pairwise weighting each item** with the rest of the group and give a preferential level to the item
- **If the model description is simple, the model description is short** [39]
  - **Many data mismatches would exist, and the mismatched data description would become longer** [39]
  - A **complicated model reduces the description of mismatched data, but the model description would be longer** [39]



Clustering Arrangements				
	n_c	cl_i	$\lvert S_1 \rvert$	$\lvert S_2 \rvert$
SAR Model	9	12, 12, 23, 40, 81, 157, 195, 236, 282	66120.45	11300.39

$$MDL = \frac{1}{3}\left(n_c log(n_n) + log(n_n)\sum_{i-1}^{n_c} cl_i w\right) + \frac{1}{3}S_1 + \frac{1}{3}S_2$$

	Description Length	Ratio
SAR CONOP Model	139.38	0.333
Type I Mismatch	13767.06	0.333
Type II Mismatch	2353.15	0.333
Total MDL	16259.59	

SAR Overall Results

- DEQ Findings:
  - **DEQ2 and DEQ6 Showed some degree of modularity** is present in the architecture.
  - **Unrelated elements on DoDAF Views**
  - The implications of **unjustified alternative behavior present** on the diagrams had no driving factor present.
  - Many elements had **missing description** difficulty understanding what elements were representing for the architecture was common place.
  - Several DEQ values the **had high VIF causing multicollinearity and** needed to be removed for PCA analysis.
- LEQ Findings:
  - Several **activities and other behaviors did not have proper termination** and would cause model execution problems and potential for rework development for the SAR system design.
  - Several **LEQ values had high correlation with other evaluation factors in DEQ and REQ**
  - In several **cases improper stereotypes were used and would only be felt during** compiled execution of a model activity.
- REQ Findings: Many of the element in the SAR DoDAF CONOP architecture **did not have a sufficient requirement element instantiation** with in the architecture.
  - The **Performance measurable values were not completely** specified directly impacts test verification.
  - **Not all elements had performance design attributes** associated with them and the DIV-1 was not complete strictly impacting overall ability to complete verification.
  - The **analysis showed that non consistent decomposition** from System to Sub-system in the architecture.
  - Analysis **found key significance in the REQ criteria from the QCC for the SAR architecture**.

SAR Rating was “Acceptable” to “Good” with sensitivity to *REQ* factors

- DEQ was yellow to green but very close to a value of 3.73 or "Good" rating
- The LEQ was a green score of a value of 3.91 but still a "Good" rating
- The REQ was a red score of 3.50 in a "Poor" to "Acceptable" rating
- The SAR Overall score is a 3.72 or "Acceptable" to "Good" rating

Overall Model Quality		
	Mean Value	Quality Score
DEQ	5.0992	3.73
LEQ	5.3702	3.91
REQ	4.7523	3.50
Total		3.72
Degree of Modulairty		
Model	139.38	
Type I	13767.06	
Type II	2353.15	
Total MDL	16259.59	

Recommendations and Reviews

Summary and Recommendations

- **DQCF presents an advantage to the industry and DoD in a new methodical approach** to quality within MBSE environment.
- However, despite the fact that there is no ideal technique for quality evaluation, the suggested approach demonstrated **promising ability to detect quality and model sensitivities to quality analysis**.
- In truth, basic scoring techniques have increased in favor primarily because they **are quick and straightforward to utilize** [68]
- By providing a **renewed focus on a quality-based system engineering process** when applying DoDAF, **improved trust in the system and data architecture** of the completed models can be achieved

The technical approach using the DQCF presents a unique opportunity for baseline understanding to be set for development with respect to quality and save money on development of DoD programs

Cost of Quality (CoQ) savings could be at minmum 15% or 81.315 Billion ~2576 years, 9 months, 7 days, and 20 hours

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Additional Publications and Efforts

Ph.D. Candidate Accomplishments

- Accomplishments
  - Certified Project Management Professional (PMP) (2020)
  - National Defense Industrial Association (NDIA) Modular Open System Architecture (MOSA) Architecture Committee
  - National Defense Industrial Association (NDIA) Systems Engineering Education and Training Committee
  - System Engineering Research Center (SERC) Contributing Author
  - Aerospace Industrial Association (AIA) Digital Engineering Acquisition Metrics Committee
  - Boeing MBSE Metric Community of Practice (CoP) Committee Chair
- Conferences and Publications
  - A. R. Miller, D. R. Herber. *'Digital Engineering Transformation of Requirements Analysis Within Model-Based Systems Engineering*.' In World Conference of the Society for Industrial and Systems Engineering, Sep 2021.
  - A. R. Miller, R. Scheurer. '*Functional Completeness and Stability',* Practical Software and Systems Measurement Continuous Iterative Development Measurement Specifications, Jan 2022.
  - Contributing Author: A. R. Miller, *'Digital Engineering Measurement Framework*.', System Engineering Research Center, March 2022
  - A. R. Miller, D. R. Herber. '*Applying Model-Based System Engineering in Search of Quality by Design for Architecture Analysis*.' Wiley System Engineering Journal, TBD, 2022
  - The research has led to five invention disclosures, three technical abstracts, three technical poster videos, and several training sessions in support of the author's role as a Sr. Digital Engineering Lead
- Professional Accomplishments (2001 to present)
  - Current: Lead Digital Engineer MWS Product Security, The Boeing Company
    - Lead Ground Based Mid-Course Defense (GMD) Cyber Architecture, System Integration and Test Readiness (SITR), and many others
  - Sr. System Engineer, Cummings Aerospace
  - Lead Threat Modeling Engineering, Allpoints LLC.
  - Sr. System Engineer, Modern Technology Solutions Inc. (MTSI)
  - General Engineer, Department of Defense (DoD) Missile Defense Agency (MDA)
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    - Mr. Moen serves as Sr. System Engineering Team Lead/Architecture Lead at the Boeing Company and helped provided case studies and technical guidance for the analysis within this work.
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  - Committee Members: Dr. Thomas Bradley, Ph. D., Dr. Erika Miller, Ph. D., Dr. Steve Simske, Ph. D., Dr. Azer P. Yalin, Ph. D.
  - Staff of System Engineering Department Colorado State University

Questions?

Thank you

Colorado State University

Reviewer Comments of Material - 3 Ph. D. Level Reviewers

- All comments have been addressed and submitted to Wiley System Engineering Jounal
- Overall Comments
  - **This is very well written and well referenced manuscript (Reviewer 1)**
  - **Overall, very thorough treatment of architectural assessment (Reviewer 1)**
  - **The methodology discussed is logically clear with sufficient technical details, especially the elements on quality factors and measurement reflected the authors' contribution (Reviewer 2)**
  - **Overall this is a great piece of work in the area of operational research (Reviewer 2)**
  - **The literature review conducted is comprehensive (Reviewer 2)**

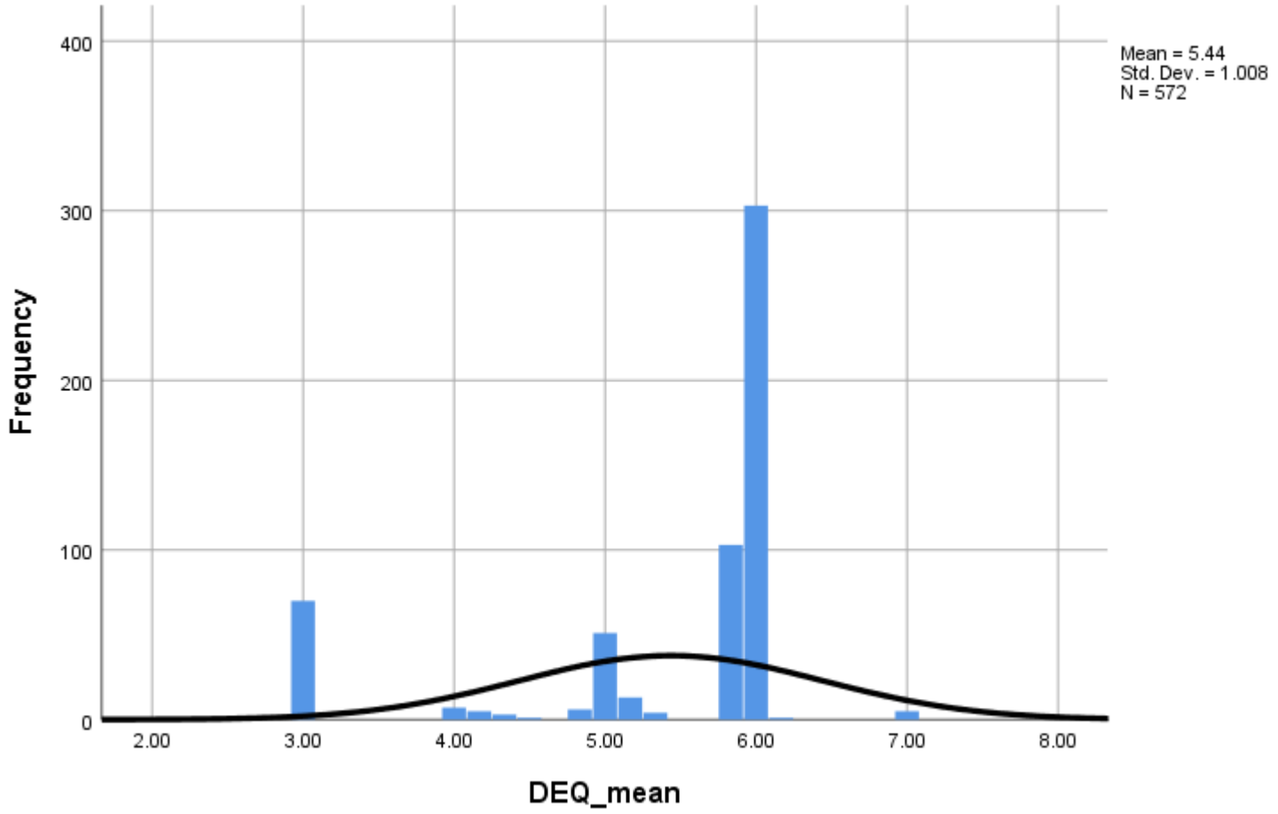
1. Is the rating how well a particular framework (now superseded by UAF) is implemented (Reviewer 3)
   - DoDAF, while still used, has been greatly deemphasized in policy as it once was when originally released (Reviewer 1)
   - While advancements have been made in the field of architecture development standards, DoDAF still leads both government and industry practice as the most widely mandated defense standard for U.S. government acquisition and continues to impact system descriptions. DoDAF was mandated in 2013 and has not been superseded [72].
2. 'Good' rating after applying the process, does this mean the design is solid or does it mean the model did not express a coherent design in terms of the DoDAF structure? What does it tell you about design risks? (Reviewer 3)
   - So one concern is the DQAP's assessment and linkage to "requirements", depending on the purpose of the architectural effort (Reviewer 1)
   - The REQ variable takes into account the SE methods of the DoDAF CONOP architecture and relates the element to requirement instantiation of the architecture in the model to understand how well requirements are met in the system solution [4]
   - It is common for the management of control risks to be implemented in order to guarantee that the result of business operations fits within a specified range [76]. Ultimately, the goal is to identify and address the sensitivity through possible mitigations presented with the variable quantifications.

Reviewer Comments of Material - 3 Ph. D. Level Reviewers Cont.

3. You state “Assess the degree of modularity based on these results—is the system considered more modular/less integrated or less modular/more integrated?” Please provide more context. (Reviewer 1)
   - Are you defining a new definition for modularity which is generally a structural attribute of a system? (Reviewer 1)
   - The degree of modularity assessment was used in order to grasp the functional reusability of the views and understand the complexity of the DoDAF architecture. In contrast, many data mismatches would exist, and the mismatched data description would become longer. A complicated model reduces the description of mismatched data, but the model description would be longer
4. Can one get a full picture of the quality of design for a mere 5% of the depictions? (Reviewer 1)
   - The Kaizer-Meyer-Olkin (KMO) addresses partial correlation between the variables [73]. The expectation is that the test should return values closer to 1.0 to 0.5 meaning the sample is adequate, less than 0.5 is considered problematic requiring further investigation[73][74].
5. Attempting to find precision on crude Likert assessments (low accuracy) correct? (Reviewer 1)
   - The reliability of the seven-point Likert scale has been shown empirically to have 90% approximate reliability and 89% approximate validity[75].

