34th Annual INCOSE international symposium

hybrid event

Dublin, Ireland
July 2 - 6, 2024

Model-Based Decision Support using Test and Evaluation: A Lightweight Architecture Approach

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This work was sponsored by
Office of the Secretary of Defense (OSD) - Director,
Operational Test and Evaluation (DOT&E) ,
under contract # W31P4Q21F0207

Operational Test & Evaluation (OT&E)

Mission: Evaluate operational *effectiveness* & *suitability* to defend our homeland & prevail in conflict

Live-Fire Test & Evaluation (LFT&E)

Mission: Evaluate *survivability* & (when necessary) *lethality* of the Joint Force to build defense & resilience

Primary DOT&E Responsibilities

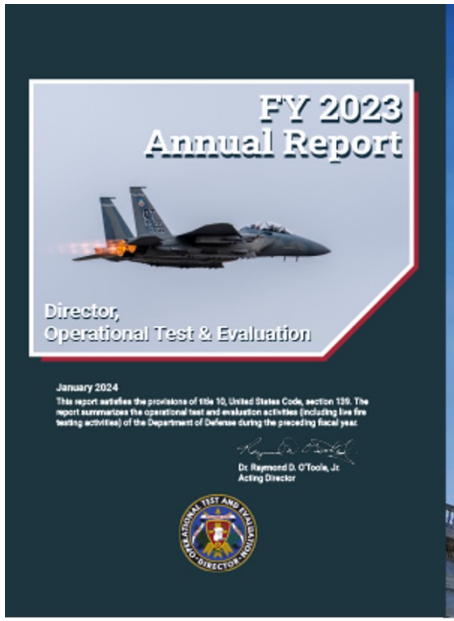
Policy & Guidance

Oversight

Reporting

Congressional Tasking

Strategic Initiatives



Test the way we fight	Architect T&E around validated mission threads & demonstrate the operational performance of the Joint Force in multi-domain operations
Accelerate the delivery of weapons that work	Embrace digital technologies to deliver high-quality systems at more dynamic rates
Improve survivability of DoD in a contested environment	Identify, assess, & act on cyber, electromagnetic spectrum, space, & other risks to DOD mission – at scale & speed
Pioneer T&E of weapon systems built to change over time	Implement fluid & iterative T&E across the entire system lifecycle to help assure continued combat credibility as the system evolves to meet warfighter needs
Foster an agile & enduring T&E enterprise workforce	Centralize & leverage efforts to assess, curate, & engage T&E talent to quicken the pace of innovation across the T&E enterprise

DOT&E Strategic Pillars

PILLAR 1
Test The Way We Fight

PILLAR 3
Improve the Survivability of DoD in a Contested Environment

PILLAR 4
T&E of Weapon Systems Built to Change Over Time

PILLAR 2
Accelerate The Delivery of Weapons That Work

Questions & Answers
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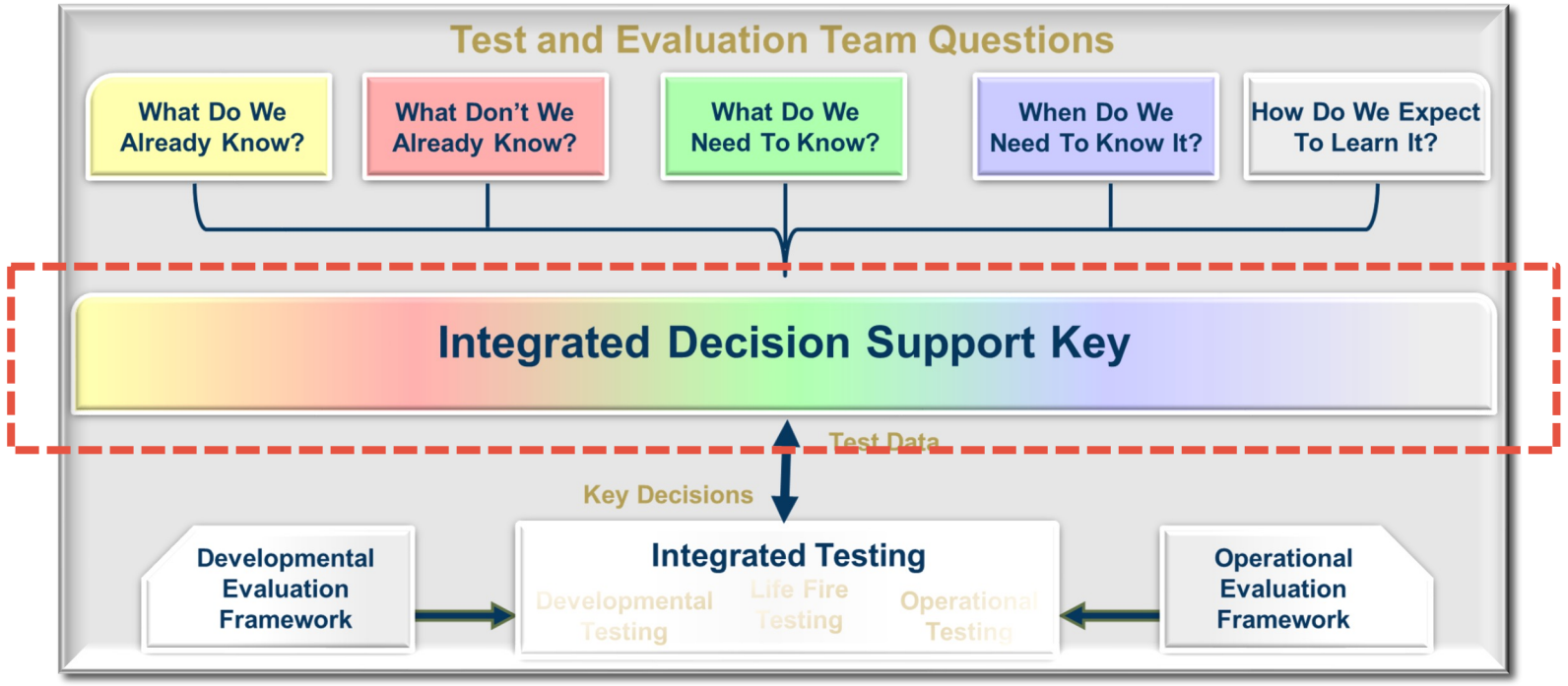
PILLAR 5
Foster an Agile & Enduring T&E Enterprise Workforce

Overcome limitations w/tradition T&E to address today's transformed battlefield

Timely decision support during test & evaluation (T&E) leads to the delivery of products with a competitive edge.

- The IDSK clearly identify decisions of interest to a program/product and ties these decisions to tests and data sources needed to support these decisions.

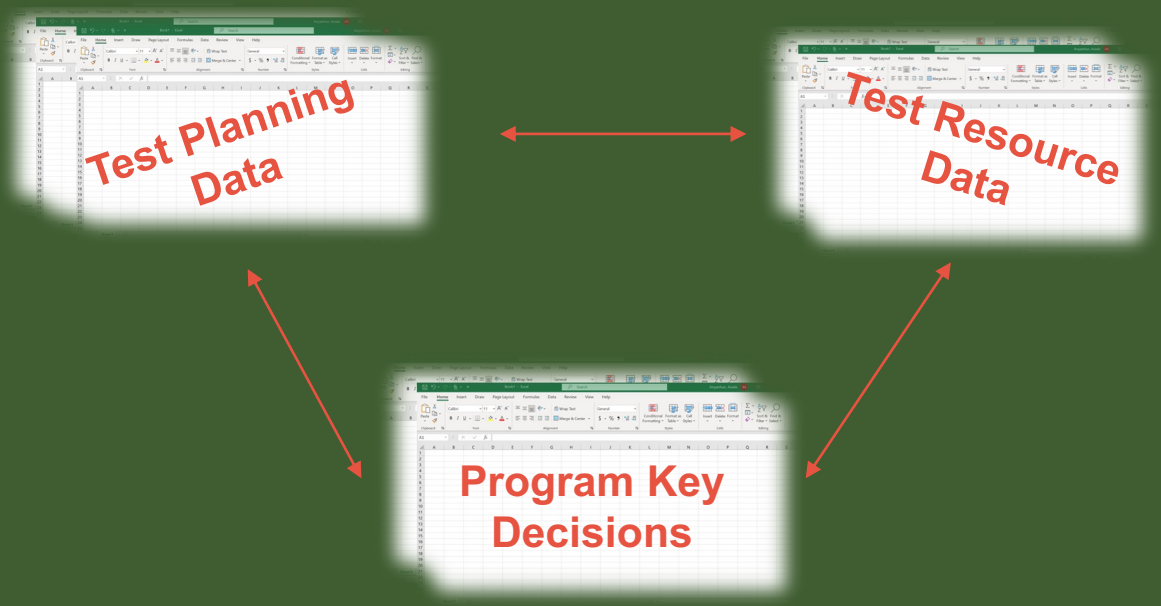


Integrated T&E Framework
(modified from DoDI 5000.89)

Challenge

1. The IDSK is structured as a set of Excel Spreadsheets that link decisions to test-related data.

2. This structure limits the ability of the IDSK to use important data currently being captured in digital models.



Value Proposition

Implementing decision support in a form consistent with current model-based system engineering (MBSE) methods will enable program offices integrate testing and decision-making.

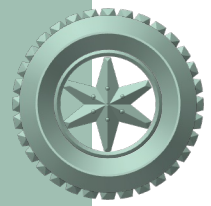
An MBSE approach:

- ✓ Links requirements, test, and decisions in a consistent manner.
- ✓ Links various technical and programmatic aspects of a program to the critical decision making process.
- ✓ Focuses program resources on getting data needed to make critical decisions in a timely manner.
- ✓ Integrates information, knowledge, decision - making and risk across the lifecycle.

m A
SK

Program B
MB-IDSK

am C
DSK



The Digital-IDSK Reference Architecture provides practical guidelines for program-specific implementations.

STEP-1

Conceptualize a LRA for Decision Support

The digital-IDSK key business drivers influence the weight of the reference architecture.

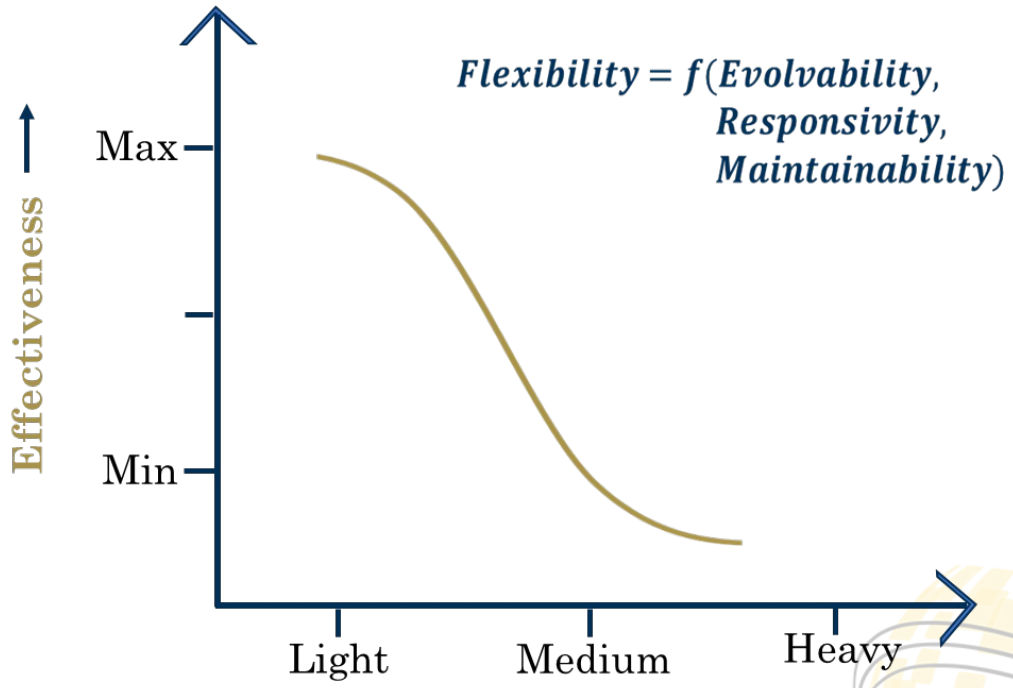
The weight of a reference architecture directly impacts its effectiveness and acceptance.

Key Business Drivers:

- Inform decisions using data from existing digital models
  - ✓ Plug into a program's existing digital ecosystem
  - ✓ Acceptance and use by programs

Architecture Drivers:

- Standardization
- Flexibility
  - ✓ Decomposed Quality Attributes:
    - [QA-1] Evolvability
    - [QA-2] Responsivity
    - [QA-3] Maintainability



Weight vs. Effectiveness Graph
(modified from Muller, 2020)

Computing the Architectural Weight for the Digital-IDSK LRA

The IDSK-LRA Ruleset are used as drivers to define constraints imposed on the reference architecture.

