Shifting Left: Opportunities to Reduce Defense Acquisition Cycle Time by Fully Integrating Test and Evaluation in Model Based Systems Engineering

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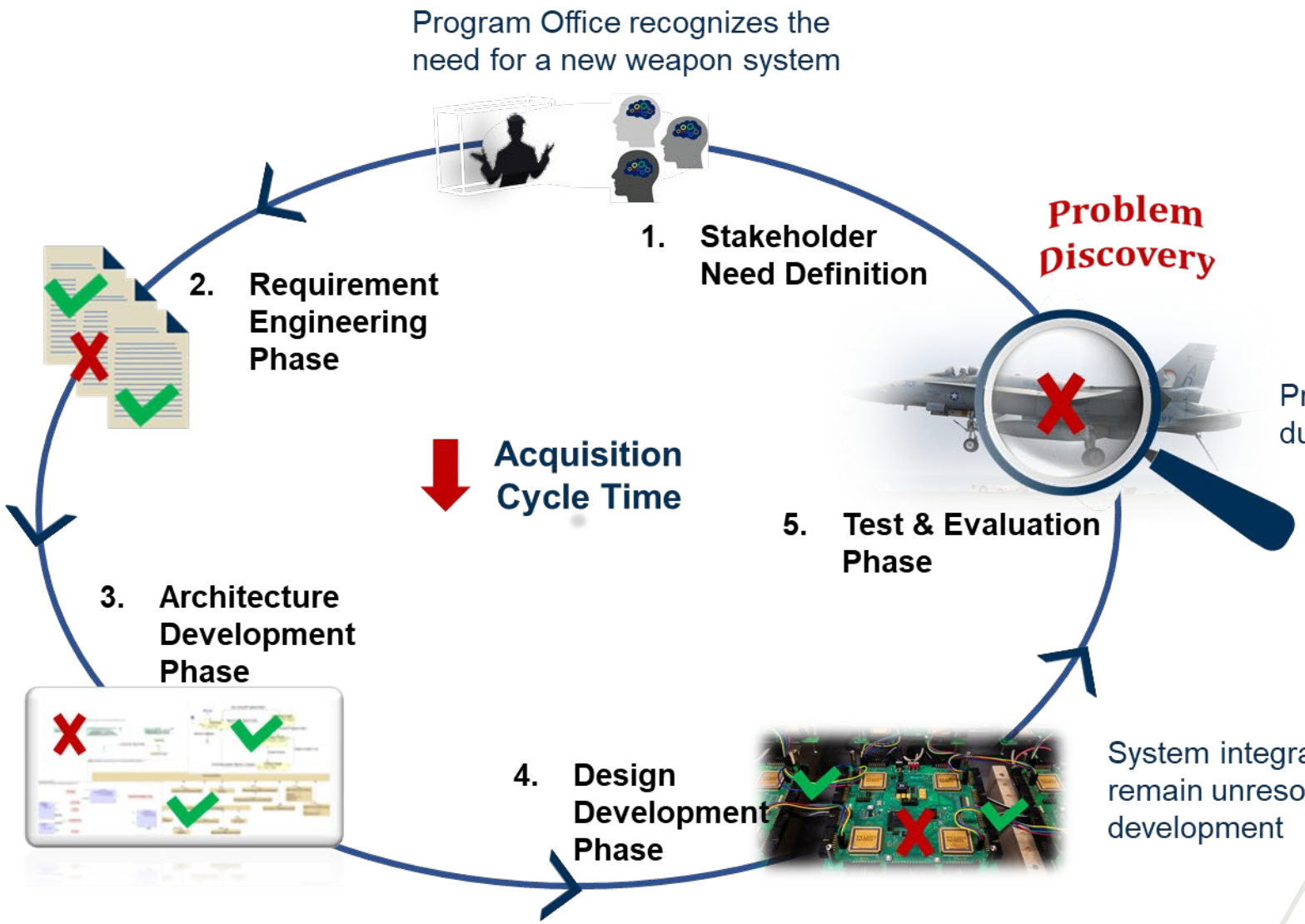
Problem Discovery during test and evaluation (T&E) significantly impacts the acquisition cycle time of programs.