DEQ_mean

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3.00	70	12.2	12.2	12.2
	4.00	7	1.2	1.2	13.5
	4.17	5	.9	.9	14.3
	4.33	3	.5	.5	14.9
	4.50	1	.2	.2	15.0
	4.83	6	1.0	1.0	16.1
	5.00	51	8.9	8.9	25.0
	5.17	13	2.3	2.3	27.3
	5.33	4	.7	.7	28.0
	5.83	103	18.0	18.0	46.0
	6.00	303	53.0	53.0	99.0
	6.17	1	.2	.2	99.1
	7.00	5	.9	.9	100.0
	Total	572	100.0	100.0	

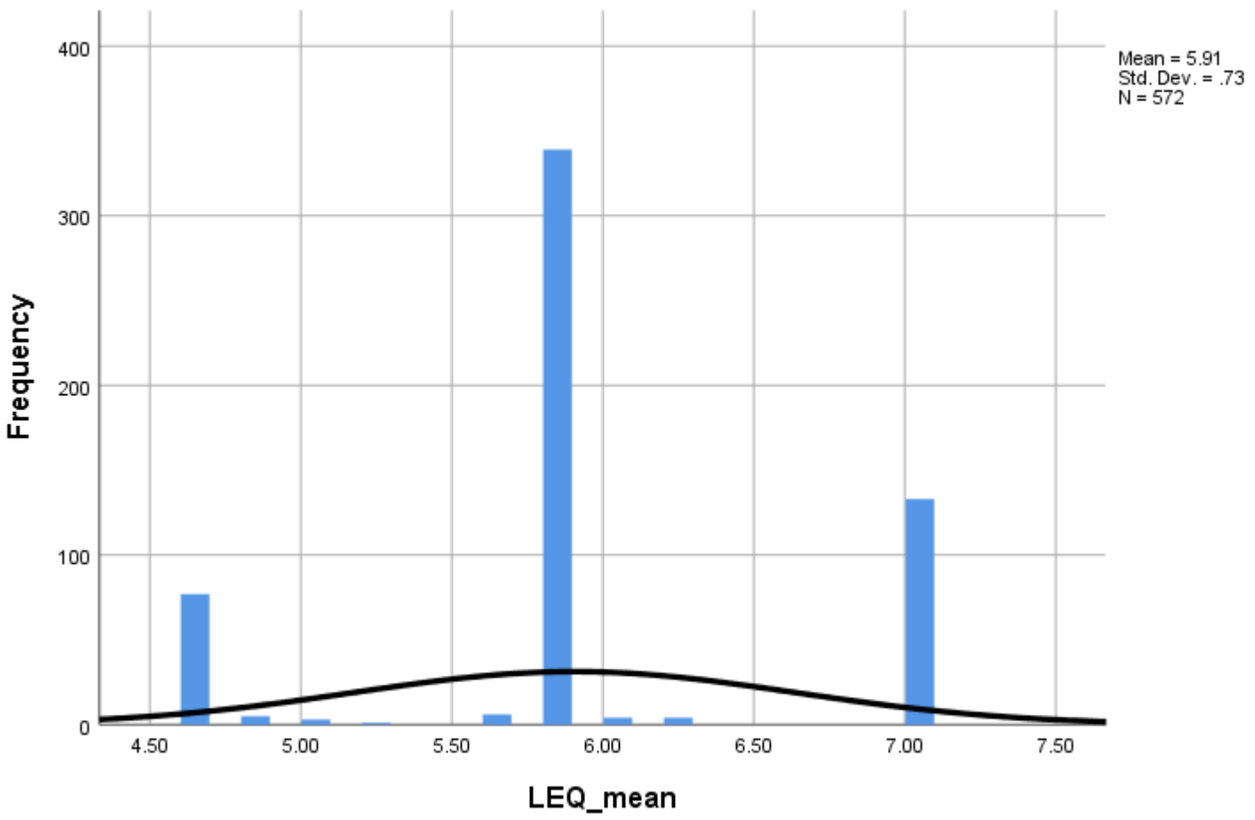


1= Strongly Disagree, 2=Disagree, 3=Somewhat Disagree, 4=Neutral, 5=Somewhat Agree, 6=Agree, 7=Strongly Agree

Back

LEQ_mean

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	4.60	77	13.5	13.5	13.5
	4.80	5	.9	.9	14.3
	5.00	3	.5	.5	14.9
	5.20	1	.2	.2	15.0
	5.60	6	1.0	1.0	16.1
	5.80	339	59.3	59.3	75.3
	6.00	4	.7	.7	76.0
	6.20	4	.7	.7	76.7
	7.00	133	23.3	23.3	100.0
	Total	572	100.0	100.0	

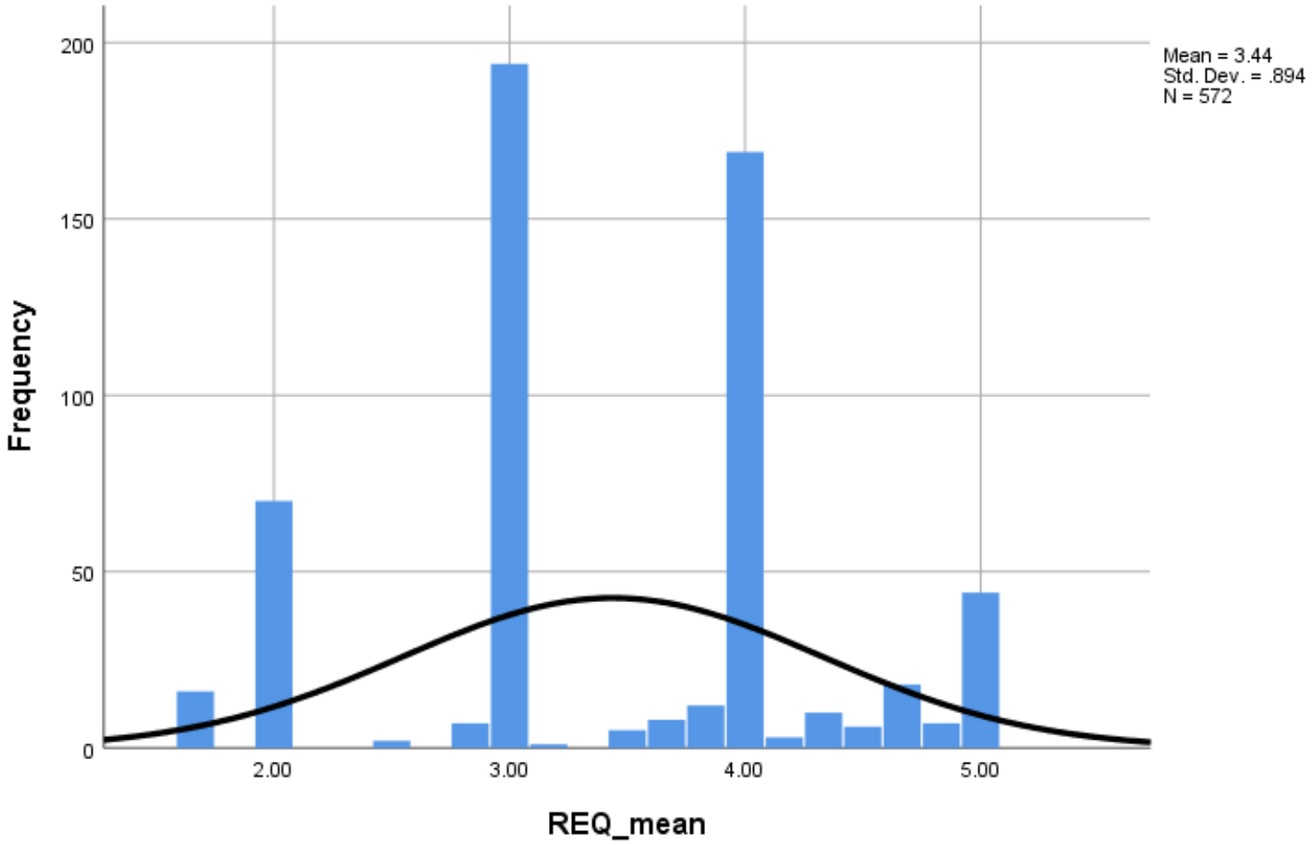


1= Strongly Disagree, 2=Disagree, 3=Somewhat Disagree, 4=Neutral, 5=Somewhat Agree, 6=Agree, 7=Strongly Agree

Back

REQ_mean

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.67	16	2.8	2.8	2.8
	2.00	70	12.2	12.2	15.0
	2.50	2	.3	.3	15.4
	2.83	7	1.2	1.2	16.6
	3.00	194	33.9	33.9	50.5
	3.17	1	.2	.2	50.7
	3.50	5	.9	.9	51.6
	3.67	8	1.4	1.4	53.0
	3.83	12	2.1	2.1	55.1
	4.00	169	29.5	29.5	84.6
	4.17	3	.5	.5	85.1
	4.33	10	1.7	1.7	86.9
	4.50	6	1.0	1.0	87.9
	4.67	18	3.1	3.1	91.1
	4.83	7	1.2	1.2	92.3
	5.00	44	7.7	7.7	100.0
	Total	572	100.0	100.0	



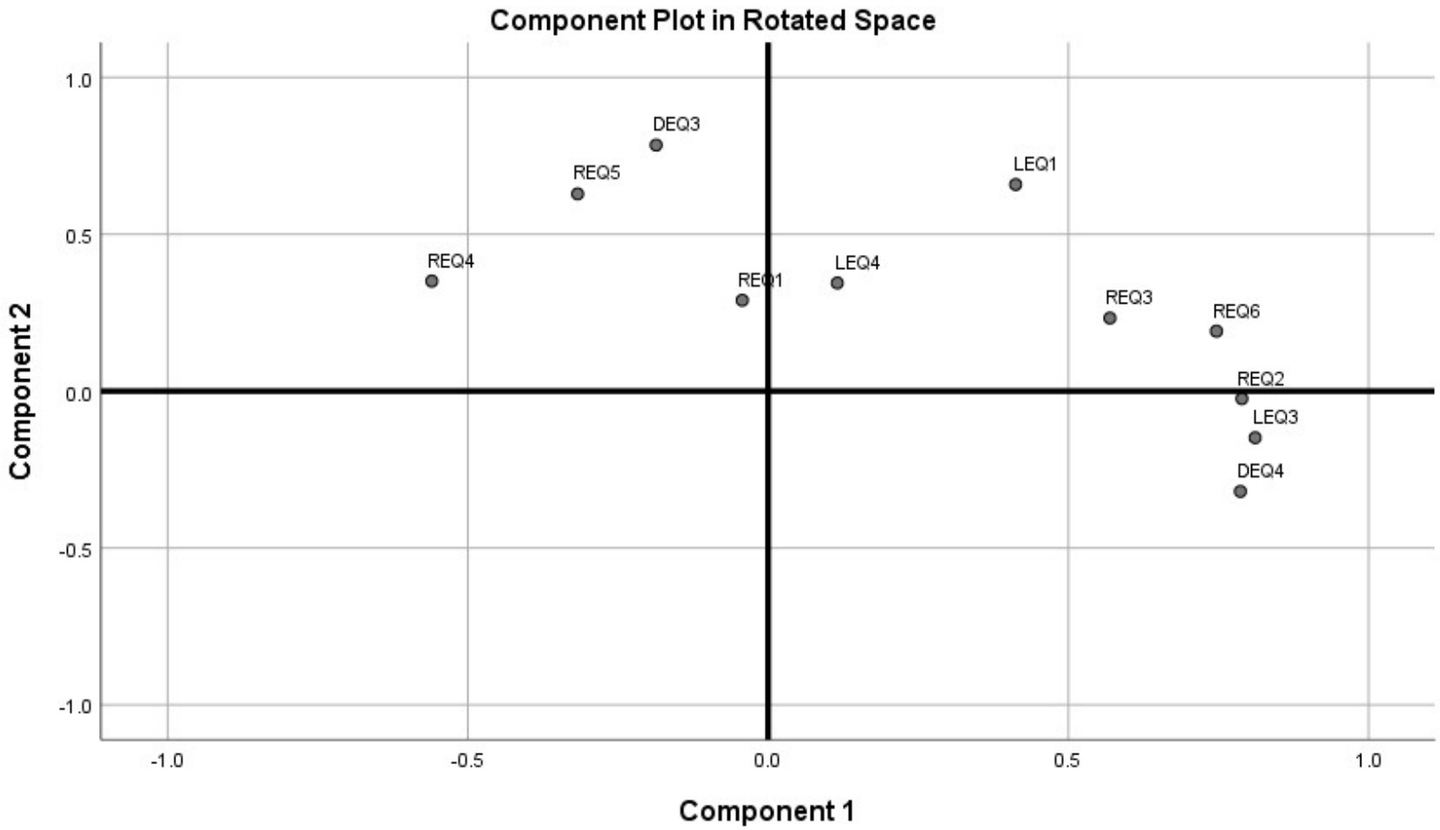
1= Strongly Disagree, 2=Disagree, 3=Somewhat Disagree, 4=Neutral, 5=Somewhat Agree, 6=Agree, 7=Strongly Agree