The weight of the architecture is the summation of the weights of all architectural rules in the ruleset.

$$IDSK - RA_{weight} = \sum_{i=1}^{n} RA\_R_{w_i}$$

$$Ref.Arch.Rule_{weight} = RA\_R_w = f(E_R, I_R, S_R, D_R)$$

- Rule weight function (F_W) variables:
  - ✓ Enforcement Level, E_R
  - ✓ Impact, I_R
  - ✓ Size, S_R
  - ✓ Number of dependencies, D_R

E_R		I_R		S_R		D_R	
Mandatory	2	Program	2	Multipage	4	Coupled	2(n)
Conditional	1	System	1	Multiline	0.5(n), n<5	Standalone	0.5
Guideline	0.5	Subsystem	0.5	Single line	0.5		

Rule types with corresponding weights

Rule	Rule Name	Rule Statement	E_R	I_R	S_R	D_R	$\sum w$
Rule 1	Maximize Benefit to Acquisition Decision Makers	The IDSK-RA shall align well with the strategic decision-making objectives of program offices and the T&E enterprise by addressing all key stakeholder concerns.	2	2	1	0.5	5.5
Rule 2	Data Accessibility	The IDSK-RA shall provide/enable easy access to acquisition and T&E data required to support test planning and decision-making.	2	1	1	0.5	4.5
Rule 3	Data Accessibility	The IDSK-RA shall be created as a minimally prescriptive, fully documented MVP	0.5	2	0.5	0.5	3.5
Rule 4	Implementation Independence	The IDSK-RA shall be independent of acquisition (program-specific) information and data.	1	0.5	0.5	0.5	2.5
Rule 5	Requirements-Based Change	Updates and changes to the IDSK-RA shall be based on business-level needs ONLY.	0.5	0.5	0.5	0.5	2
Rule 6	Evolvability	The IDSK-RA shall withstand and easily adapt to new requirements and future changes with no damage to the integrity of the RA.	2	2	1	2	7
Rule 7	Polymorphism	The IDSK-RA shall exhibit polymorphic characteristics to facilitate a maturing of the RA over time.	2	1	1	0.5	4.5
Total Weight							29.5

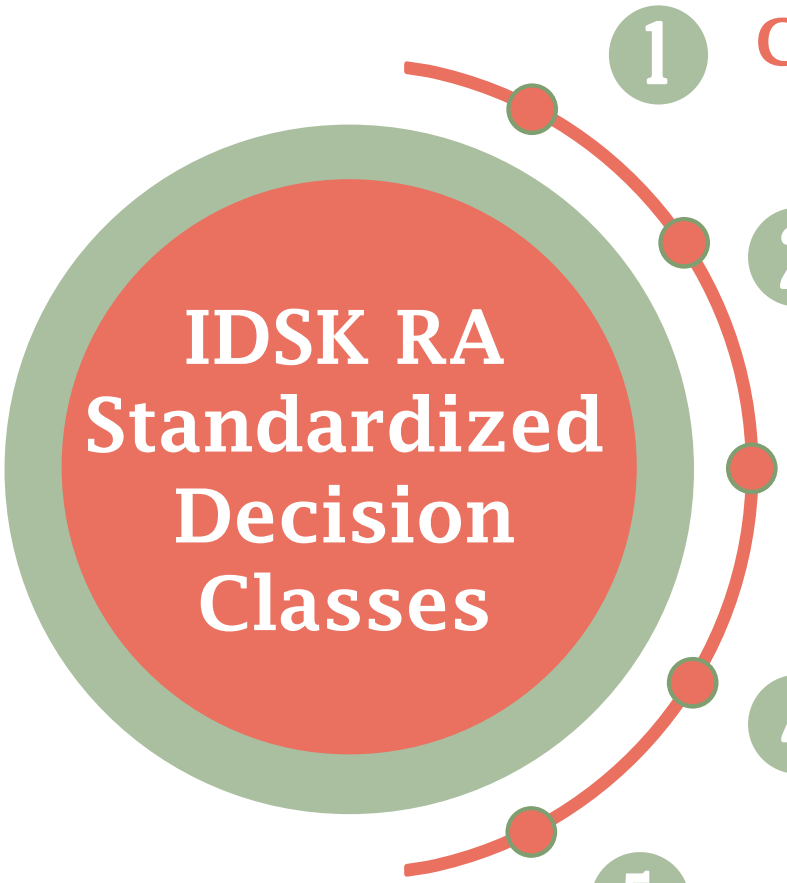
[Heavyweight <=154, Mediumweight (70 – 153), Lightweight (14 – 69)]

STEP-2

Architectural Description of the Digital-IDSK LRA

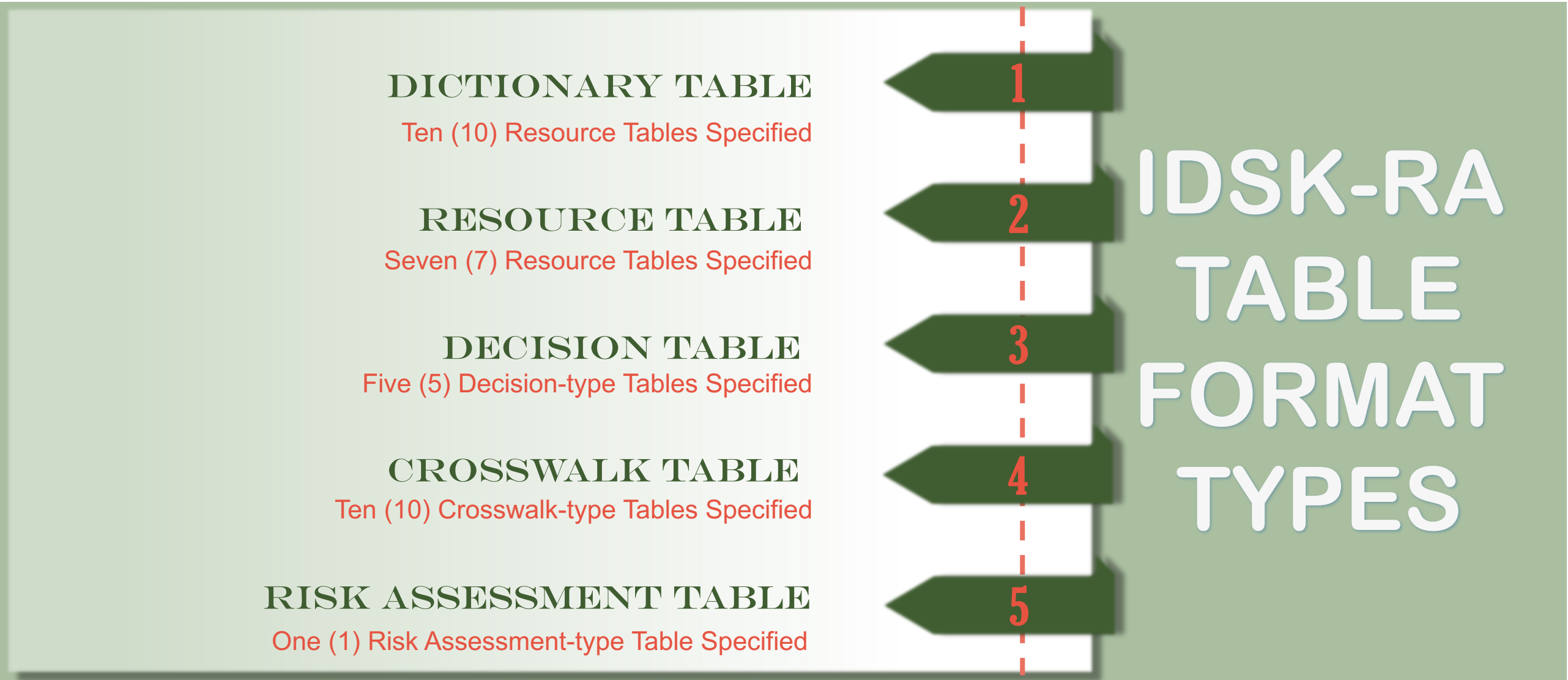
Specify Standardized Sets of Decisions & Data Formats to Support Test Planning

Five sets of standardized decision classes and data formats are identified and defined in the IDSK-LRA.



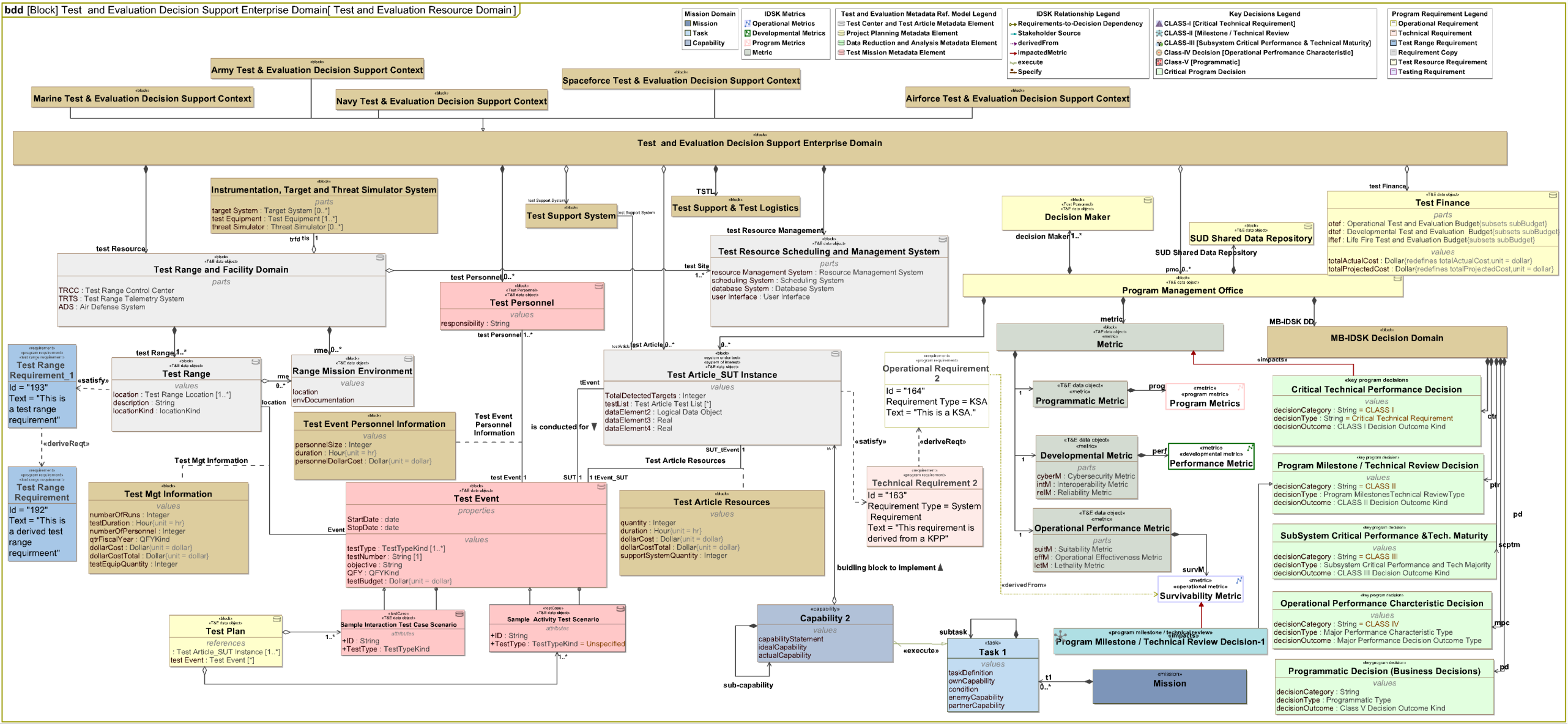
1. Critical Technical Performance Decisions
2. Program Milestone/Technical Review Decisions
3. Subsystem Critical Performance & Tech Maturity Decisions
4. Operational Performance Characteristic Decisions
5. Programmatic (Business) Decisions

Five Standardized IDSK table formats capture test, test planning, mission, and acquisition-related data.