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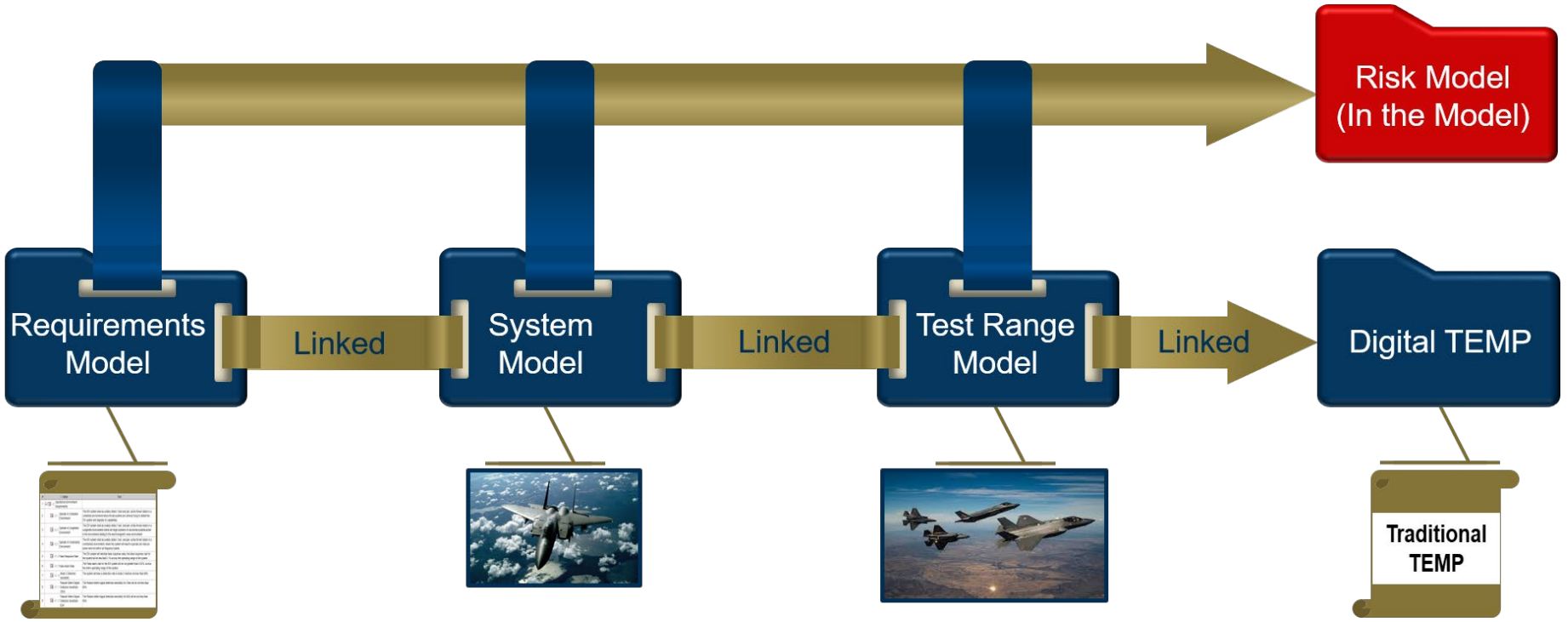
Integrating T&E into MBSE will accelerate the delivery of high-quality weapon systems at the speed of need.

- Second strategy pillar of DOT&E strategy points to the need for MBSE to achieve a shift-left
- Detailed modeling of T&E processes and risk is key to accelerating systems development.
- Data collected during T&E processes is critical to making good decisions about crucial aspects of a program



Acquisition Life Cycle Modeling Structure

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The absence of an integrated digital engineering (DE) framework for T&E impacts delivery of weapon systems.

DOD Pain Point

Current acquisition processes and engineering methods hinder meeting the demands of exponential technology growth, complexity, and access to information.

DOT&E Pain Point

Inadequate problem discovery during testing and evaluation (T&E) has significant impact on the acquisition cycle time of weapon systems.

Our goal is to optimize the shift-left approach to aid the delivery of weapon systems at the speed of need.

Proposed Strategy

Implement DE in a manner that specifically addresses speed, risk, and quality of decision making across portfolios in a manner responsive to relevant missions.

Proposed Strategy

Implement robust T&E and risk modeling to generate the data, visibility, and insights to make decisions to accelerate acquisition programs.