Back

	DEQ3	DEQ4	LEQ1	LEQ3	LEQ4	REQ1	REQ2	REQ3	REQ4	REQ5	REQ6
DEQ3		-0.420	0.363	-0.160	0.066	0.240	-0.269	-0.200	0.212	0.421	0.104
DEQ4	-0.420		0.061	0.670	-0.130	0.071	0.635	0.395	-0.396	-0.530	0.574
LEQ1	0.363	0.061		0.076	0.130	0.100	0.137	0.579	-0.197	0.119	0.204
LEQ3	-0.160	0.670	0.076		-0.087	0.048	0.593	0.265	-0.513	-0.341	0.616
LEQ4	0.066	-0.130	0.130	-0.087		0.026	0.385	0.145	0.170	0.069	-0.075
REQ1	0.240	0.071	0.100	0.048	0.026		-0.210	-0.079	0.153	-0.038	0.041
REQ2	-0.269	0.635	0.137	0.593	0.385	-0.210		0.335	-0.489	-0.374	0.544
REQ3	-0.200	0.395	0.579	0.265	0.145	-0.079	0.335		-0.024	-0.209	0.227
REQ4	0.212	-0.396	-0.197	-0.513	0.170	0.153	-0.489	-0.024		0.405	-0.251
REQ5	0.421	-0.530	0.119	-0.341	0.069	-0.038	-0.374	-0.209	0.405		0.108
REQ6	0.104	0.574	0.204	0.616	-0.075	0.041	0.544	0.227	-0.251	0.108	

Back

Total Variance Explained						
Comp	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.500	31.817	31.817	2.908	26.437	26.437
2	1.899	17.260	49.077	1.934	17.585	44.022
3	1.413	12.842	61.920	1.640	14.906	58.928
4	1.217	11.066	72.986	1.348	12.257	71.185
5	1.047	9.521	82.507	1.245	11.321	82.507
6	0.839	7.625	90.132			
7	0.414	3.761	93.893			
8	0.299	2.719	96.612			
9	0.183	1.665	98.277			
10	0.103	0.938	99.214			
11	0.086	0.786	100.000			

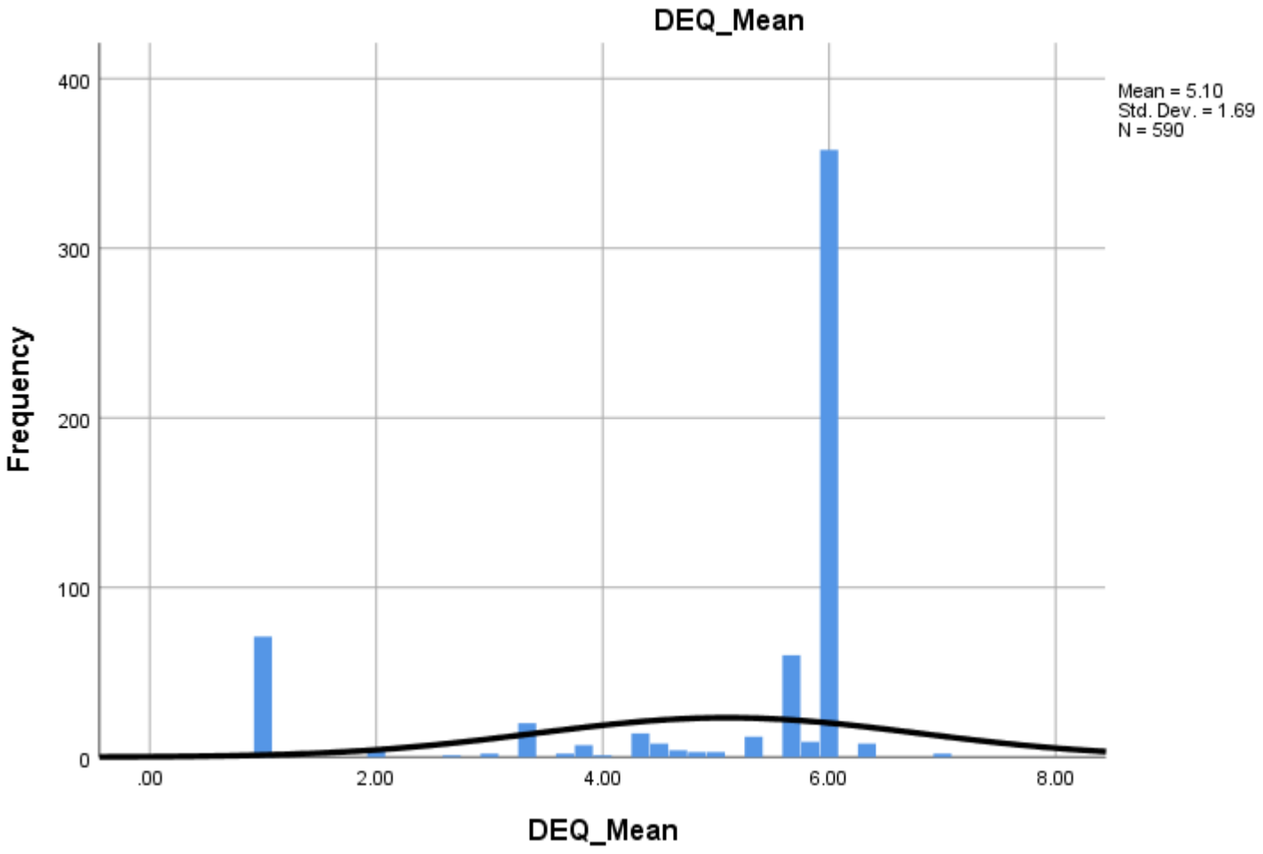


Component Matrix-a		
	Component	
	1	2
DEQ3	-0.187	0.784
DEQ4	0.786	-0.320
LEQ1	0.412	0.658
LEQ3	0.811	-0.149
LEQ4	0.115	0.344
REQ1	-0.043	0.290
REQ2	0.789	-0.024
REQ3	0.569	0.233
REQ4	-0.560	0.351
REQ5	-0.317	0.629
REQ6	0.747	0.191
Extraction Method: Principal Component Analysis. Rotation Method: Varimax		
a. Rotation converged in 3 iterations.		

Back

DEQ_Mean

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	71	12.0	12.0	12.0
	2.00	5	.8	.8	12.9
	2.67	1	.2	.2	13.1
	3.00	2	.3	.3	13.4
	3.33	20	3.4	3.4	16.8
	3.67	2	.3	.3	17.1
	3.83	7	1.2	1.2	18.3
	4.00	1	.2	.2	18.5
	4.33	14	2.4	2.4	20.8
	4.50	8	1.4	1.4	22.2
	4.67	4	.7	.7	22.9
	4.83	3	.5	.5	23.4
	5.00	3	.5	.5	23.9
	5.33	12	2.0	2.0	25.9
	5.67	60	10.2	10.2	36.1
	5.83	9	1.5	1.5	37.6
	6.00	358	60.7	60.7	98.3
	6.33	8	1.4	1.4	99.7
	7.00	2	.3	.3	100.0
	Total	590	100.0	100.0	

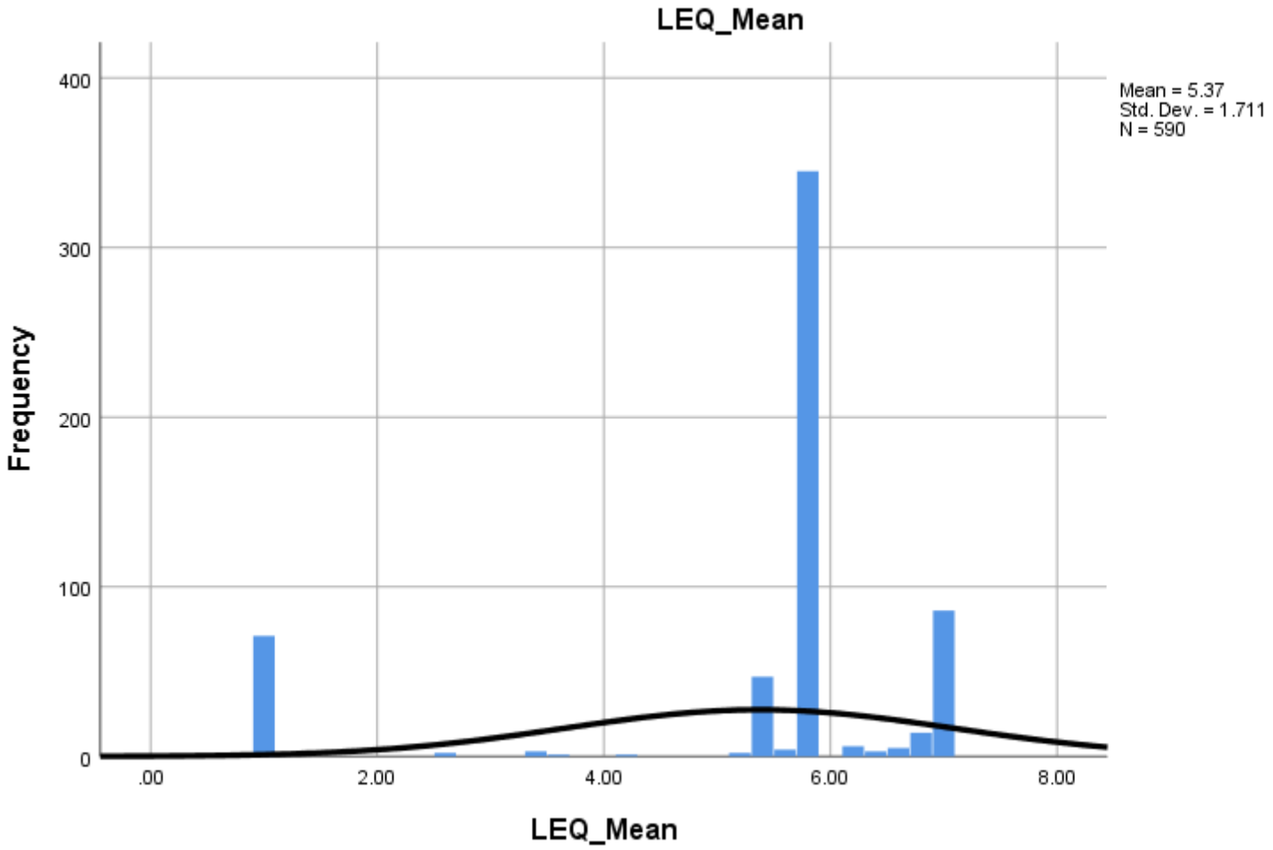


1= Strongly Disagree, 2=Disagree, 3=Somewhat Disagree, 4=Neutral, 5=Somewhat Agree, 6=Agree, 7=Strongly Agree

Back

LEQ_Mean

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	71	12.0	12.0	12.0
	2.60	2	.3	.3	12.4
	3.40	3	.5	.5	12.9
	3.60	1	.2	.2	13.1
	4.20	1	.2	.2	13.2
	5.20	2	.3	.3	13.6
	5.40	47	8.0	8.0	21.5
	5.60	4	.7	.7	22.2
	5.80	345	58.5	58.5	80.7
	6.20	6	1.0	1.0	81.7
	6.40	3	.5	.5	82.2
	6.60	5	.8	.8	83.1
	6.80	14	2.4	2.4	85.4
	7.00	86	14.6	14.6	100.0
	Total	590	100.0	100.0	