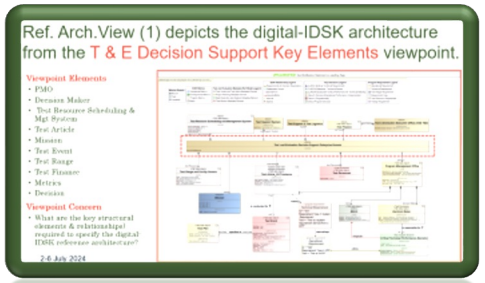
Architect the Digital-IDSK Lightweight Reference Architecture

Overarching IDSK Architecture View

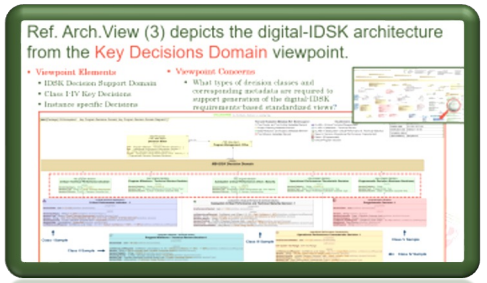


The digital-IDSK LRA comprises multiple views necessary for generating standardized decision formats.

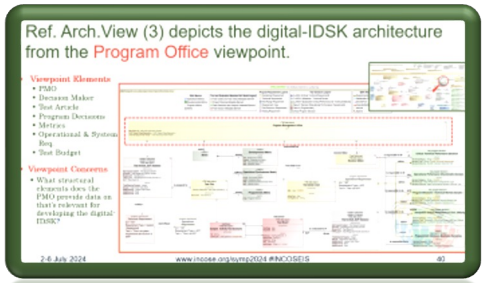
1. T&E Decision Support Views
2. Program Office Views
3. Decision Domain Views
4. Decision Maker Views
5. Metrics Views
6. Requirements Views
7. Test Article Views
8. Test Facility Views
9. Test Personnel Views
10. Test Budget Views
11. Mission Views



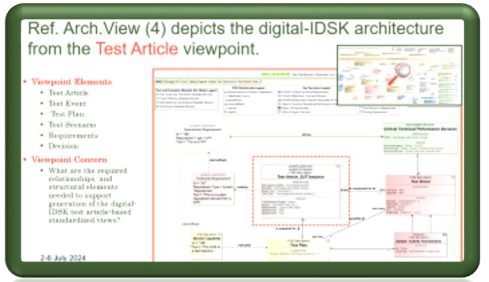
T&E Domain View



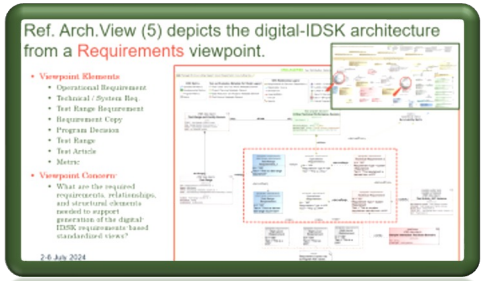
Decisions Domain View



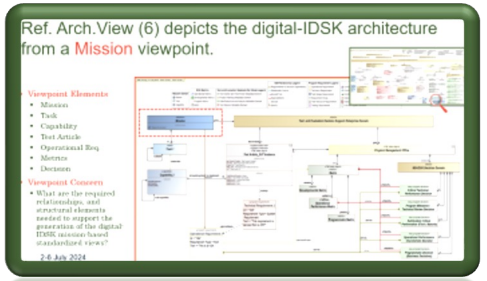
Program Office View



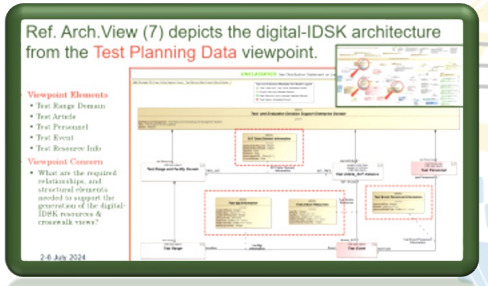
Test Article View



Requirements View



Mission View



Test Planning View

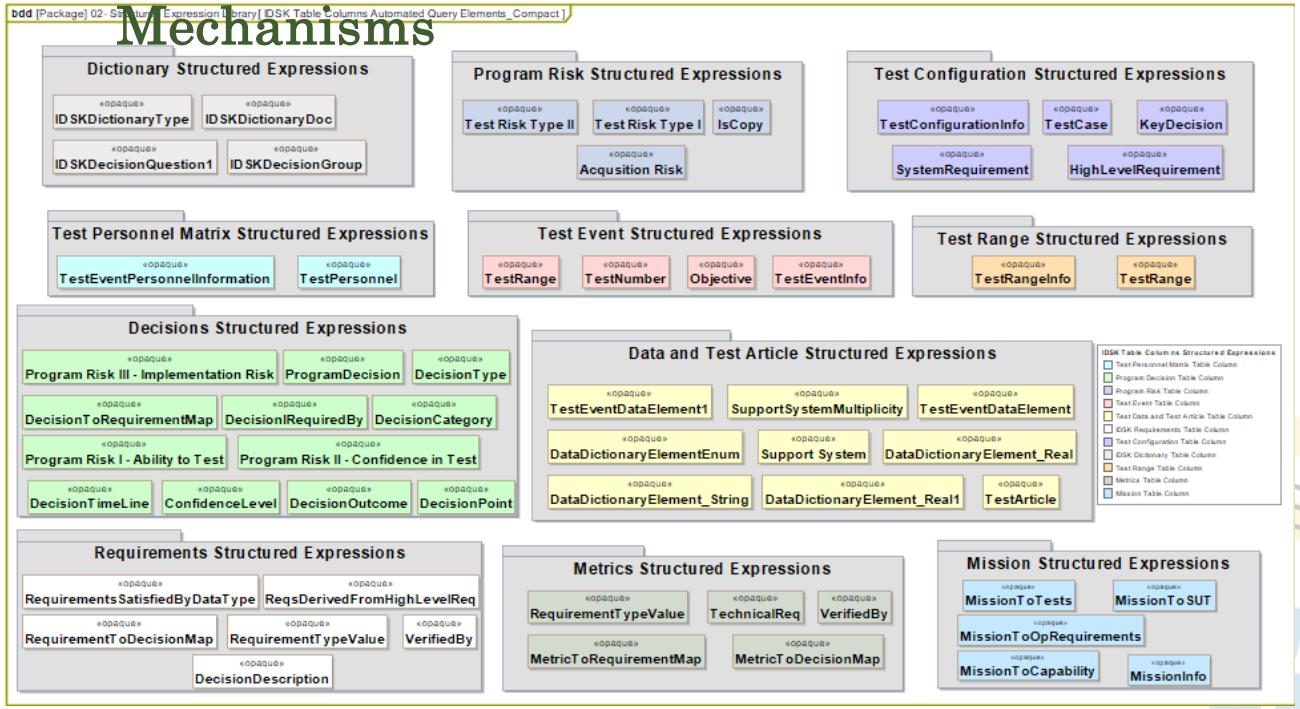
The Digital-IDSK LRA Resource Library

MB-IDSK-RA library resources help shorten the development timeline for programs.[1]

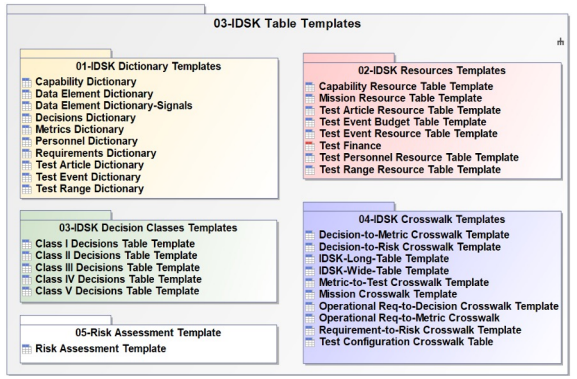
- Configurable IDSK table templates
- Well-documented model query mechanisms (i.e. structured expression syntax)

1. Dictionary table queries
2. Test Personnel table queries
3. Test Event-related queries
4. Test Range-related queries
5. Decision table queries
6. Data & Test Article queries
7. Requirements table queries
8. Metrics-related queries
9. Mission-related queries
10. Test Config. table queries
11. Risk Assessment table queries

Structured Expression Query Mechanisms



MB-IDSK-RA library resources help shorten the development timeline for programs.[2]



Test Article Dictionary Template

#	Test Article	Test Article Type	Test Article Description
1	Demo		

Decision Dictionary Template

#	Decision	Decision Type	Decision Question	Decision Category
1	Demo			

Test Personnel Resource Template

#	Test Personnel	Test Personnel Type	Number of Test Personnel	Duration (Hours)	Personnel Dollar Cost
1	Demo				

Test Range Resource Template

#	Test Range	Test Range Asset	Range Asset Quantity	Number of Runs	Duration (Hours)	Range Asset Dollar Cost	Range Asset Dollar Cost Total
1	Dem						

MB-IDSK-RA library resources help shorten the development timeline for programs.[3]

Key Program Decision (Class I-V) Template

#	Key Decision	Key Decision Question	Decision Category	Decision Type	Confidence Level Required	Lifecycle Point	Decision Date	Decision Outcome	Operational Requirement	Technical Requirement	Data Source	Test Data Required
1	Demo											

Operational Requirement-to-Metric Crosswalk Template

#	Id	Name	Text	Operational Requirement Type	Technical Requirement	Key Decision	Decision Question	Impacted Metrics
1	236	Req						

Decision-to-Risk Crosswalk Template

#	Key Decision	Decision Question	Decision Outcome	Requirement(s) Driving Decision Outcome	Program Risk I (Ability-to-Test Risk)	Program Risk II (Confidence-in-Test Risk)	Program Risk III (Acquisition Risk)
1	Demo						

Metrics-to-Test Crosswalk Template

#	Metrics	Operational Requirement	Operational Requirement Type	Derived Technical Requirement	Key Decision	Tests
1	Missile System Suitability	229.1 Missile Speed Requirement	KPP	219 Missile Speed Requirement	Missile System Functional Review	All Scenarios Test Missile Speed Test Scenario

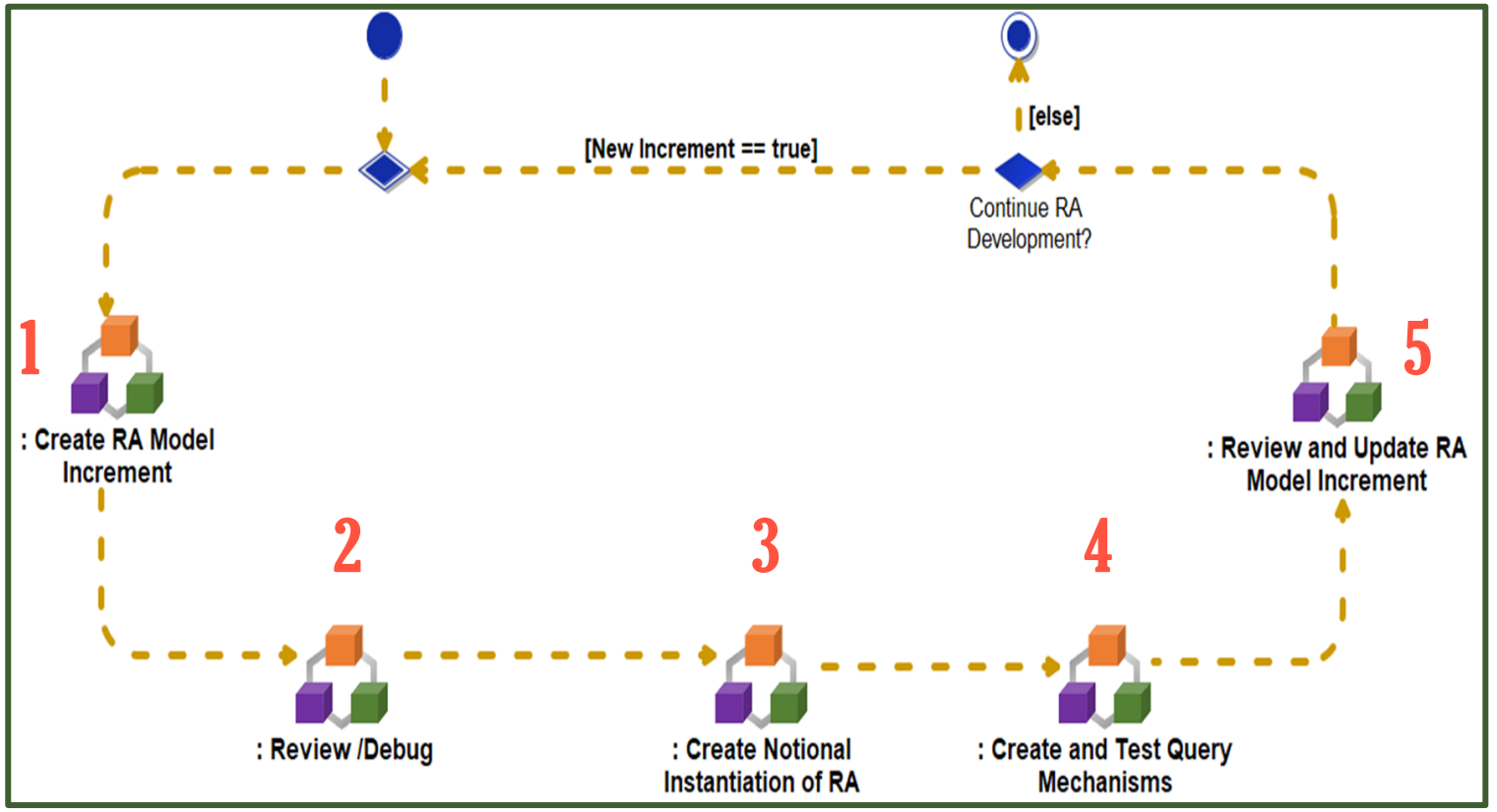
STEP-3

Using the Digital-IDSK LRA: A Missile System Exemplar

Creating Specific Implementations: An Iterative Modeling Approach

An iterative modeling approach helps mitigate complexity in a controllable manner.