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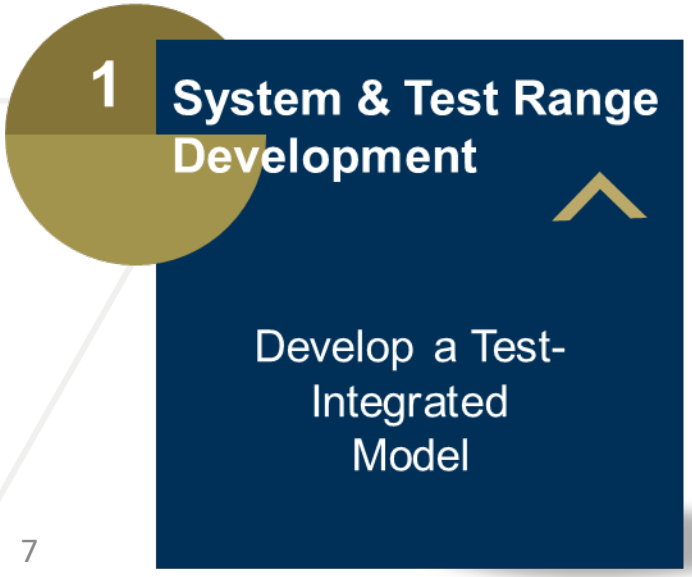
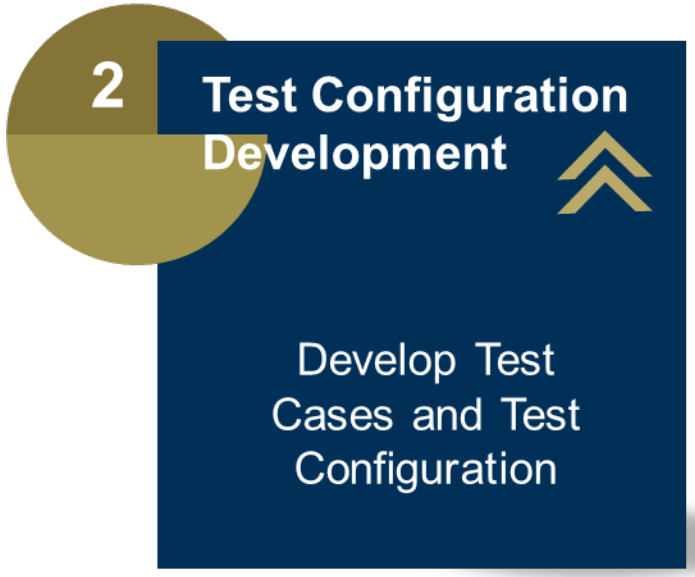
A model-based T&E and risk modeling integrated approach aligns DE technologies with current acquisition policies.

The 3-step integrated approach involves:

- **Requirements, System, and Test Capability Definition**
- **KPP's and MOEs Test Case Definition**
- **Risk Function Definition**





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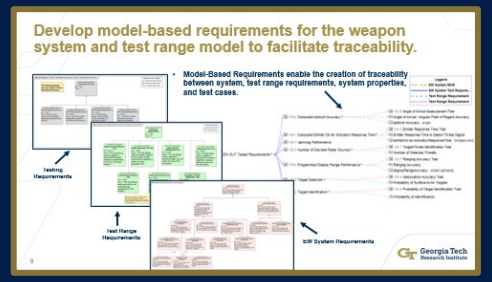
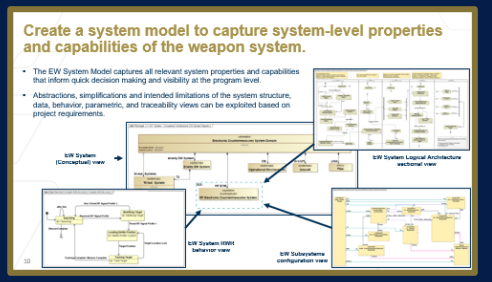
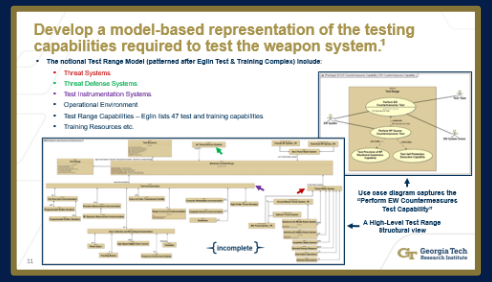
Develop a set of models that specify and define the requirements, weapon system, and test range data.