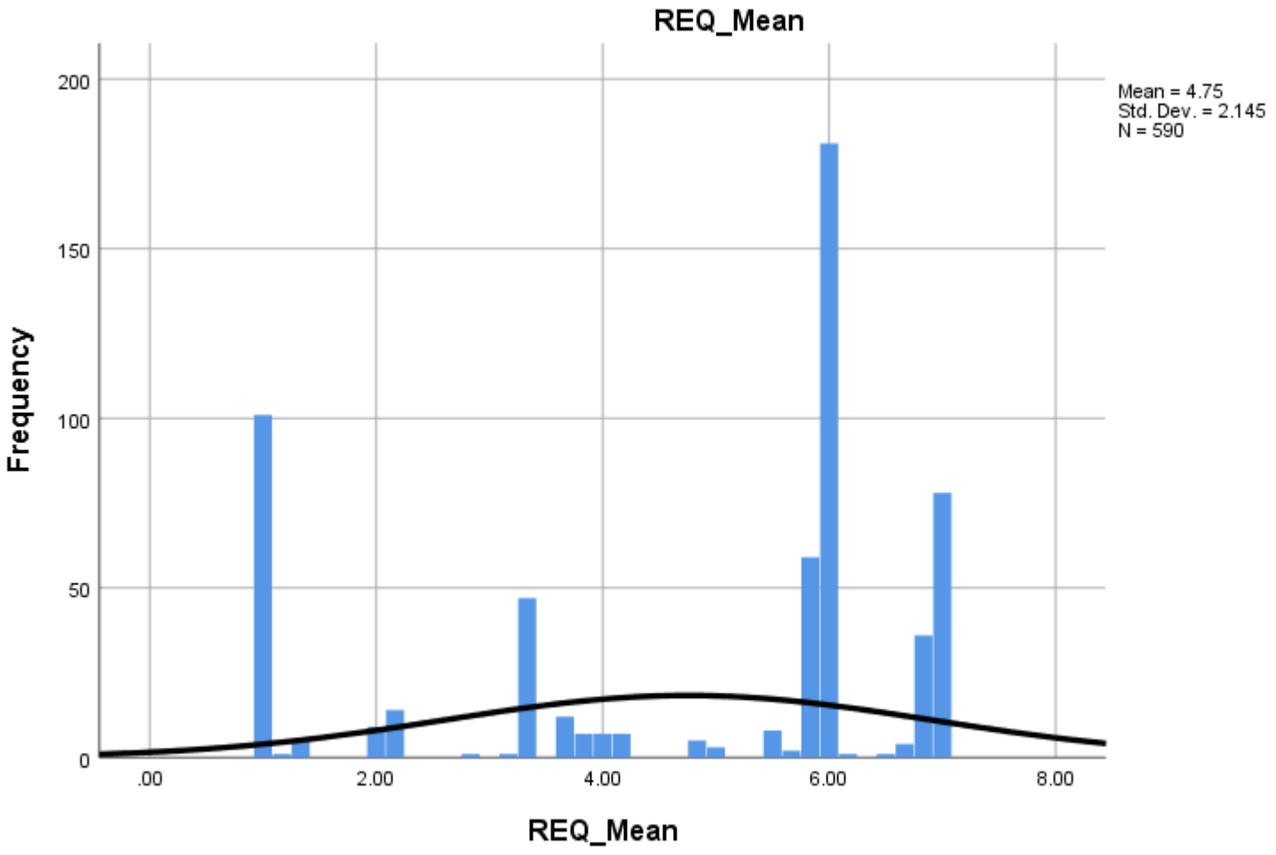


1= Strongly Disagree, 2=Disagree, 3=Somewhat Disagree, 4=Neutral, 5=Somewhat Agree, 6=Agree, 7=Strongly Agree

Back

REQ_Mean

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	101	17.1	17.1	17.1
	1.17	1	.2	.2	17.3
	1.33	5	.8	.8	18.1
	2.00	9	1.5	1.5	19.7
	2.17	14	2.4	2.4	22.0
	2.83	1	.2	.2	22.2
	3.17	1	.2	.2	22.4
	3.33	47	8.0	8.0	30.3
	3.67	12	2.0	2.0	32.4
	3.83	7	1.2	1.2	33.6
	4.00	7	1.2	1.2	34.7
	4.17	7	1.2	1.2	35.9
	4.83	5	.8	.8	36.8
	5.00	3	.5	.5	37.3
	5.50	8	1.4	1.4	38.6
	5.67	2	.3	.3	39.0
	5.83	59	10.0	10.0	49.0
	6.00	181	30.7	30.7	79.7
	6.17	1	.2	.2	79.8
	6.50	1	.2	.2	80.0
	6.67	4	.7	.7	80.7
	6.83	36	6.1	6.1	86.8
	7.00	78	13.2	13.2	100.0
	Total	590	100.0	100.0	

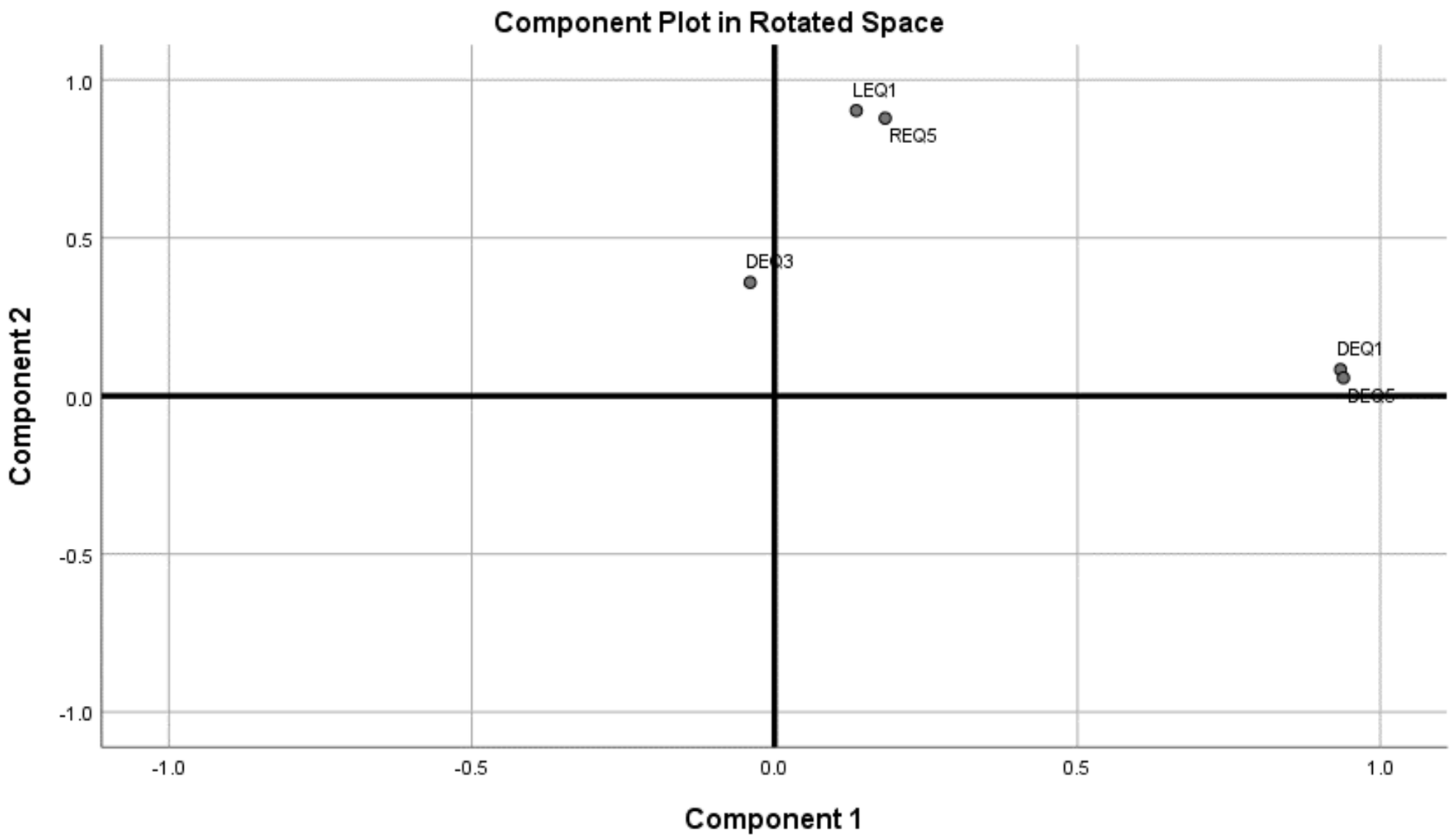


1= Strongly Disagree, 2=Disagree, 3=Somewhat Disagree, 4=Neutral, 5=Somewhat Agree, 6=Agree, 7=Strongly Agree

Back

	DEQ1	DEQ3	DEQ5	LEQ1	REQ5
DEQ1		0.062	0.782	0.199	0.224
DEQ3	0.062		0.019	0.228	0.123
DEQ5	0.782	0.019		0.123	0.162
LEQ1	0.199	0.228	0.123		0.692
REQ5	0.224	0.123	0.162	0.692	

Back



Component Matrix-a		
	Component	
	1	2
DEQ1	0.934	0.083
DEQ5	-0.040	0.359
REQ5	0.939	0.057
LEQ1	0.135	0.903
DEQ3	0.135	0.878
Extraction Method: Principal Component Analysis. Rotation Method: Varimax		
a. Rotation converged in 3 iterations.		

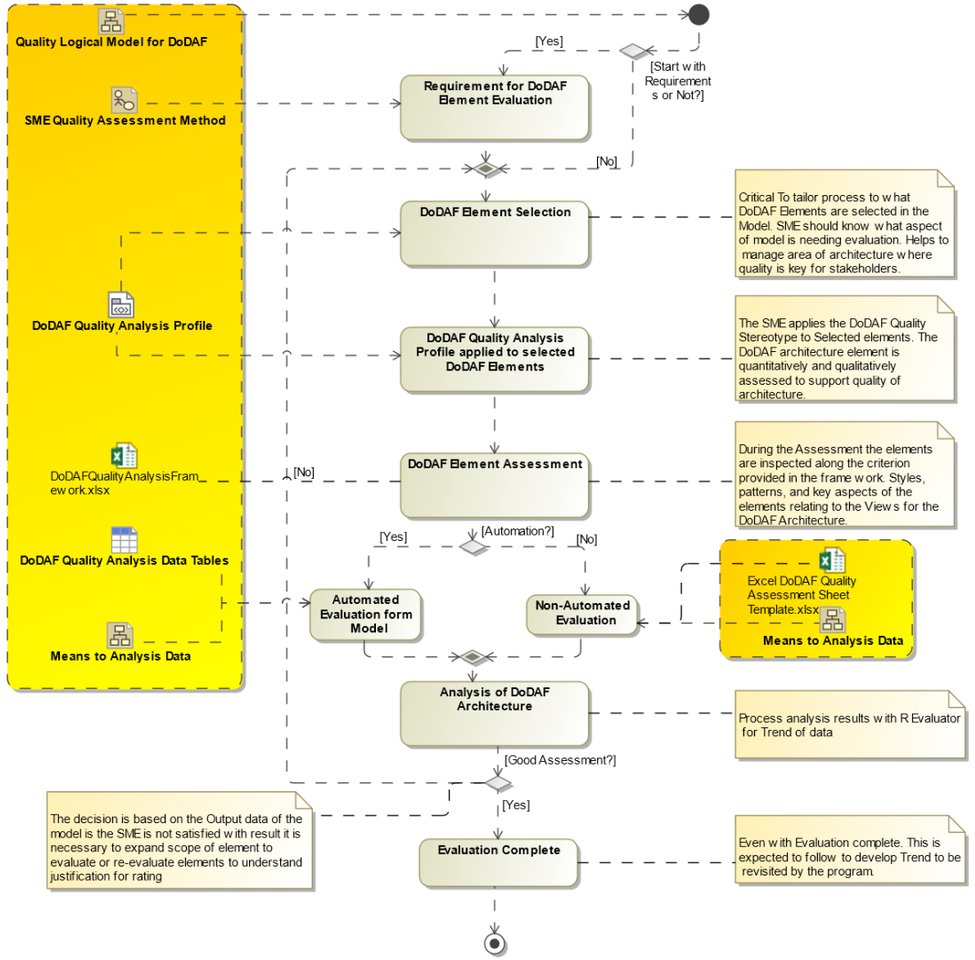
Back

act [Activity] DoDAF Quality Assessment [DoDAF Quality Assessment]

DoDAF Quality Framework Execution activity

The below Activity shows the execution of the key step to application of the framework. The process can be both automated through the use of Cameo Developed Plugin or Manual through the use of Excel. The R code can be executed on both Cameo plugin Data and Manual created data. Manual process my take longer.

Orange indicates Data Areas of Framework and Applicability to the Flow process.