- To assess the IDSK LRA for consistency, integrity, balance, utility, and ease of use, notional exemplars of varying complexity were developed.



Step 1: Create LRA Model Increment 1

Step 2: Review diagram views, check for error/debug errors.

Step 3: Create a notional instance using SysML inheritance property

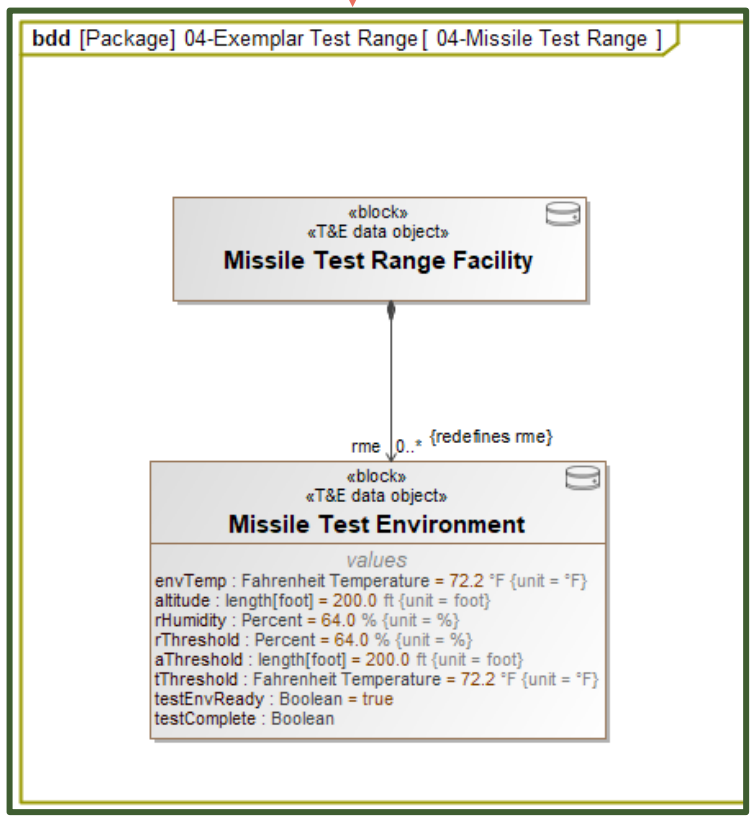
Step 4: Create and Test query mechanisms by generating tables

Step 5: Review and update the LRA model increment

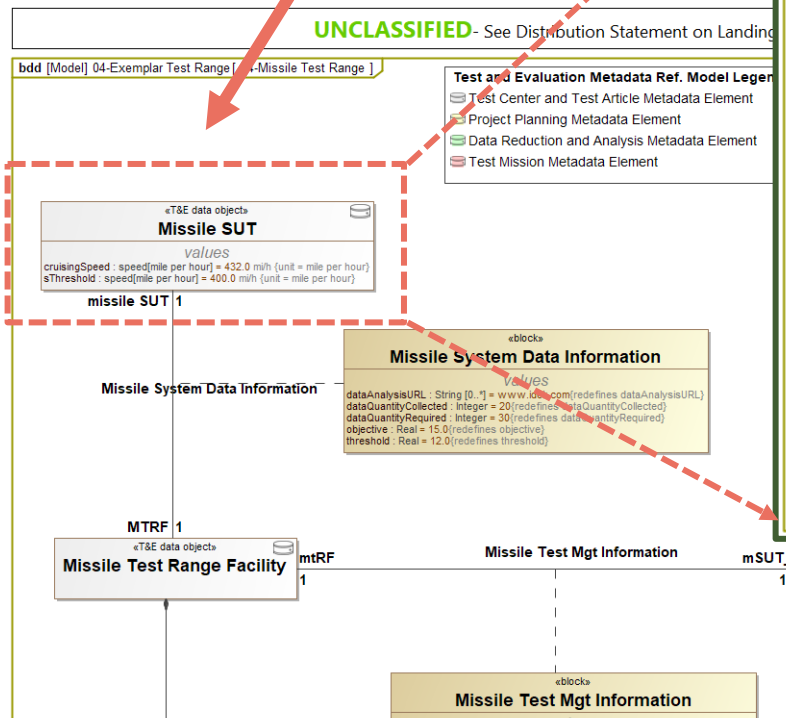
Notional Missile System Digital-IDSK Architecture

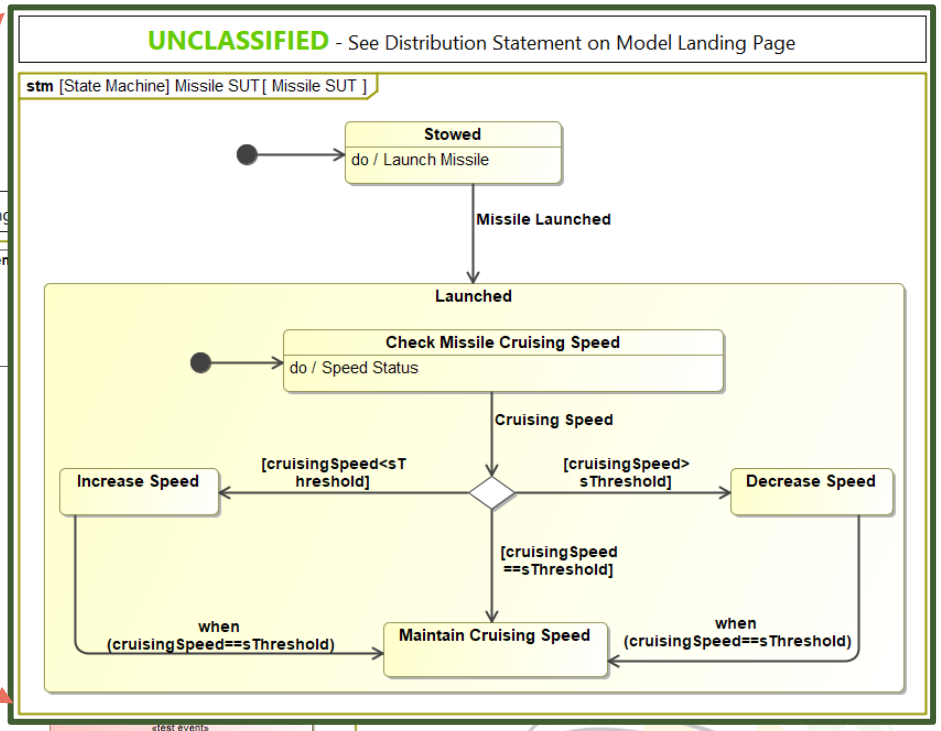
The missile system digital-IDSK proof-of-concept model validates the MB-IDSK development process[1].

Missile Test Facility View



Black Box Missile System Element

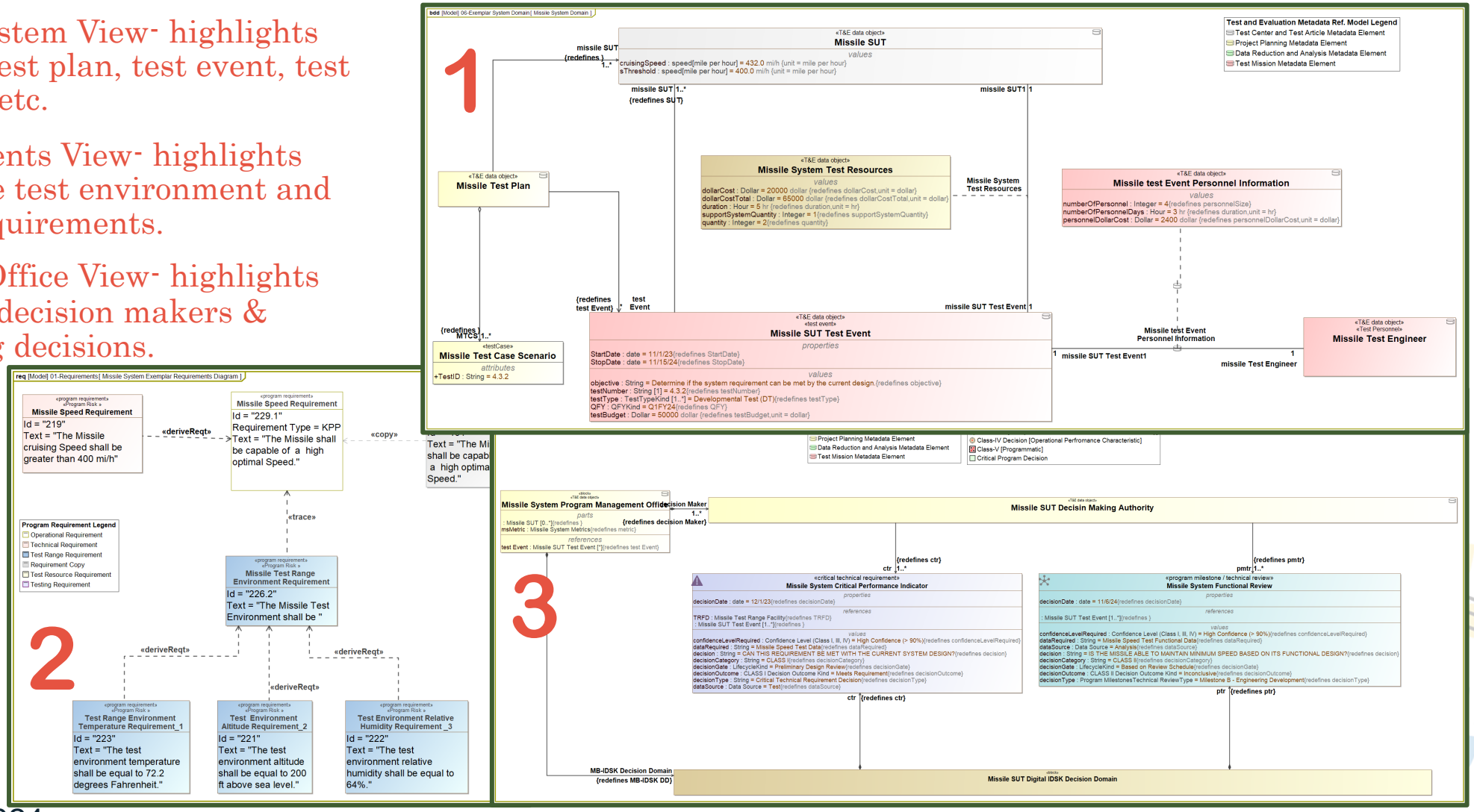




Missile System Speed Behavior Specification

The missile system digital-IDSK proof-of-concept model validates the MB-IDSK development process[2].

1. Missile System View- highlights the SUT, test plan, test event, test personnel etc.
2. Requirements View- highlights the missile test environment and system requirements.
3. Program Office View- highlights the PMO, decision makers & supporting decisions.