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Element Assessment

Back

Element Assessment Data

Content Diagram DoDAF Quality Analysis Data Tables [DoDAF Quality Analysis Data Tables]

DASSAULT SYSTEMES

DoDAF Quality View Application Understanding Within Model

CAMEO ENTERPRISE ARCHITECTURE
UPDM / DODAF / MODAF / SYSML / BPMN / SOAML

DoDAF Quality View Stereotype Applied Stereotype Indicator

«DoDAF Quality View»
«OperationalActivity»
Find Victim

DoDAF Quality View Stereotype Applied Icon Indicator

Orange Block indicate instruction about Applied DoDAF Quality View Stereotype

Tags

Profile: <ALL>

Property: REQ6 : Quality Attribute Ranking

- «Activity»
  - activityPerformableUnderCondition
- «DoDAF Quality View»
  - DEQ1 = 4
  - DEQ2 = 2
  - DEQ3 = 5
  - DEQ4 = 2
  - DEQ5 = 3
  - DEQ6 = 5
  - LEQ1 = 5
  - LEQ2 = 4
  - LEQ3 = 3
  - LEQ4 = 2
  - LEQ5 = 5
  - REQ1 = 4
  - REQ2 = 5
  - REQ3 = 4
  - REQ4 = 5
  - REQ5 = 6
  - REQ6 = 4

Value: 4

Likert Applied Data for Evaluation

Find Victim

Properties: All

Supported By Resource	Maritime Rescue Unit [Systems Viewpoint::SV-1]
Used Classifier	
Observation	
Owning Template Parameter	
Partition	
Conforms To	
Owner	OV-5 [Operational Viewpoint]
Applied Stereotype	DoDAF Quality View [Element] [DoDAF Quality Analy OperationalActivity [Activity] [UAF::Operational::Prc
Active Hyperlink	
Applied Stereotype Instance	: DoDAF Quality Analysis Profile and Templates::...
Owned Comment	
Owned Element	: DoDAF Quality Analysis Profile and Templates::Mo
Image	
To Do	
Qualified Name	Operational Viewpoint::OV-5::Find Victim
Is Read Only	false
Is Single Execution	false

Identified Applied Stereotype from DQAP

Unique ID for Element | Name of Element | Qualified Path | Likert Evaluation of Element

#	Element ID	Name	Qualified Name	DEQ1	DEQ2	DEQ3	DEQ4	DEQ5	DEQ6	LEQ1
1	_16_5beta1_8f40297_1232616548301_796563_6555	Find Victim	Operational Viewpoint::OV-5::Find Victim	4	2	5	2	3	5	5

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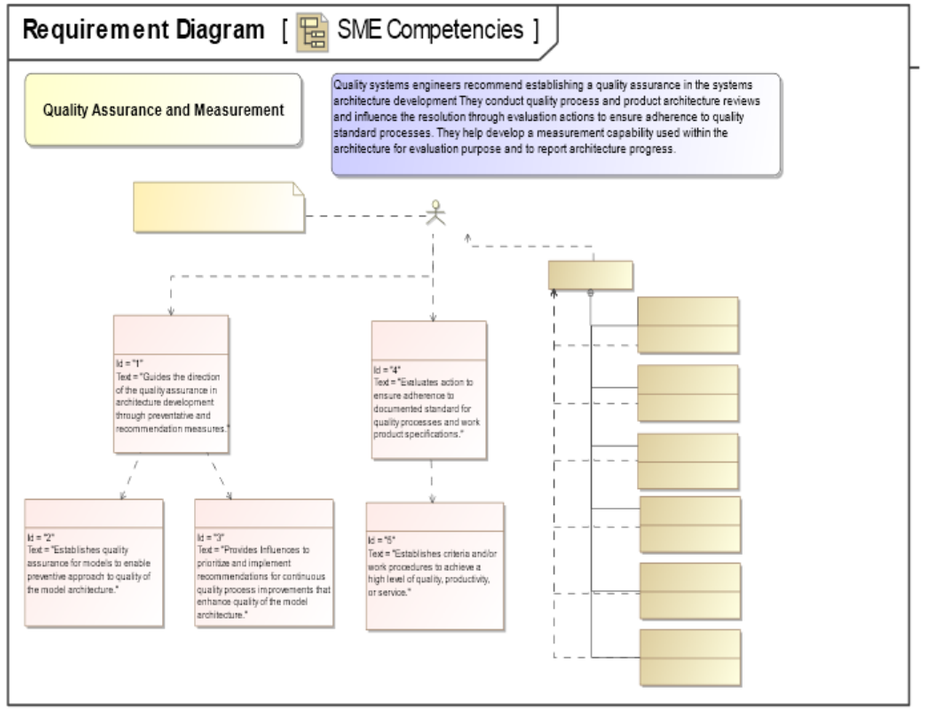
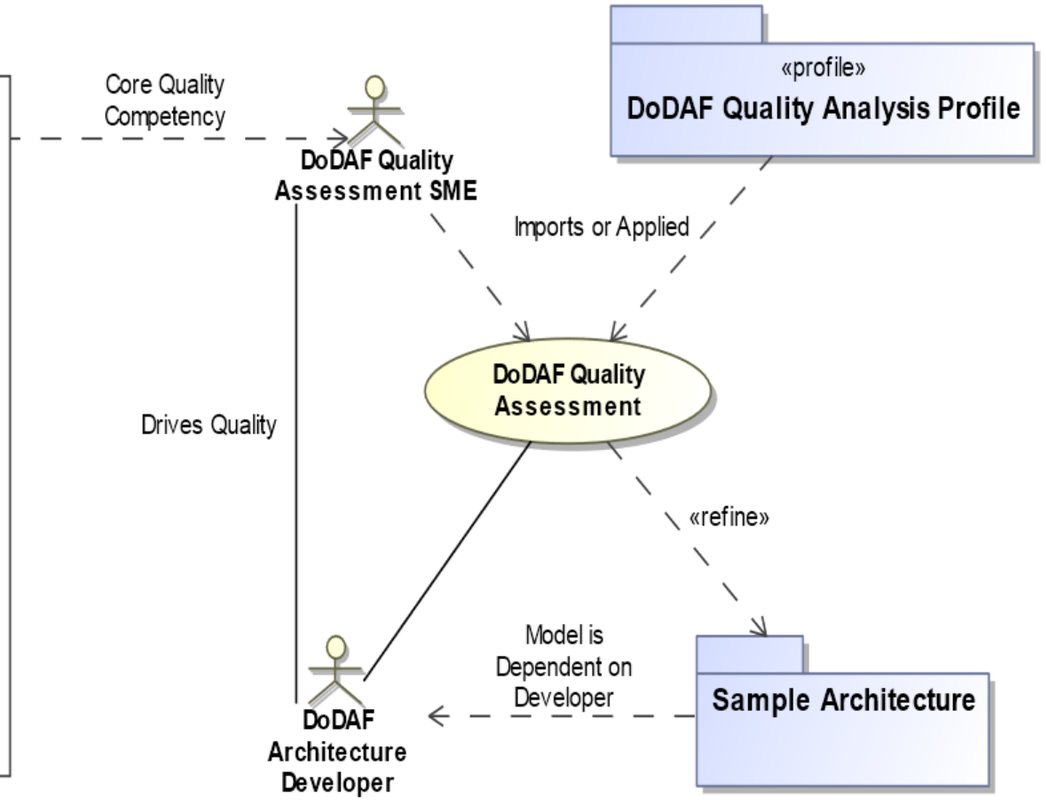
uc [Package] SME Quality Assessment Method [SME Quality Assessment Method]

Quality System Engineering Competency Understanding to Apply DoDAF Quality Analysis Profile For Model Assessment



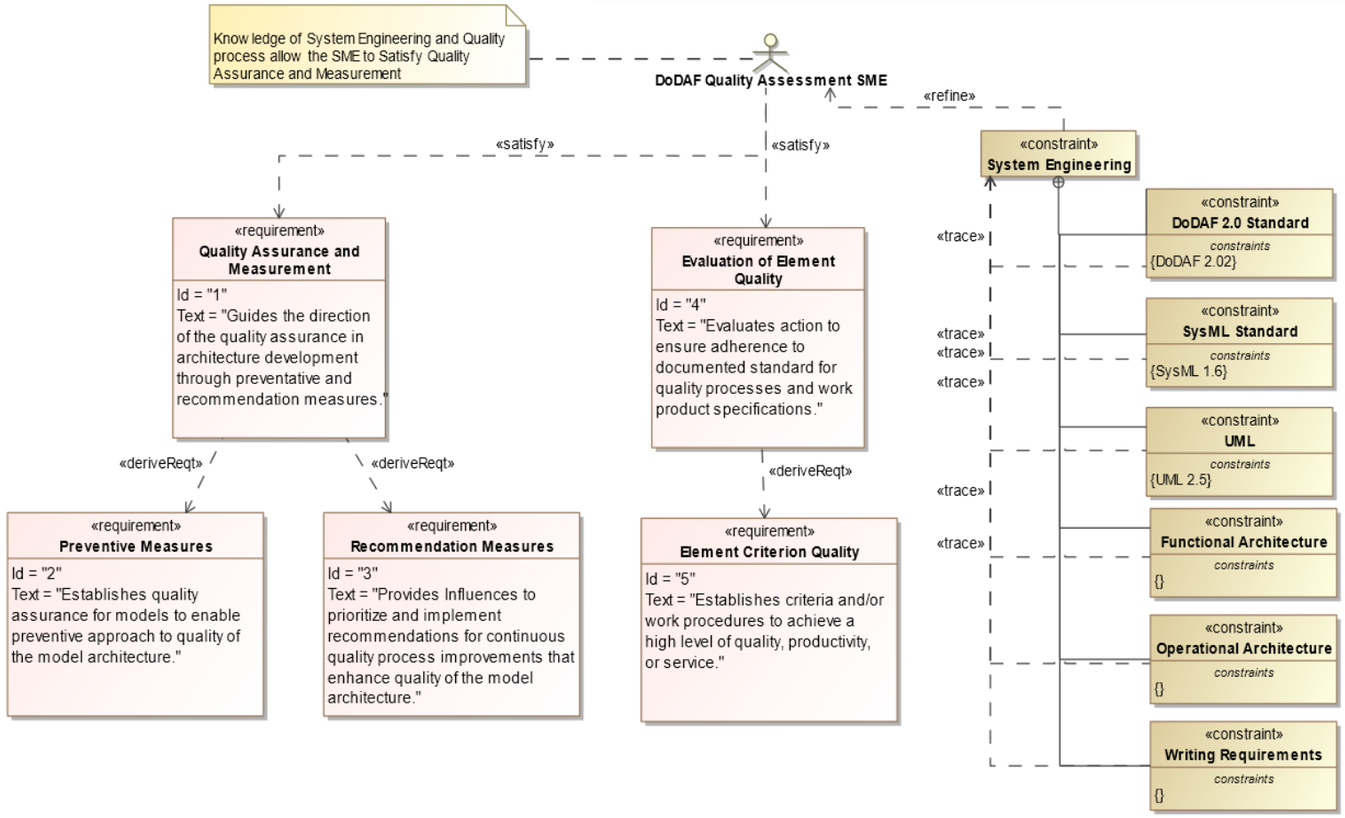
Click



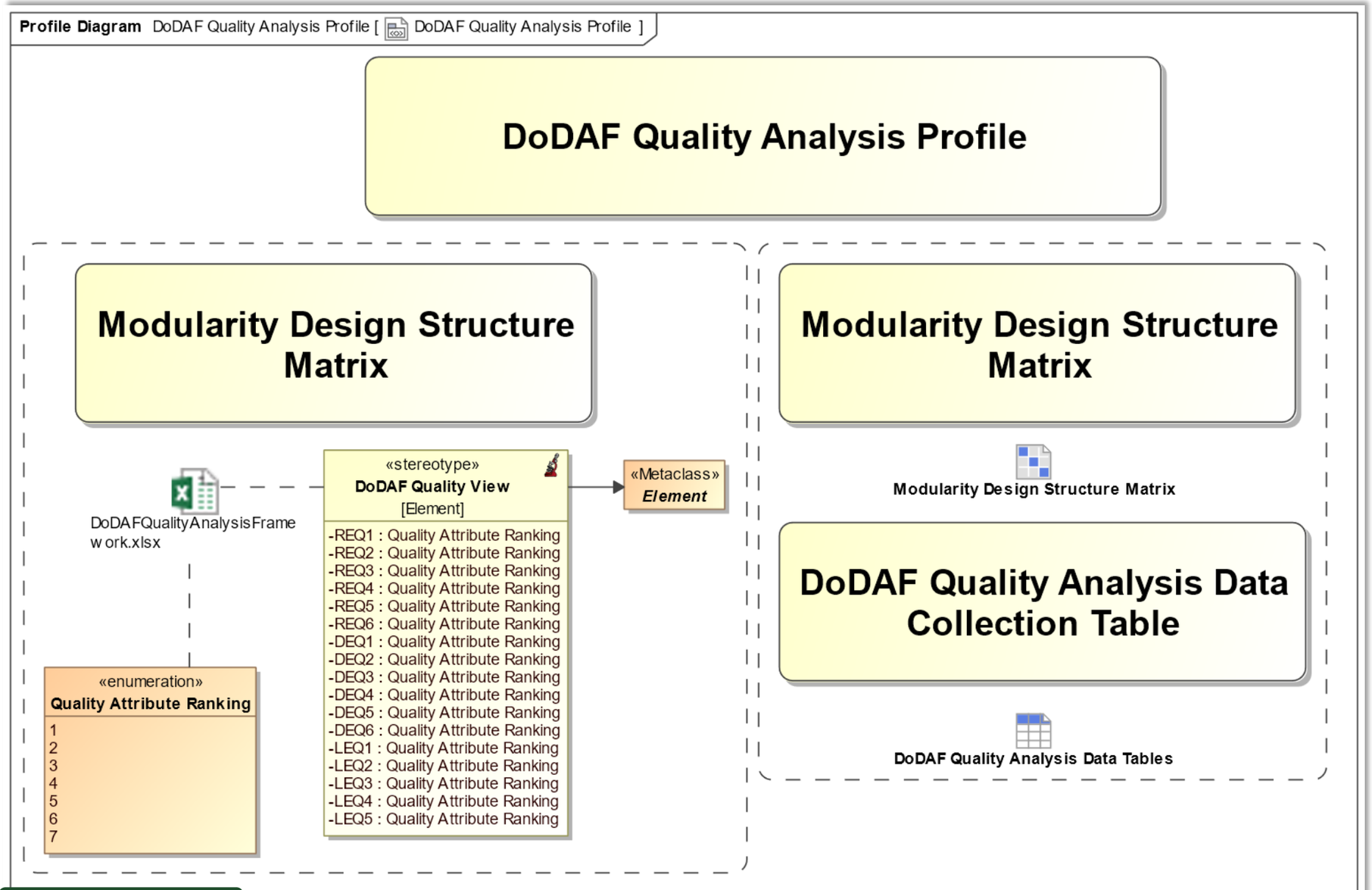
req [Package] SME Competencies [SME Competencies]

Quality Assurance and Measurement

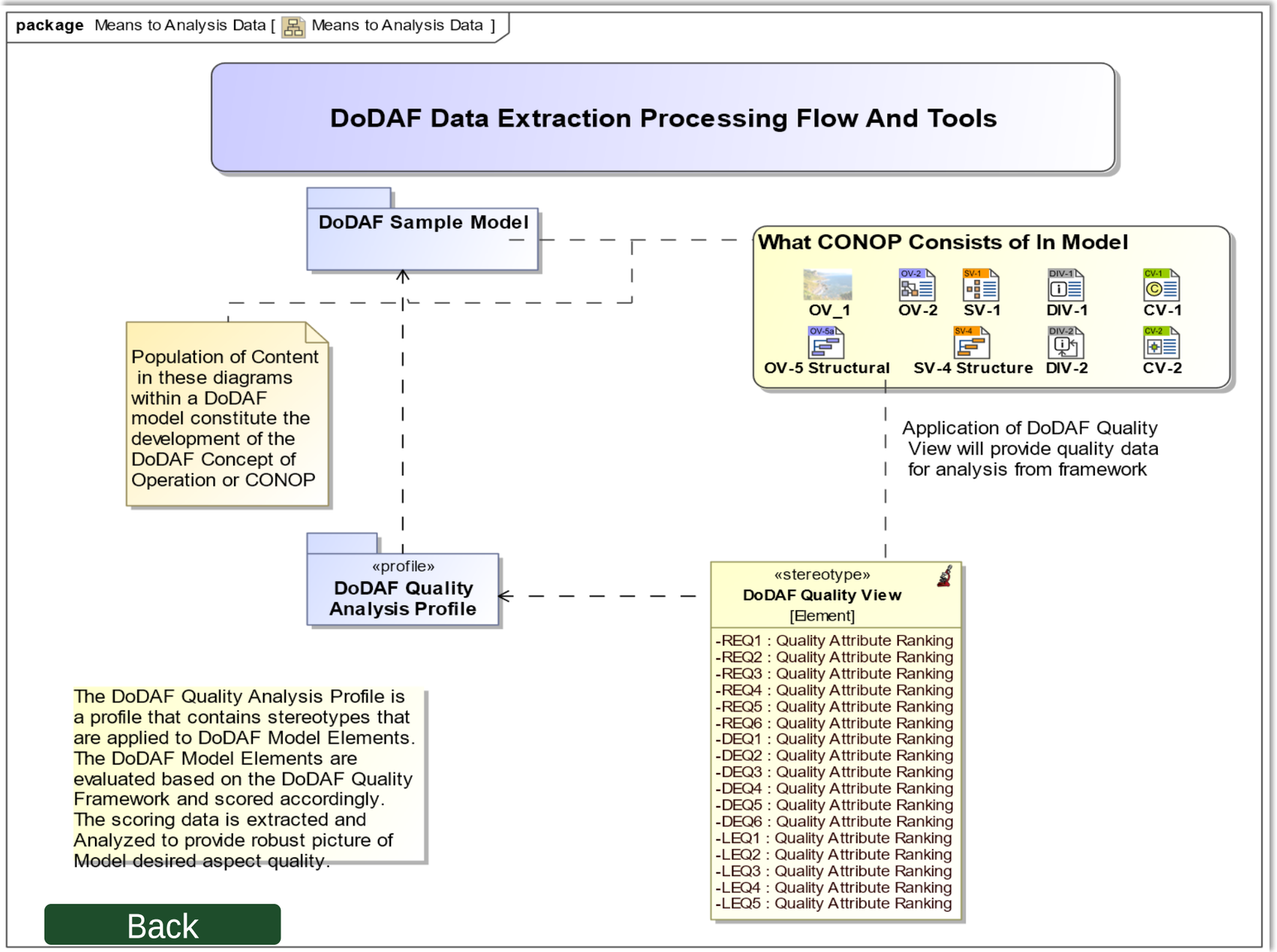
Quality systems engineers recommend establishing a quality assurance in the systems architecture development They conduct quality process and product architecture reviews and influence the resolution through evaluation actions to ensure adherence to quality standard processes. They help develop a measurement capability used within the architecture for evaluation purpose and to report architecture progress.

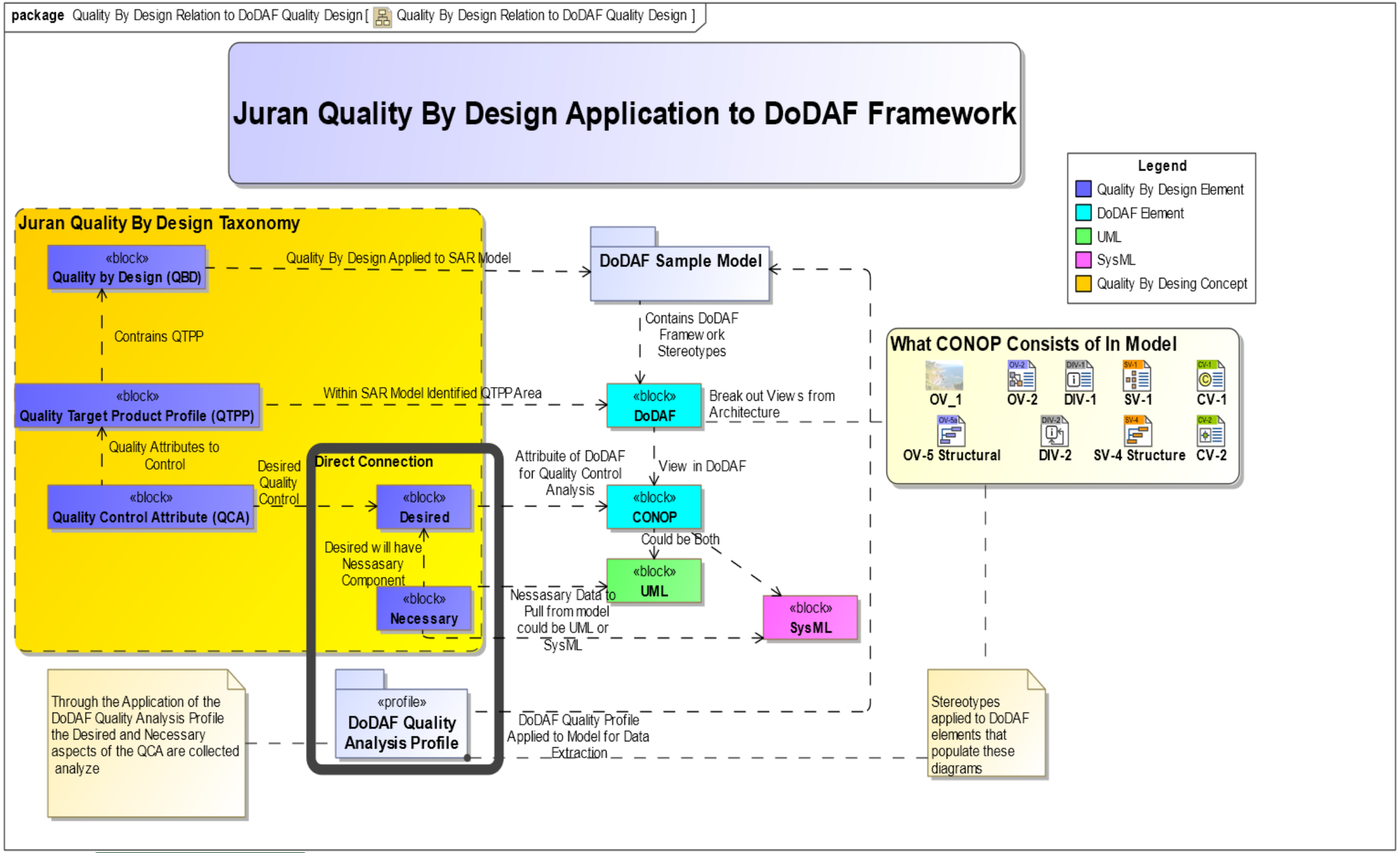


Back


Profile Diagram DoDAF Quality Analysis Profile [DoDAF Quality Analysis Profile]
DoDAF Quality Analysis Profile
Modularity Design Structure Matrix
DoDAFQualityAnalysisFrame
w ork.xlsx
«stereotype»
DoDAF Quality View
[Element]
-REQ1 : Quality Attribute Ranking
-REQ2 : Quality Attribute Ranking
-REQ3 : Quality Attribute Ranking
-REQ4 : Quality Attribute Ranking
-REQ5 : Quality Attribute Ranking
-REQ6 : Quality Attribute Ranking
-DEQ1 : Quality Attribute Ranking
-DEQ2 : Quality Attribute Ranking
-DEQ3 : Quality Attribute Ranking
-DEQ4 : Quality Attribute Ranking
-DEQ5 : Quality Attribute Ranking
-DEQ6 : Quality Attribute Ranking
-LEQ1 : Quality Attribute Ranking
-LEQ2 : Quality Attribute Ranking
-LEQ3 : Quality Attribute Ranking
-LEQ4 : Quality Attribute Ranking
-LEQ5 : Quality Attribute Ranking
«Metaclass»
Element
«enumeration»
Quality Attribute Ranking
1
2
3
4
5
6
7
Modularity Design Structure Matrix
Modularity Design Structure Matrix
DoDAF Quality Analysis Data Collection Table
DoDAF Quality Analysis Data Tables

Back


package Means to Analysis Data [Means to Analysis Data]
DoDAF Data Extraction Processing Flow And Tools
DoDAF Sample Model
What CONOP Consists of In Model
OV_1
OV-2
SV-1
DIV-1
CV-1
OV-5 Structural
SV-4 Structure
DIV-2
CV-2
Population of Content in these diagrams within a DoDAF model constitute the development of the DoDAF Concept of Operation or CONOP
Application of DoDAF Quality View will provide quality data for analysis from framework
«profile»
DoDAF Quality Analysis Profile
«stereotype»
DoDAF Quality View
[Element]
-REQ1 : Quality Attribute Ranking
-REQ2 : Quality Attribute Ranking
-REQ3 : Quality Attribute Ranking
-REQ4 : Quality Attribute Ranking
-REQ5 : Quality Attribute Ranking
-REQ6 : Quality Attribute Ranking
-DEQ1 : Quality Attribute Ranking
-DEQ2 : Quality Attribute Ranking
-DEQ3 : Quality Attribute Ranking
-DEQ4 : Quality Attribute Ranking
-DEQ5 : Quality Attribute Ranking
-DEQ6 : Quality Attribute Ranking
-LEQ1 : Quality Attribute Ranking
-LEQ2 : Quality Attribute Ranking
-LEQ3 : Quality Attribute Ranking
-LEQ4 : Quality Attribute Ranking
-LEQ5 : Quality Attribute Ranking
The DoDAF Quality Analysis Profile is a profile that contains stereotypes that are applied to DoDAF Model Elements. The DoDAF Model Elements are evaluated based on the DoDAF Quality Framework and scored accordingly. The scoring data is extracted and Analyzed to provide robust picture of Model desired aspect quality.
Back


package Quality By Design Relation to DoDAF Quality Design [Quality By Design Relation to DoDAF Quality Design]
Juran Quality By Design Application to DoDAF Framework
Legend
Quality By Design Element
DoDAF Element
UML
SysML
Quality By Desing Concept
Juran Quality By Design Taxonomy
«block» Quality by Design (QBD)
Quality By Design Applied to SAR Model
DoDAF Sample Model
Contrains QTPP
Contains DoDAF Framework Stereotypes
«block» Quality Target Product Profile (QTPP)
Within SAR Model Identified QTPP Area
«block» DoDAF
Break out Views from Architecture
What CONOP Consists of In Model
OV_1
OV-2
DIV-1
SV-1
CV-1
OV-5 Structural
DIV-2
SV-4 Structure
CV-2
Quality Attributes to Control
Desired Quality Control
Direct Connection
Attribute of DoDAF for Quality Control Analysis
View in DoDAF
«block» Quality Control Attribute (QCA)
«block» Desired
«block» CONOP
Desired will have Nessasary Component
Could be Both
«block» UML
«block» Necessary
Nessasary Data to Pull from model could be UML or SysML
«block» SysML
Through the Application of the DoDAF Quality Analysis Profile the Desired and Necessary aspects of the QCA are collected analyze
«profile» DoDAF Quality Analysis Profile
DoDAF Quality Profile Applied to Model for Data Extraction
Stereotypes applied to DoDAF elements that populate these diagrams