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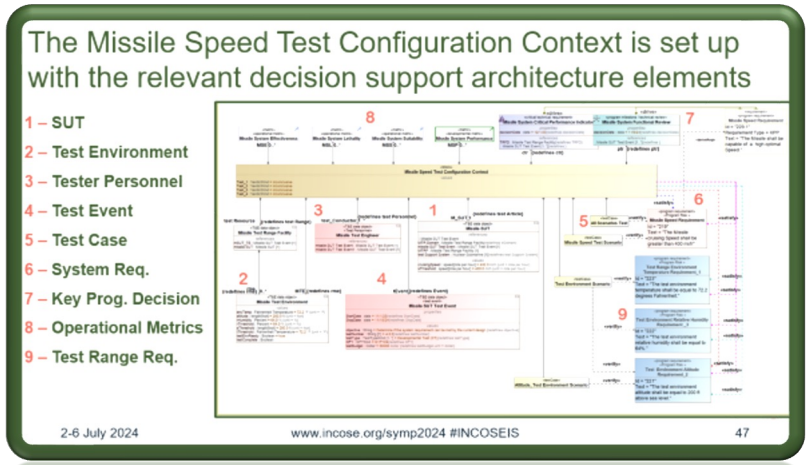
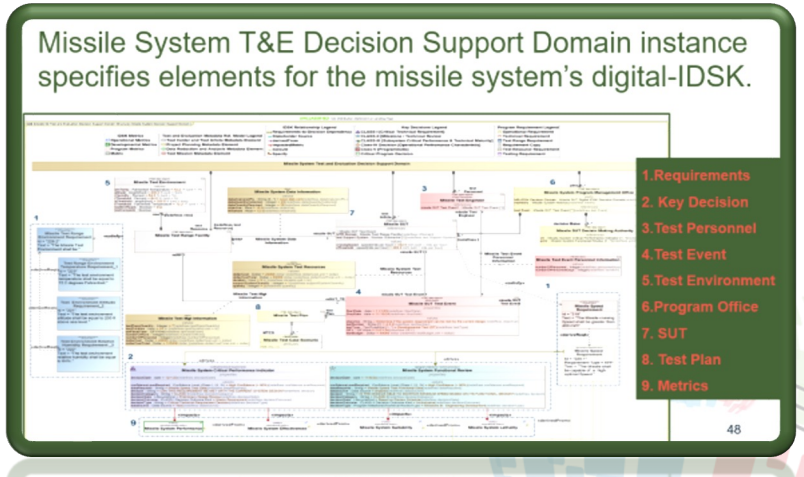


Missile System Test-Integrated View

- ✓ Missile System Data
- ✓ Missile Test Range Data
- ✓ Requirements Data
- ✓ Program Office T&E Data

Test Results

Missile System IDSK Architecture View



Mission Speed Test Exemplar Digital-IDSK Standardized Tables

Digital-IDSK Tables for Exemplar Missile Speed Test Context.[1]

1 Class I Program Decision Point Digital-IDSK Standardized Format

Key Decisions Legend: CLASS-I [Critical Technical Requirement] CLASS-II [Milestone / Technical Review] CLASS-III [Subsystem Critical Performance & Technical Maturity]
Class-V [Programmatic] Critical Program Decision

#	Name	Decision Question	Decision Type	Decision Category	Decision Outcome	Decision Date	Lifecycle Point	Confidence Level Required for Decision
1	Missile System Critical Performance Indicator	CAN THIS REQUIREMENT BE MET WITH THE CURRENT SYSTEM DESIGN?	Critical Technical Requirement Decision	CLASS I	Meets Requirement	12/1/23	Preliminary Design Review	High Confidence (> 90%)

ational Perfromance Characteristic]

Operational Requirement	Technical Requirement	Data Required	Data Source
229.1 Missile Speed Requirement	219 Missile Speed Requirement	Missile Speed Test Data	Test

- ✓ Key Decision
- ✓ Decision Question
- ✓ Decision Type
- ✓ Decision Category
- ✓ Decision Date
- ✓ Lifecycle Point
- ✓ Confidence Level
- ✓ Decision Outcome
- ✓ Operational Req.
- ✓ Technical Req
- ✓ Data Required
- ✓ Data Source

2 Class II Program Decision Point Digital-IDSK Standardized Format

Key Decisions Legend: CLASS-I [Critical Technical Requirement] CLASS-II [Milestone / Technical Review] CLASS-III [Subsystem Critical Performance & Technical Maturity] Class-I
Class-V [Programmatic] Critical Program Decision

#	Name	Decision Question	Decision Type	Decision Category	Decision Outcome	Decision Date	Lifecycle Point	Confidence Level Required for Decision
1	Missile System Functional Review	IS THE MISSILE ABLE TO MAINTAIN MINIMUM SPEED BASED ON ITS FUNCTIONAL DESIGN?	Milestone B - Engineering Development	CLASS II	Inconclusive	11/6/24	Based on Review Schedule	High Confidence (> 90%)

Perfromance Characteristic]

Operational Requirement	Technical Requirement	Data Required	Data Source
229.1 Missile Speed Requirement	219 Missile Speed Requirement	Missile Speed Test Functional Data	Analysis

Digital-IDSK Tables for Exemplar Missile Speed Test Context.[2]

3 Test Personnel Resource Format

#	Test Event	Test Personnel Type	Number of Test Personnel	Duration (Hours)	Personnel Dollar Cost
1	Missile SUT Test Event	Missile Test Engineer	4	3	2400

4 Test Article Resource Format

#	Test Event	Test Article (SUT)	Quantity (SUT)	Support System	Quantity (Support System)	Duration_H...	Dollar Cost	Dollar Cost Total
1	Missile SUT Test Event	Missile SUT	2	Nuclear Submarine	1	5	20000	65000

5 Metric-to-Test Crosswalk Standardized Format

#	Metrics	Operational Requirement	Operational Requirement Type	Derived Technical Requirement	Key Decision	Tests
1	Missile System Lethality	229.1 Missile Speed Requirement	KPP	219 Missile Speed Requirement	Missile System Functional Review	All Scenarios Test Missile Speed Test Scenario

Digital-IDSK Tables for Exemplar Missile Speed Test Context.[3]

6 Test Result Table Format

#	Name	Test_1 : VerdictKind	Test_2 : VerdictKind	Test_3 : VerdictKind	Test_4 : VerdictKind	M_SUT.cruisingSpeed : speed[mile per hour]	MTE.altitude : length[foot]
1	missile Speed Test Configuration Context at 2023.11.16 07.18	pass	pass	pass	fail	432 mi/h	200 ft

MTE.envTemp : Fahrenheit Temperature	MTE. rHumidity : Percent	ptr.decision : String	ctr.decision : String
72.2 °F	64 %	IS THE MISSILE ABLE TO MAINTAIN MINIMUM SPEED BASED ON ITS FUNCTIONAL DESIGN?	CAN THIS REQUIREMENT BE MET WITH THE CURRENT SYSTEM DESIGN?

7 Test Configuration Crosswalk Format

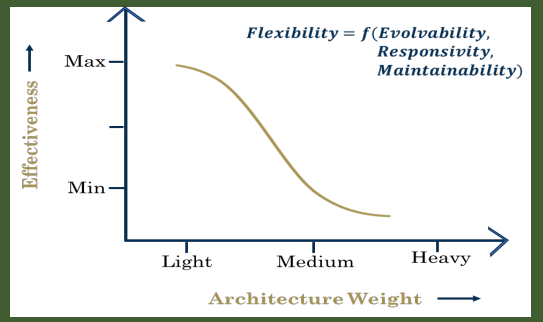
#	Name	Test Mission Environment	System Under Test	Test Personnel	Test Range	Test Event	Test Case	Technical Requirement
1	Missile Speed Test Configuration Context	Missile Test Environment	Missile SUT	Missile Test Engineer	Missile Test Range Facility	Missile SUT Test Event	All Scenarios Test Missile Speed Test Scenario Test Environment Scenario Altitude_Test Environment Scenario	219 Missile Speed Requirement 223 Test Range Environment Temperature Requirement_1 222 Test Environment Relative Humidity Requirement _3 221 Test Environment Altitude Requirement_2

Operational Requirement	Key Decision informed by Test Configuration	Impacted Metrics
229.1 Missile Speed Requirement 226.2 Missile Test Range Environment Requirement	Missile System Critical Performance Indicator Missile System Functional Review	Missile System Lethality Missile System Effectiveness Missile System Performance Missile System Suitability

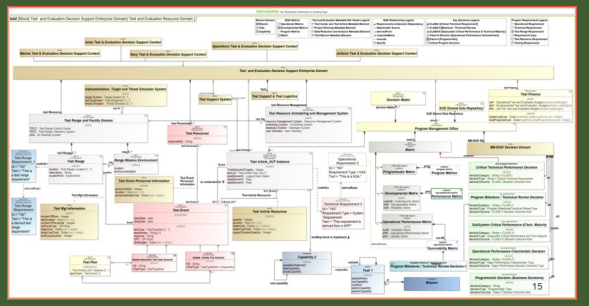
- ✓ Test Environment
- ✓ Test Article,
- ✓ Test Personnel
- ✓ Test Range
- ✓ Test Event
- ✓ Test Cases
- ✓ Technical Req.
- ✓ Operational Req.
- ✓ Decisions
- ✓ Metrics

Conclusion

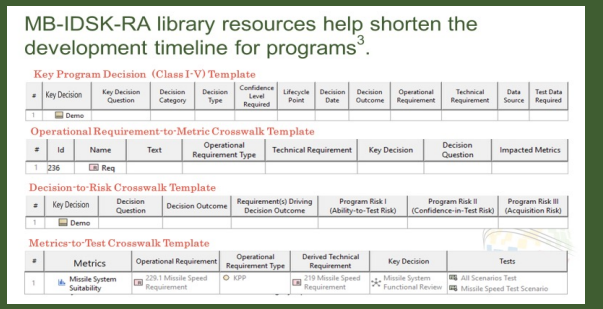
The digital-IDSK is developed as a lightweight reference architecture using an MBSE approach to facilitate the generation of standardized IDSK tables to support timely decision-making during acquisition test & evaluation.



Lightweight Reference Architecture

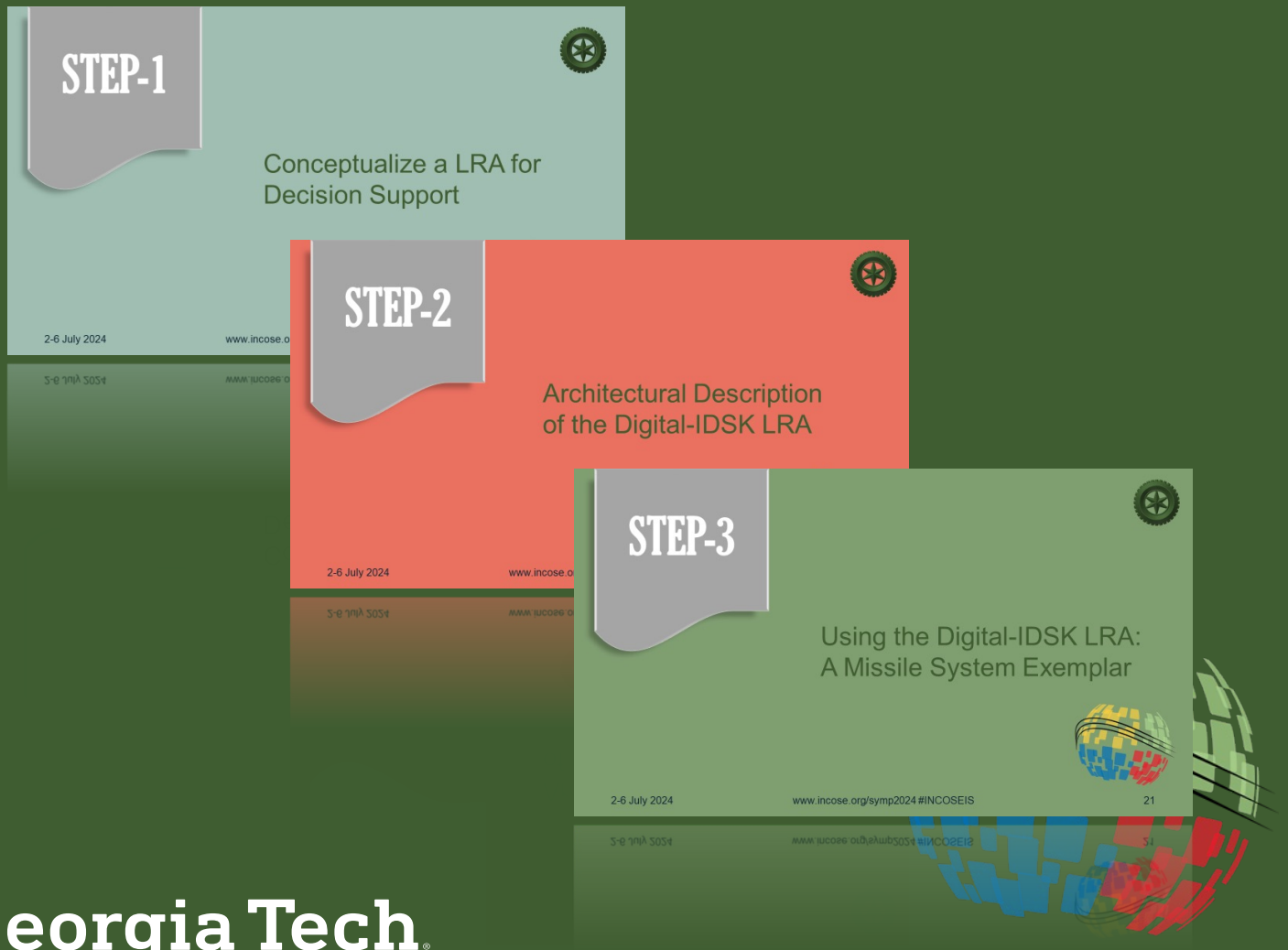


Model-based Approach



Standardized IDSK (Decision Support) Tables

Model-Based Decision Support using Test and Evaluation: A Lightweight Architecture Approach