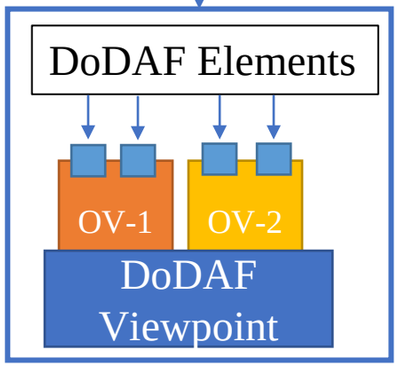
Back

MDS Model Relation Clustering examples

Non-Clustered Model Relations

	A	B	C	D	E	F	G	H
A	■		<-		<-	<-		<-
B		■		<-			<-	
C	<-		■		<-			<-
D		<-		■			<-	
E	<-		<-		■		<-	<-
F	<-					■		
G		<-		<-			■	
H	<-				<-			■

- DoDAF Element
- Relations Drive Clustering to understand Modularity
- Blacked out Same element relation



Clustered Model Relations

	B	D	G	A	C	E	H	F
B	■	<-	<-					
D	<-	■	<-					
G	<-	<-	■					
A				■	<-	<-	<-	
C				<-	■	<-	<-	
E				<-	<-	■	<-	
H				<-		<-	■	
F								■

- Clusters were considered as weighted DSMs
- S1 Mismatch
- S2 Mismatch

Clustered Model Weight Relations

	B	D	G	A	C	E	H	F
B	■	1	2					
D	1	■	3					
G	2	3	■					
A				■	3	2	1	
C				3	■	1		
E				2	1	■	2	
H				1		2	■	
F								■

- Weighted Relation indicators added to Cluster

Scale	Meaning
1	Weak Relation
2	Good Relation
3	Strong Relation

Length	$\log n_n$	$3\log n_n$	$\log n_n$	$4\log n_n$
Description	3	B,D,G	4	A,C,E,H

$$\sum_{(i,j)\in S_1}(logn_n + logn_n + 1) + \sum_{(i,j)\in S_2}(logn_n + logn_n + 1)$$

Type 1 Mismatch

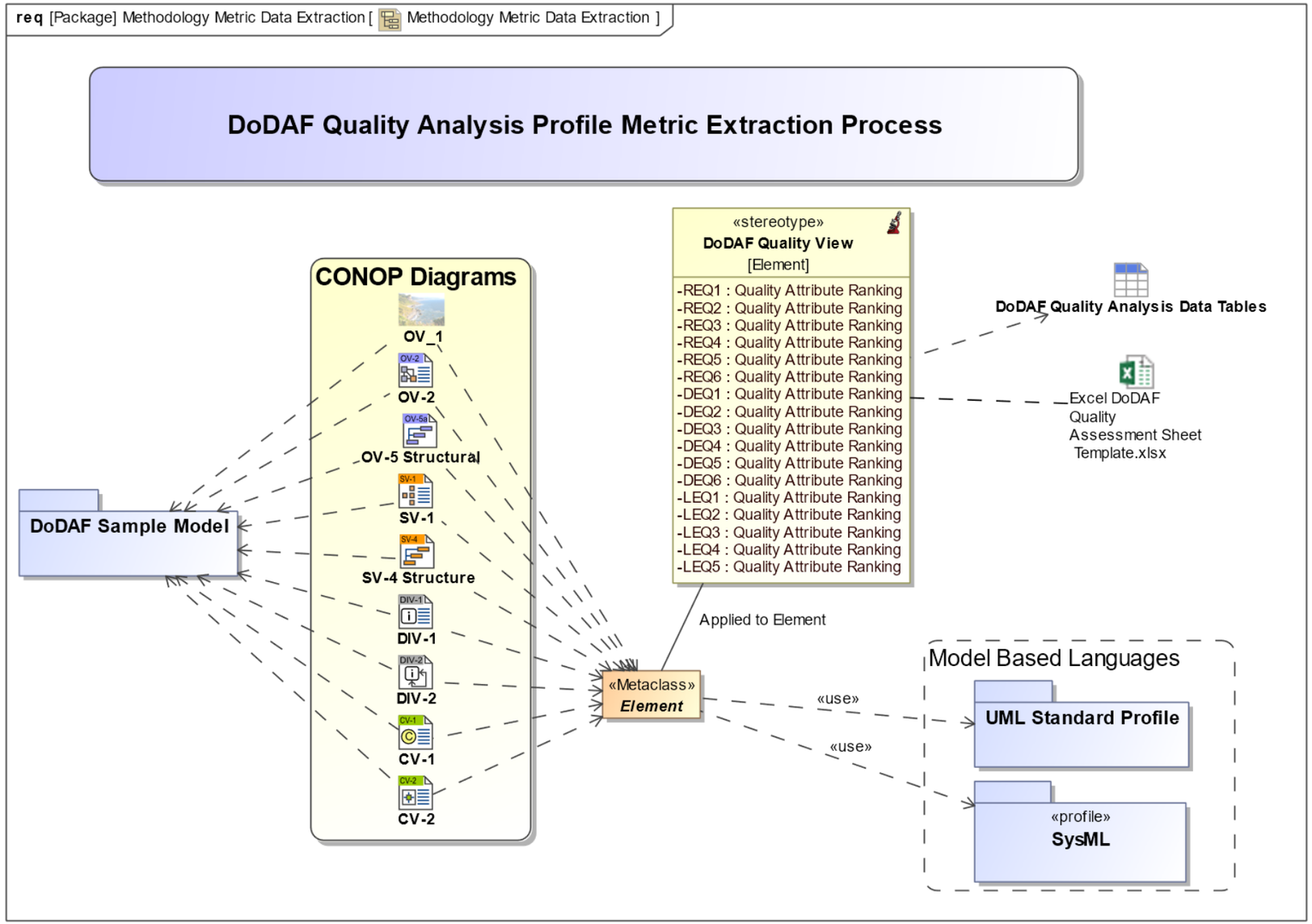
$$S_1 = \sum_{d_{ij}=0} p_{ij}$$

Type 2 Mismatch

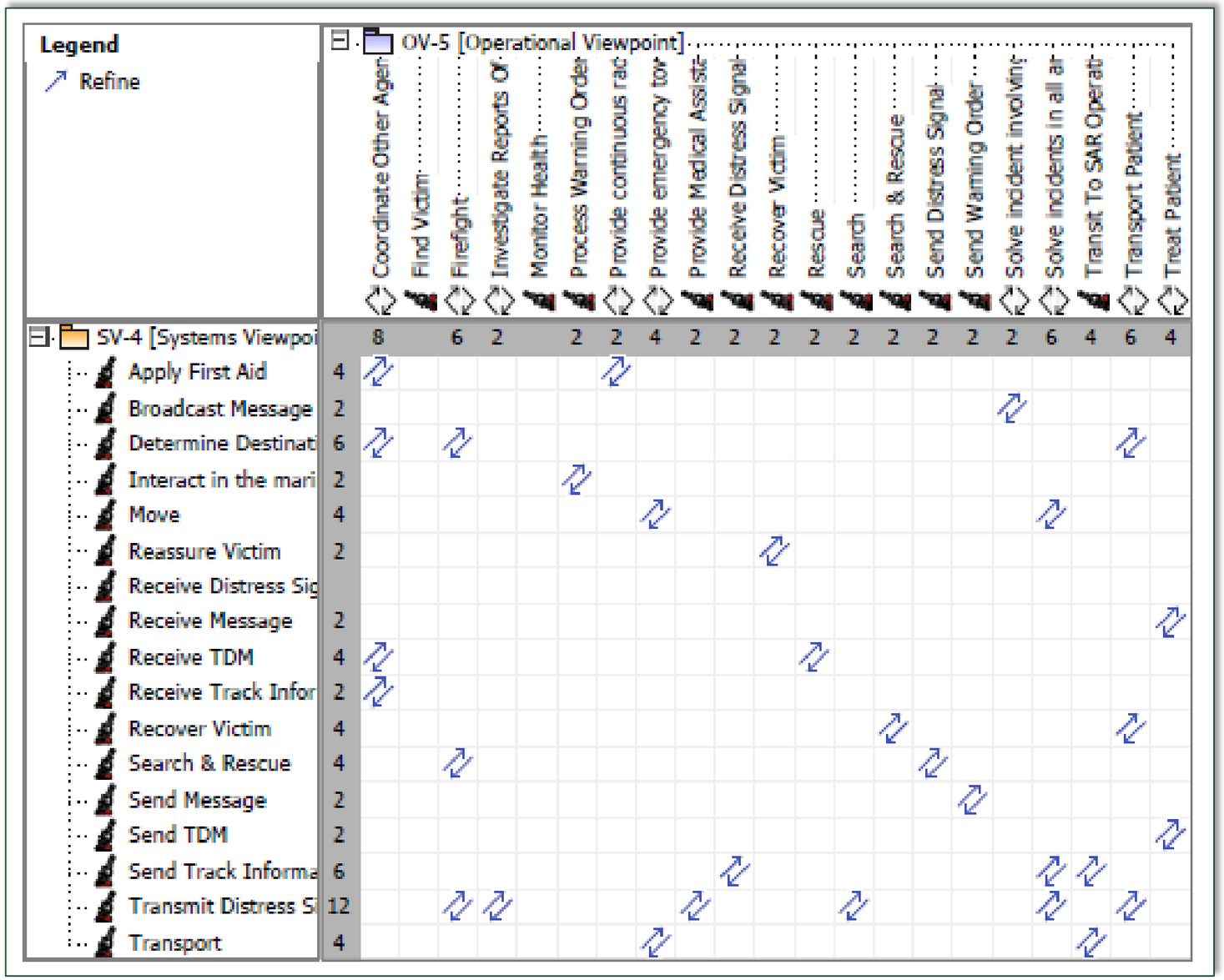
$$S_2 = \sum_{d_{ij}=1} (1 - p_{ij})$$

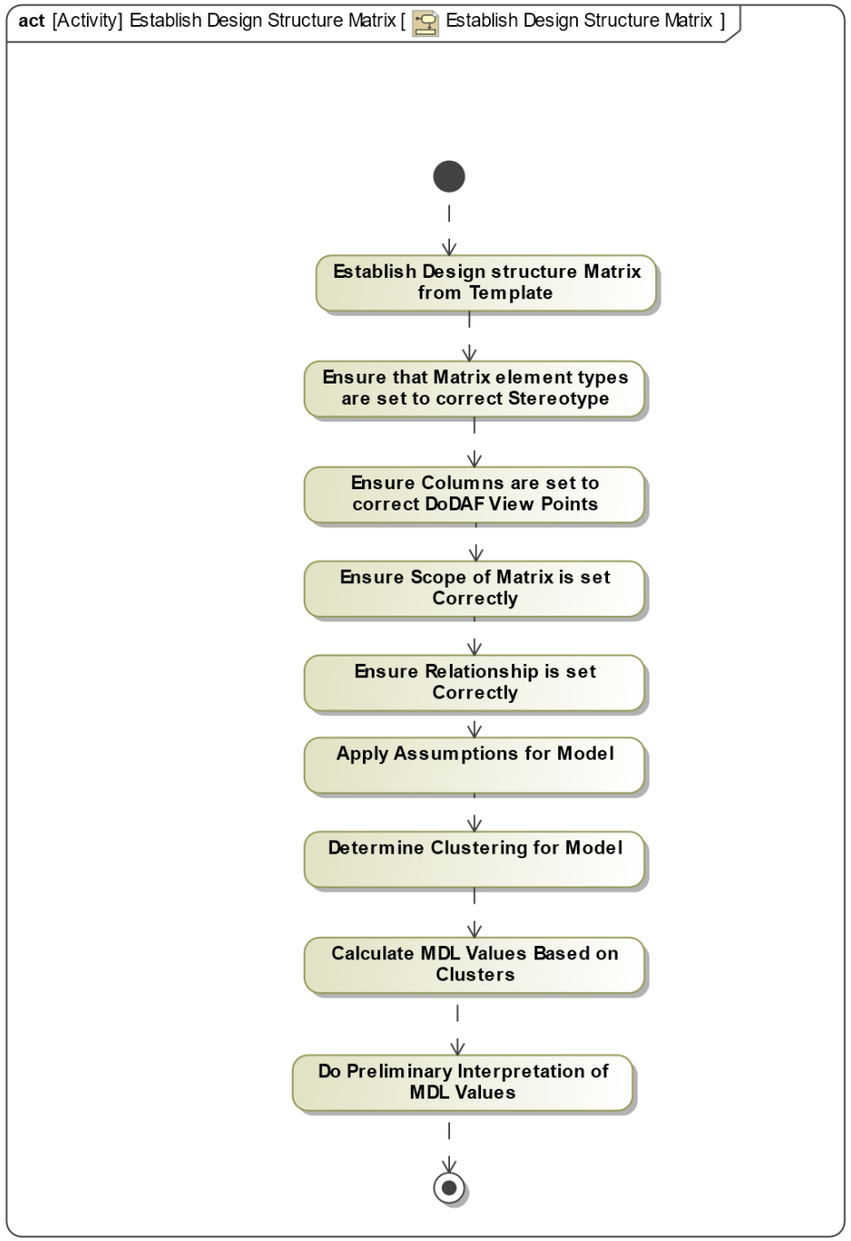
Execution of Step for Data of Dependency Matrix