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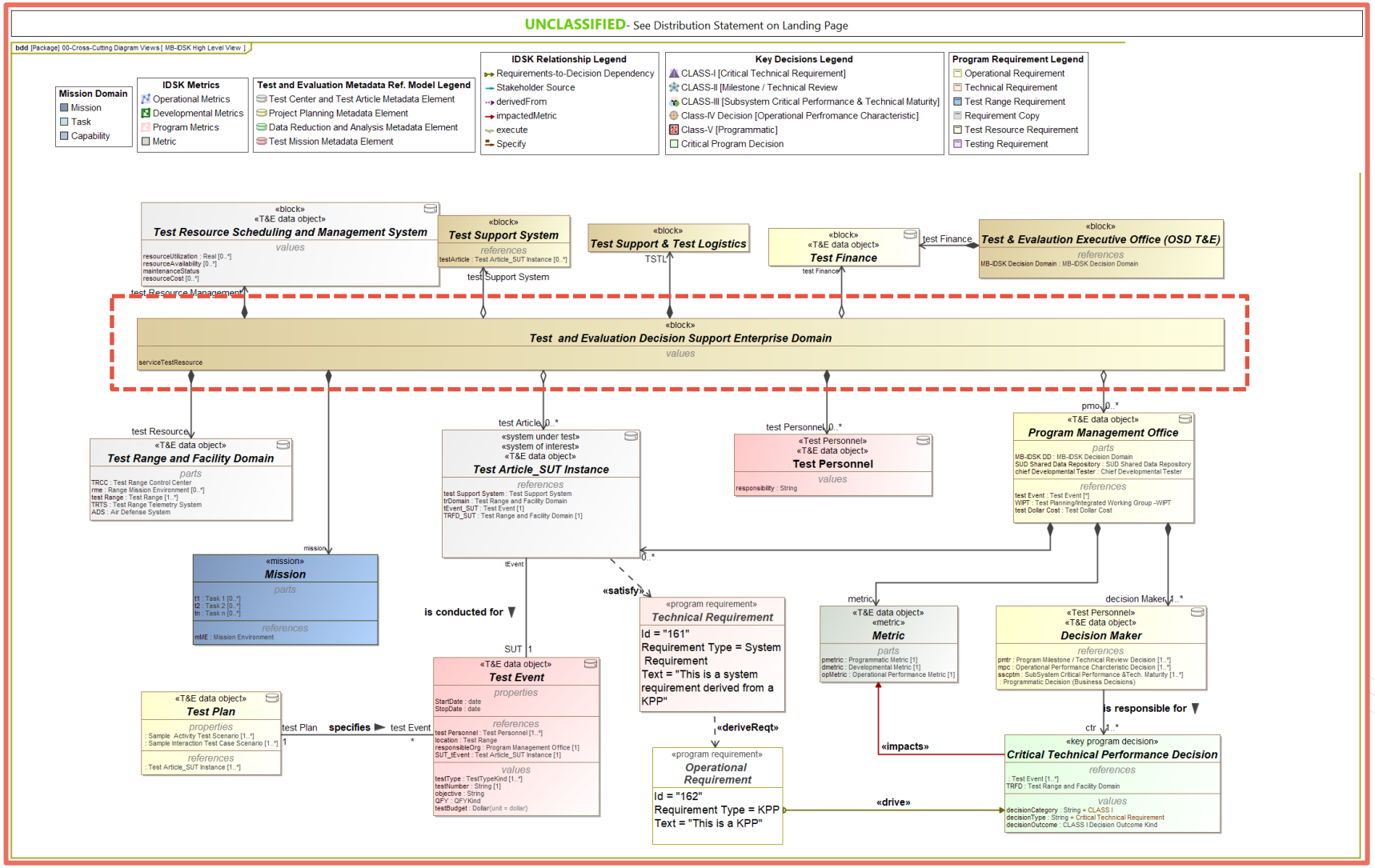
www.incose.org/symp2024

#INCOSEIS

Ref. Arch.View (1) depicts the digital-IDSK architecture from the T & E Decision Support Key Elements viewpoint.

- **Viewpoint Elements**
  - PMO
  - Decision Maker
  - Test Resource Scheduling & Mgt System
  - Test Article
  - Mission
  - Test Event
  - Test Range
  - Test Finance
  - Metrics
  - Decision
- **Viewpoint Concern**
  - What are the key structural elements & relationships) required to specify the digital-IDSK reference architecture?



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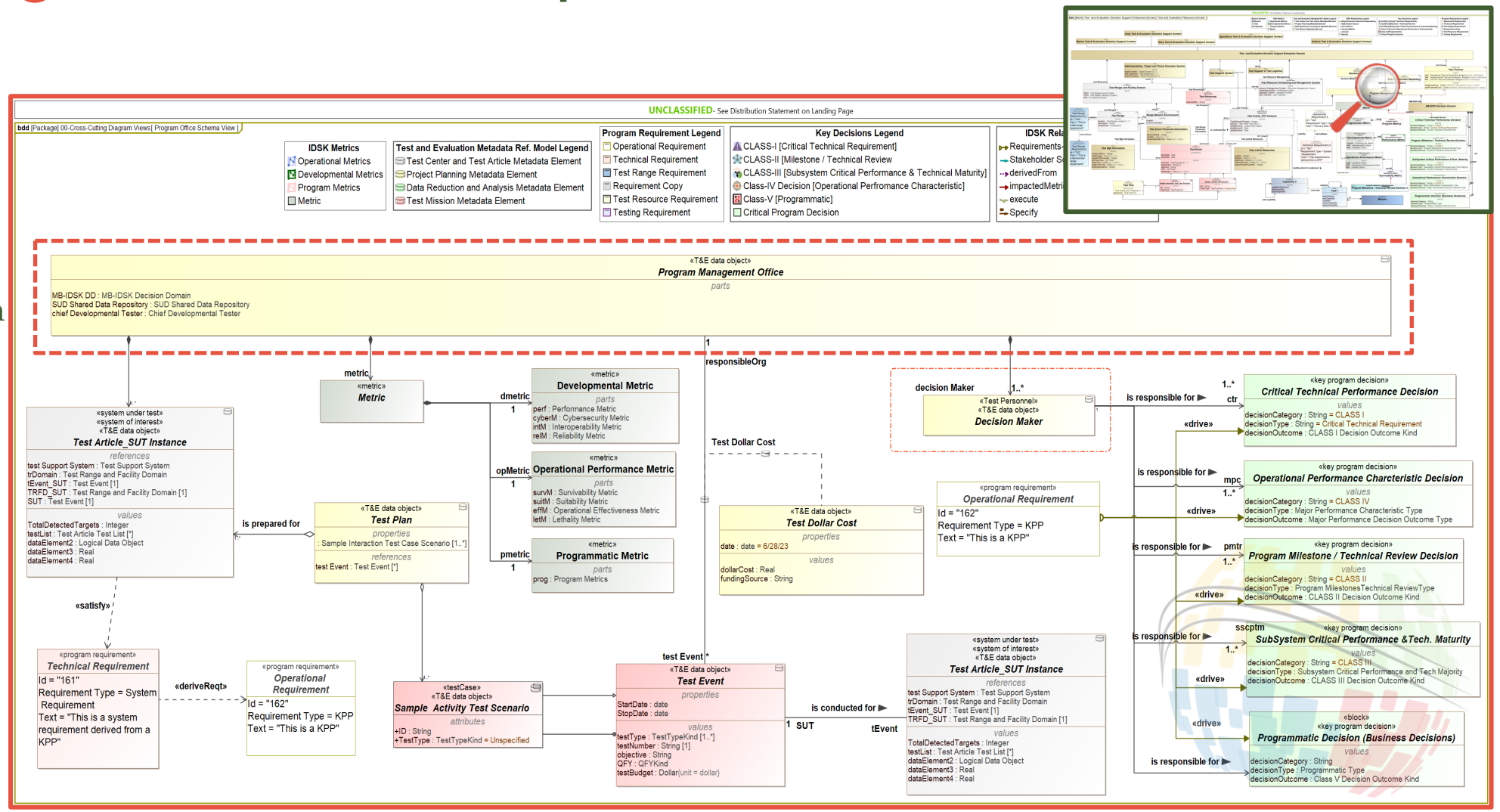
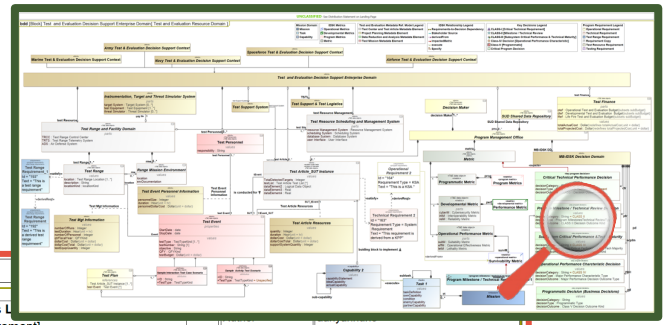
Ref. Arch.View (3) depicts the digital-IDSK architecture from the Program Office viewpoint.

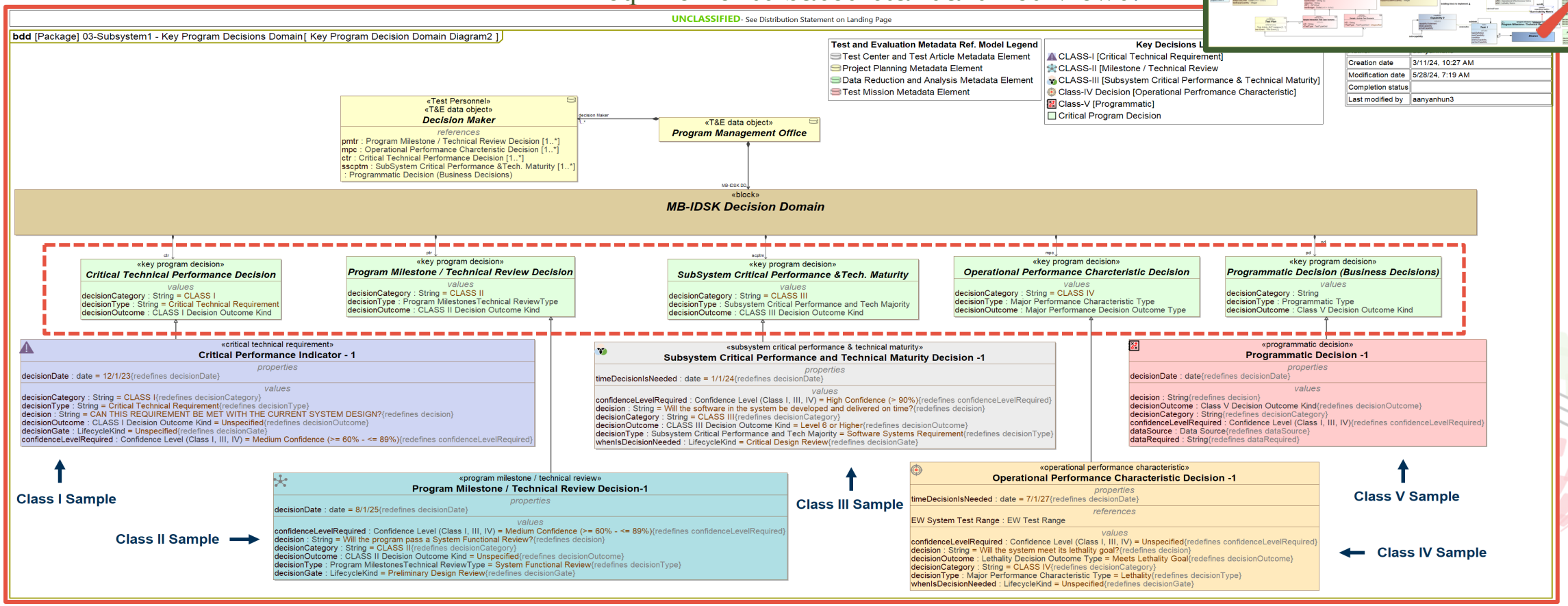
- **Viewpoint Elements**
  - PMO
  - Decision Maker
  - Test Article
  - Program Decisions
  - Metrics
  - Operational & System Req.
  - Test Budget
- **Viewpoint Concerns**
  - What structural elements does the PMO provide data on that's relevant for developing the digital-IDSK?



Ref. Arch.View (3) depicts the digital-IDSK architecture from the Key Decisions Domain viewpoint.

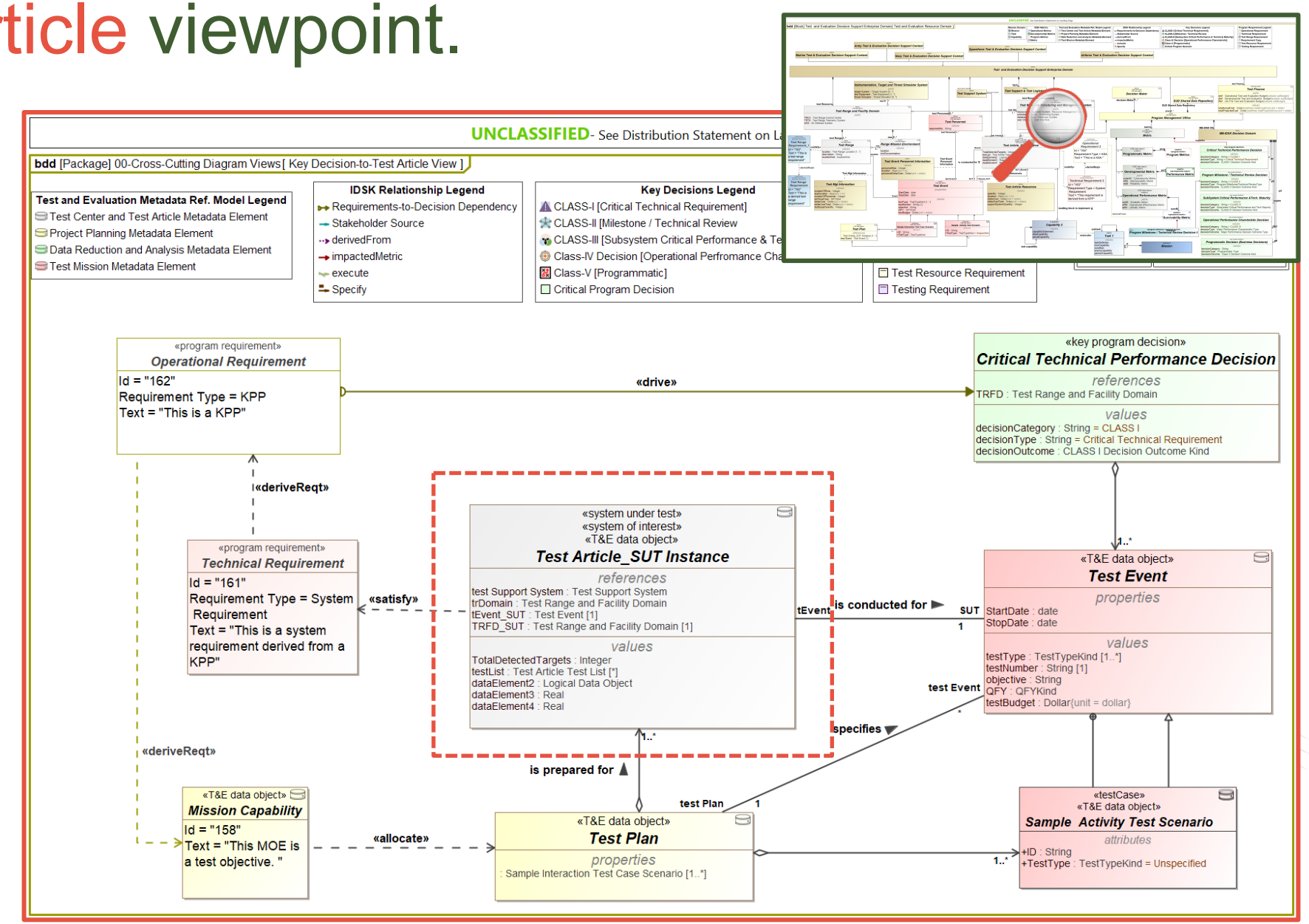
- **Viewpoint Elements**
  - IDSK Decision Support Domain
  - Class I-IV Key Decisions
  - Instance specific Decisions
- **Viewpoint Concerns**
  - What types of decision classes and corresponding metadata are required to support generation of the digital-IDSK requirements-based standardized views?





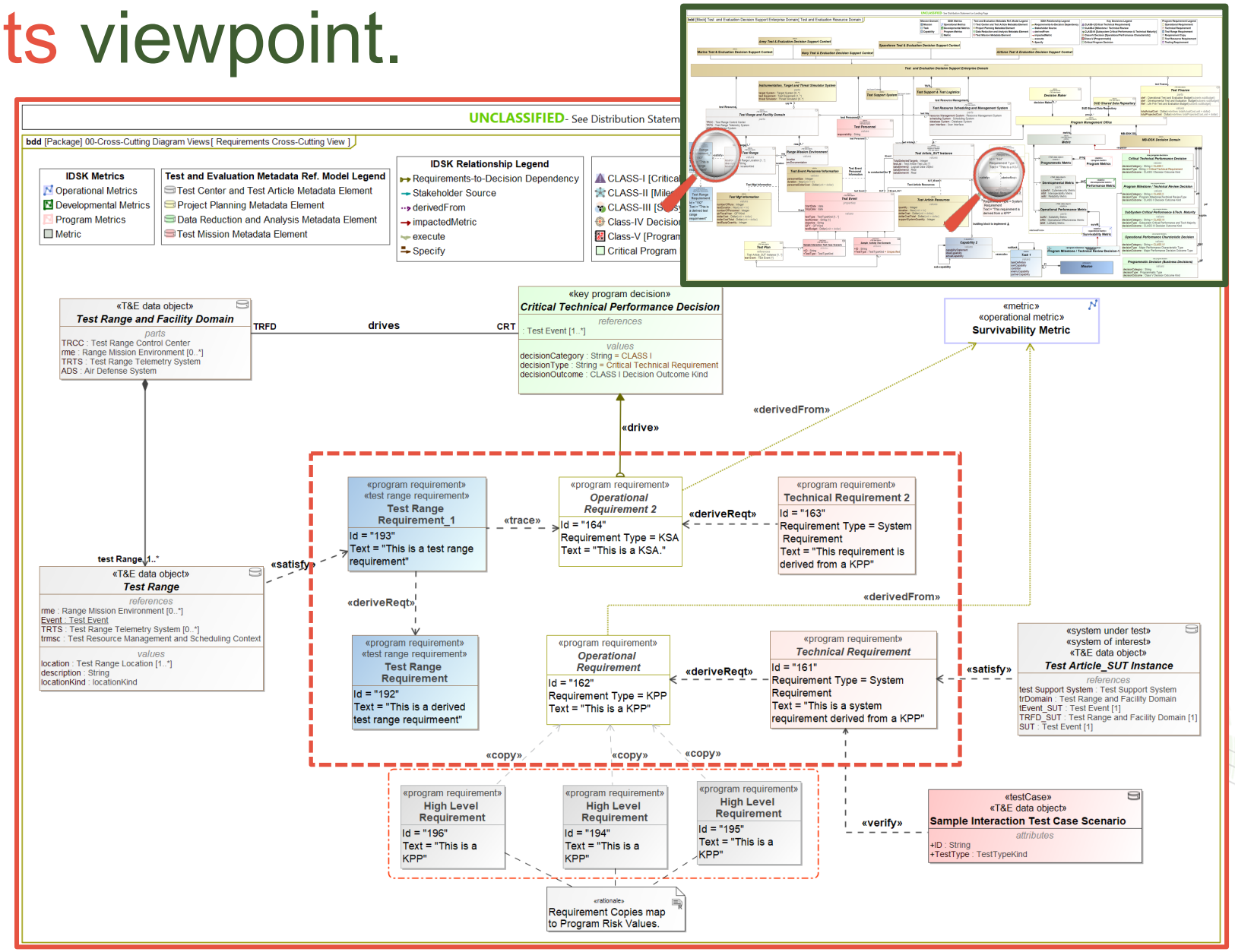
Ref. Arch.View (4) depicts the digital-IDSK architecture from the Test Article viewpoint.

- **Viewpoint Elements**
  - Test Article
  - Test Event
  - Test Plan
  - Test Scenario
  - Requirements
  - Decision
- **Viewpoint Concern**
  - What are the required relationships, and structural elements needed to support generation of the digital-IDSK test article-based standardized views?



Ref. Arch.View (5) depicts the digital-IDSK architecture from a Requirements viewpoint.

- **Viewpoint Elements**
  - Operational Requirement
  - Technical / System Req.
  - Test Range Requirement
  - Requirement Copy
  - Program Decision
  - Test Range
  - Test Article
  - Metric
- **Viewpoint Concern-**
  - What are the required requirements, relationships, and structural elements needed to support generation of the digital-IDSK requirements-based standardized views?



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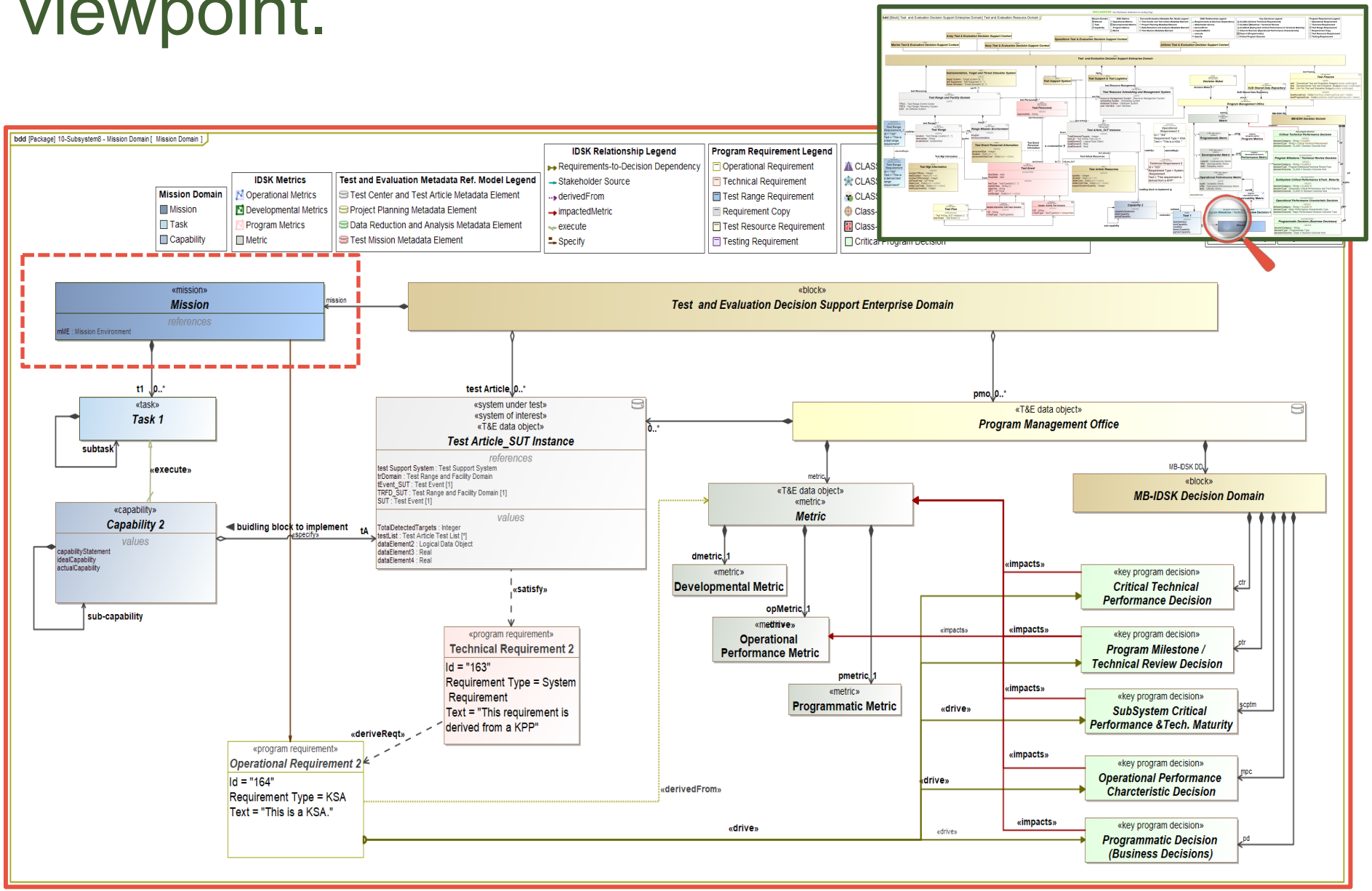
Ref. Arch.View (6) depicts the digital-IDSK architecture from a Mission viewpoint.