Back


req [Package] Methodology Metric Data Extraction [Methodology Metric Data Extraction]
DoDAF Quality Analysis Profile Metric Extraction Process
CONOP Diagrams
OV_1
OV-2
OV-5 Structural
SV-1
SV-4 Structure
DIV-1
DIV-2
CV-1
CV-2
DoDAF Sample Model
«stereotype»
DoDAF Quality View
[Element]
-REQ1 : Quality Attribute Ranking
-REQ2 : Quality Attribute Ranking
-REQ3 : Quality Attribute Ranking
-REQ4 : Quality Attribute Ranking
-REQ5 : Quality Attribute Ranking
-REQ6 : Quality Attribute Ranking
-DEQ1 : Quality Attribute Ranking
-DEQ2 : Quality Attribute Ranking
-DEQ3 : Quality Attribute Ranking
-DEQ4 : Quality Attribute Ranking
-DEQ5 : Quality Attribute Ranking
-DEQ6 : Quality Attribute Ranking
-LEQ1 : Quality Attribute Ranking
-LEQ2 : Quality Attribute Ranking
-LEQ3 : Quality Attribute Ranking
-LEQ4 : Quality Attribute Ranking
-LEQ5 : Quality Attribute Ranking
DoDAF Quality Analysis Data Tables
Excel DoDAF Quality Assessment Sheet Template.xlsx
Applied to Element
«Metaclass»
Element
«use»
«use»
Model Based Languages
UML Standard Profile
«profile»
SysML

Back

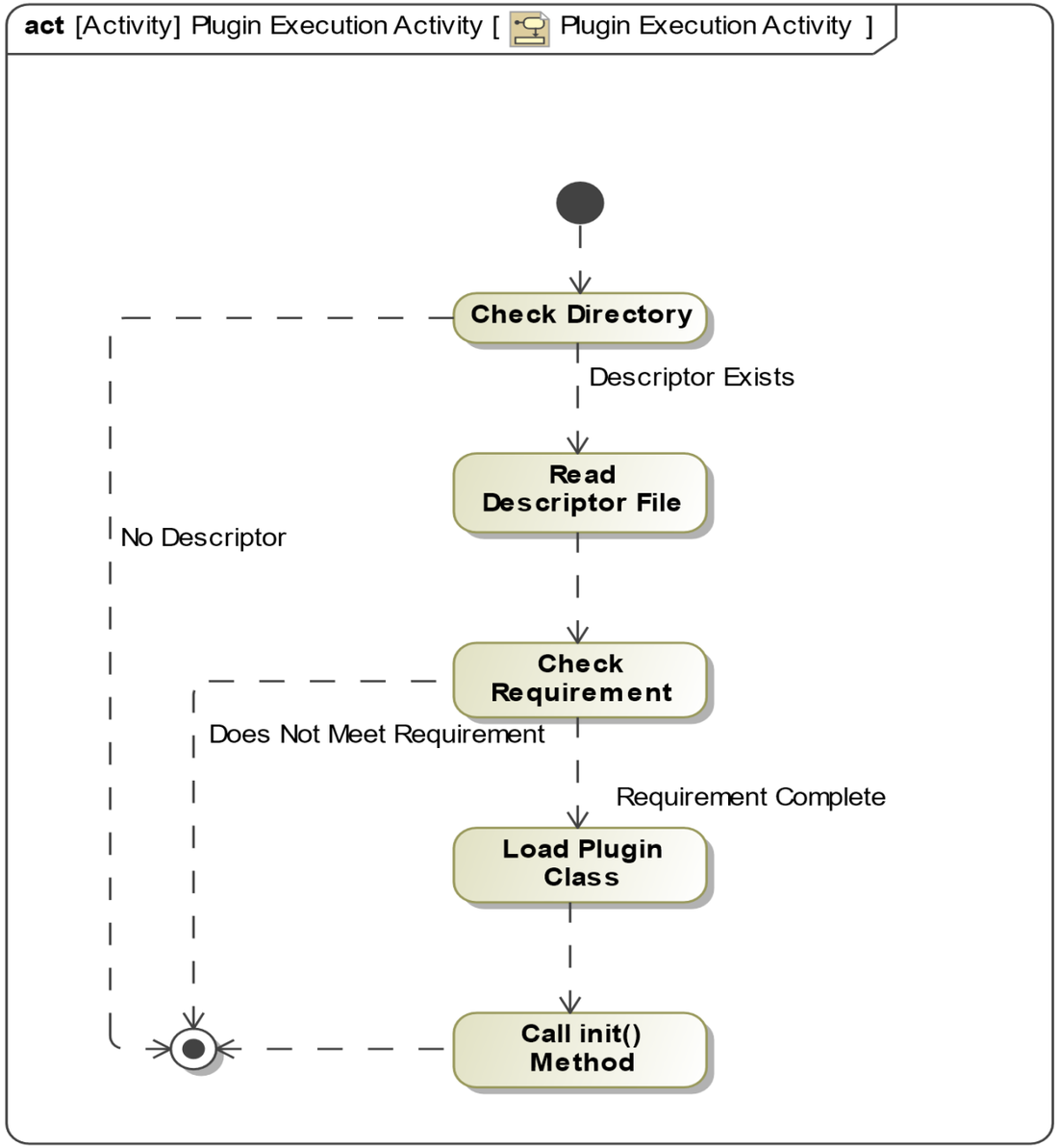

Legend
Refine
OV-5 [Operational Viewpoint]
SV-4 [Systems Viewpoi
Coordinate Other Agen
Find Victim
Firefight
Investigate Reports Of
Monitor Health
Process Warning Order
Provide continuous rac
Provide emergency tow
Provide Medical Assist
Receive Distress Signal
Recover Victim
Rescue
Search
Search & Rescue
Send Distress Signal
Send Warning Order
Solve incident involving
Solve incidents in all ar
Transit To SAR Operati
Transport Patient
Treat Patient
8 6 2 2 2 4 2 2 2 2 2 2 2 2 2 6 4 6 4
Apply First Aid 4
Broadcast Message 2
Determine Destinati 6
Interact in the mari 2
Move 4
Reassure Victim 2
Receive Distress Sig
Receive Message 2
Receive TDM 4
Receive Track Infor 2
Recover Victim 4
Search & Rescue 4
Send Message 2
Send TDM 2
Send Track Informa 6
Transmit Distress Si 12
Transport 4


act [Activity] Establish Design Structure Matrix [Establish Design Structure Matrix]
Establish Design structure Matrix from Template
Ensure that Matrix element types are set to correct Stereotype
Ensure Columns are set to correct DoDAF View Points
Ensure Scope of Matrix is set Correctly
Ensure Relationship is set Correctly
Apply Assumptions for Model
Determine Clustering for Model
Calculate MDL Values Based on Clusters
Do Preliminary Interpretation of MDL Values

Back

Variable formulation and Observation Data Collection

Back


act [Activity] Plugin Execution Activity [Plugin Execution Activity]
Check Directory
Descriptor Exists
Read Descriptor File
No Descriptor
Check Requirement
Does Not Meet Requirement
Requirement Complete
Load Plugin Class
Call init() Method

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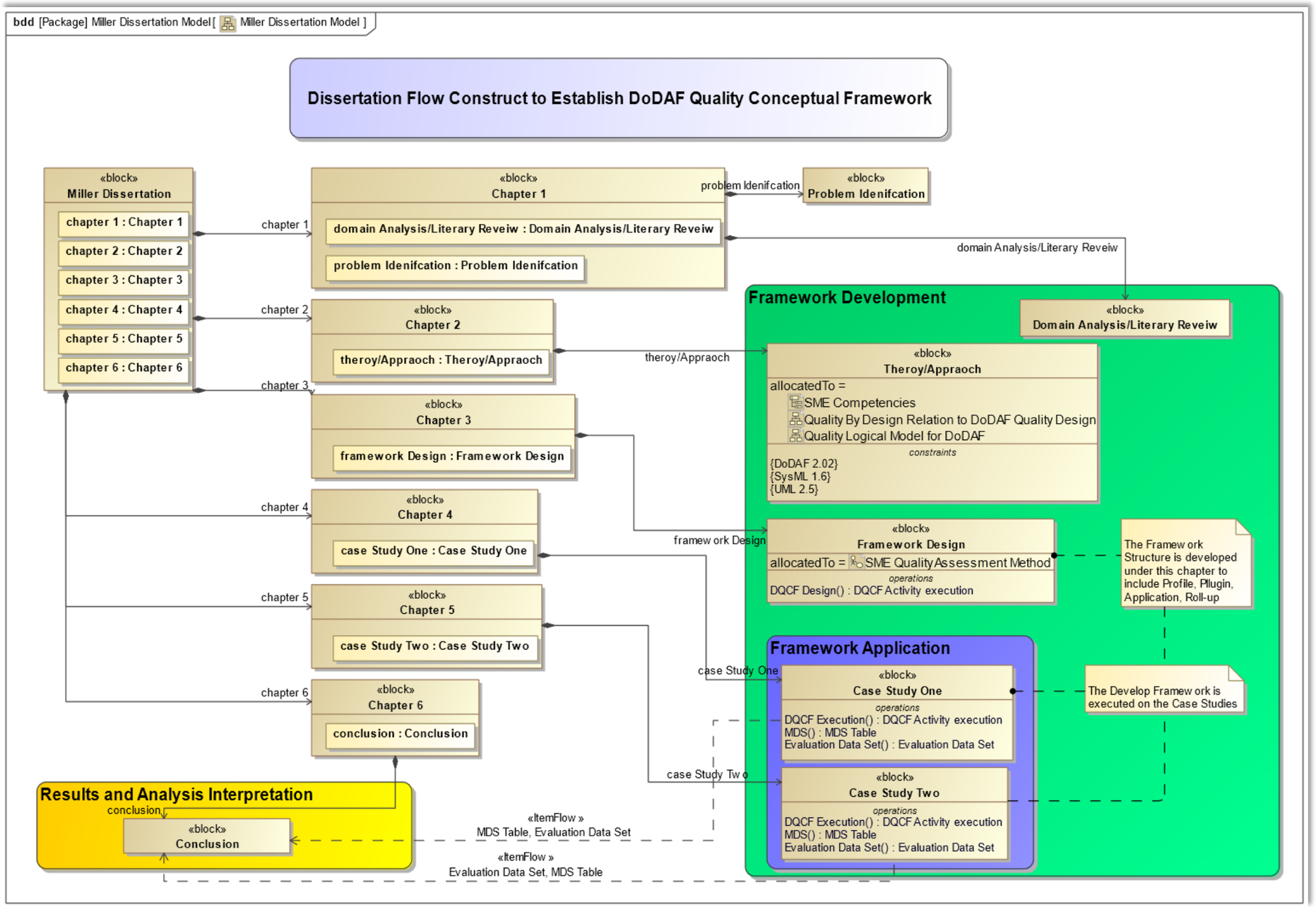
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