- Viewpoint Elements
  - Mission
  - Task
  - Capability
  - Test Article
  - Operational Req.
  - Metrics
  - Decision
- Viewpoint Concern
  - What are the required relationships, and structural elements needed to support the generation of the digital-IDSK mission-based standardized views?



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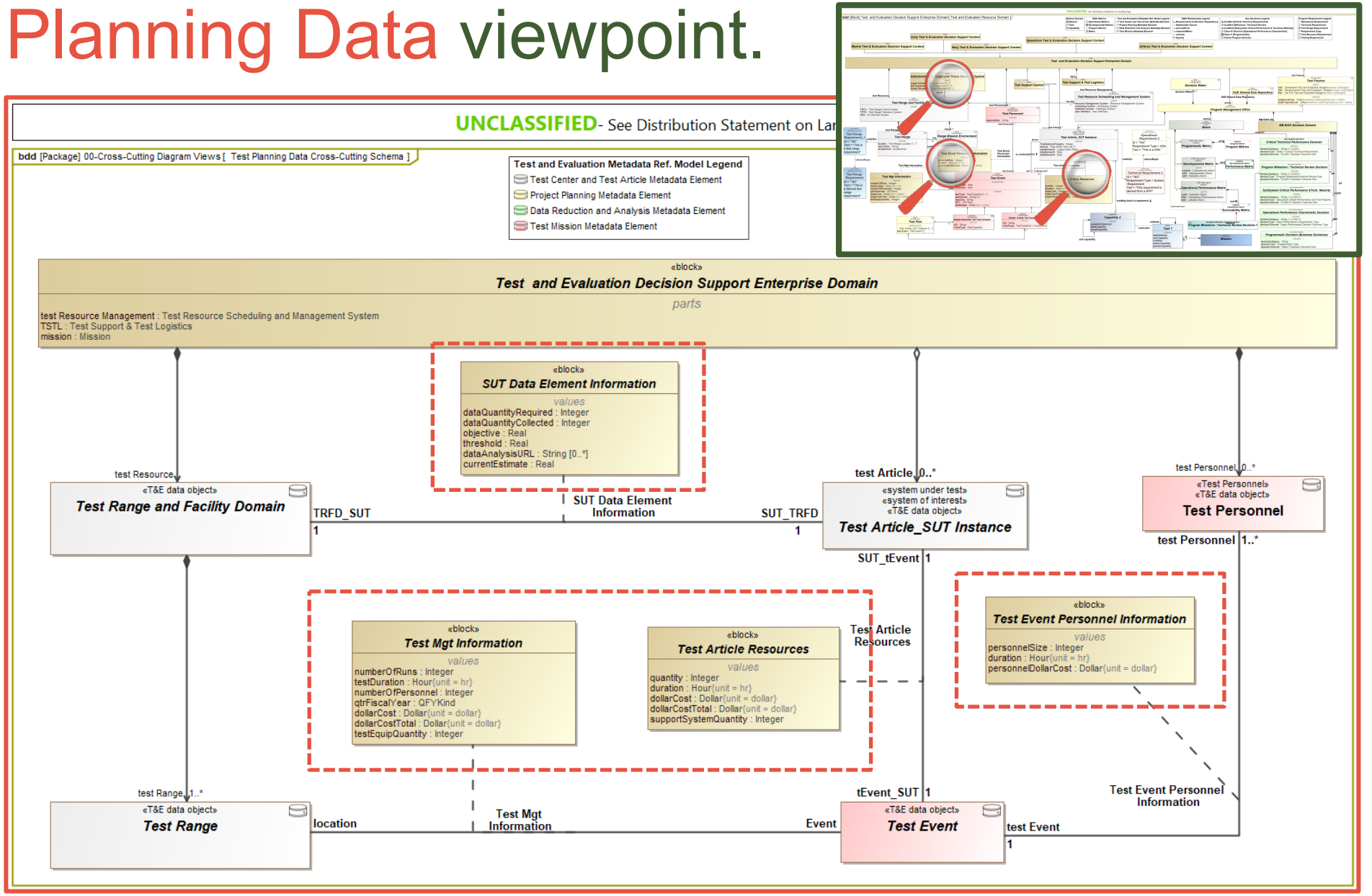
Ref. Arch.View (7) depicts the digital-IDSK architecture from the Test Planning Data viewpoint.

- **Viewpoint Elements**
  - Test Range Domain
  - Test Article
  - Test Personnel
  - Test Event
  - Test Resource Info
- **Viewpoint Concern**
  - What are the required relationships, and structural elements needed to support the generation of the digital-IDSK resources & crosswalk views?



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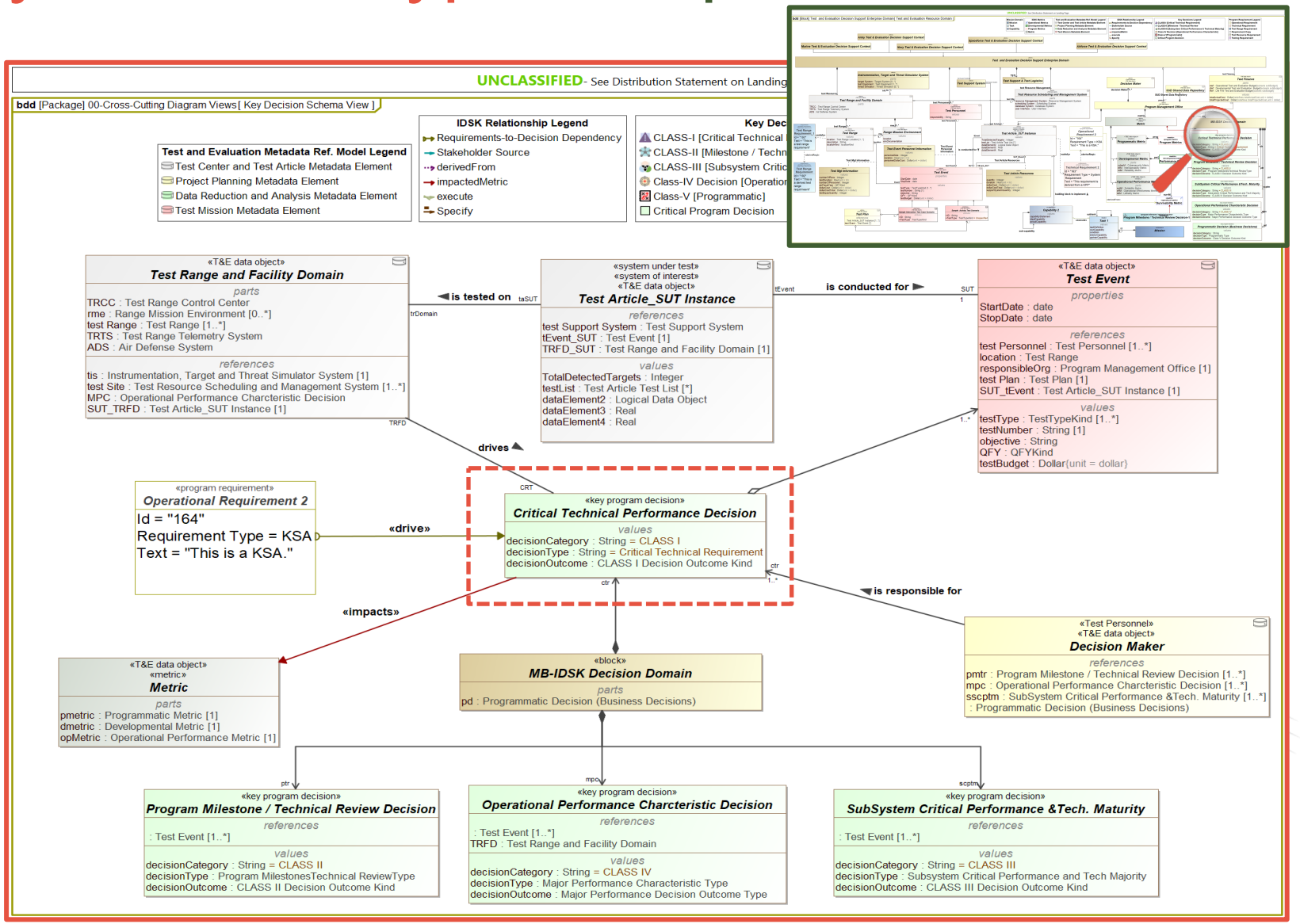
Ref. Arch.View (8) depicts the digital-IDSK architecture from the Class I Key Decision-type viewpoint.

- **Viewpoint Elements**
  - Key Decisions
  - Decisions Domain
  - Decision Maker
  - Test Range
  - Test Event
- **Viewpoint Concern**
  - What are the required relationships, and structural elements needed to support the generation of the digital-IDSK program decision standardized views?



The Missile Speed Test Configuration Context is set up with the relevant decision support architecture elements

1 – SUT

2 – Test Environment

3 – Tester Personnel

4 – Test Event

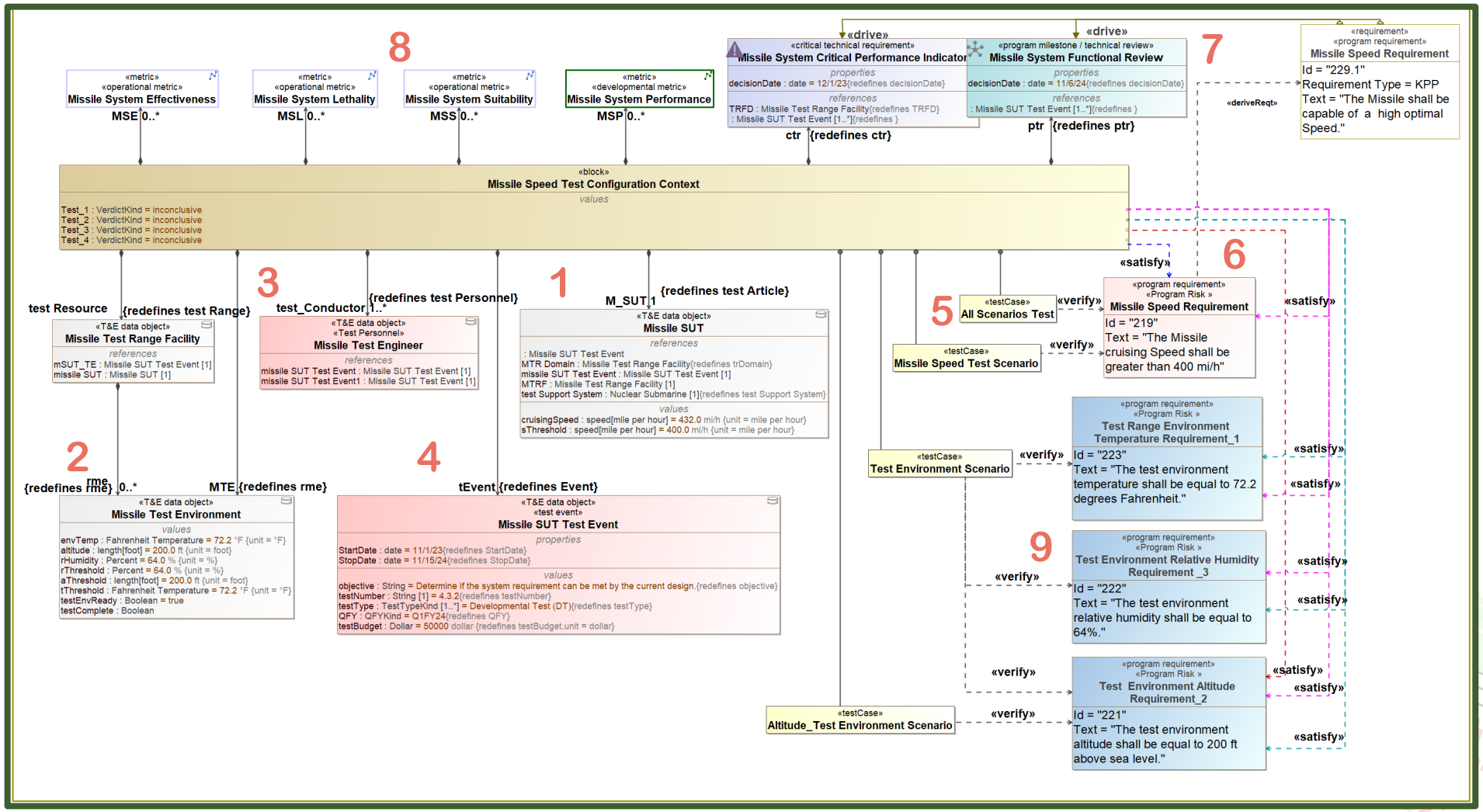
5 – Test Case

6 – System Req.

7 – Key Prog. Decision

8 – Operational Metrics

9 – Test Range Req.



Missile System T&E Decision Support Domain instance specifies elements for the missile system's digital-IDSK.