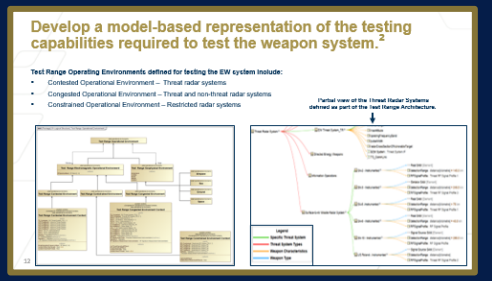
1 **System & Test Range Development**

Develop a Test-Integrated Model









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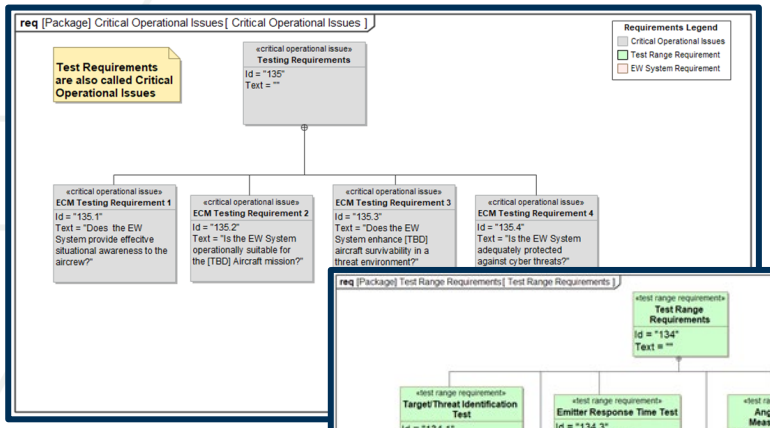
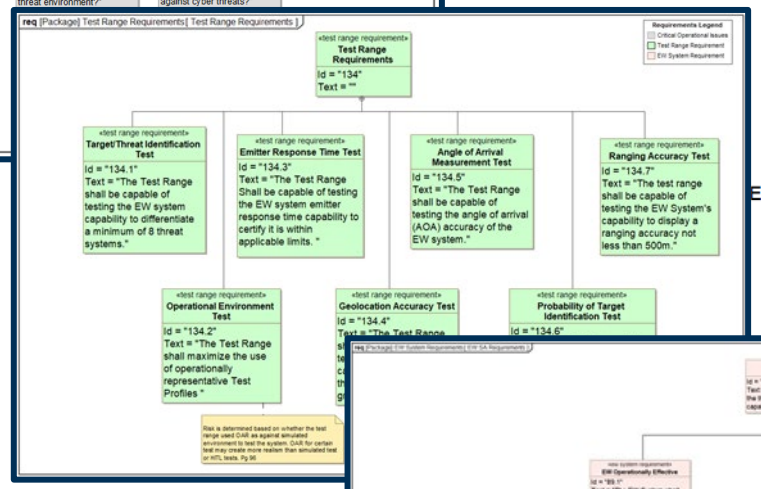
Develop model-based requirements for the weapon system and test range model to facilitate traceability.

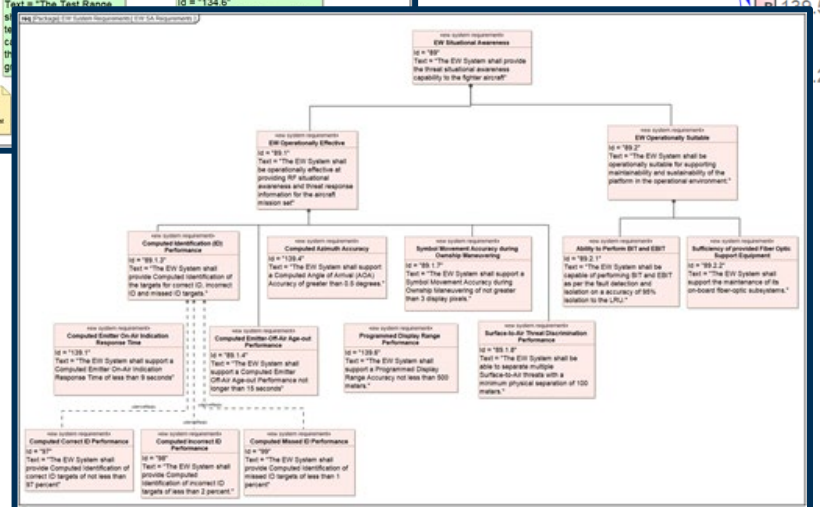
- **Model-Based Requirements enable the creation of traceability between system, test range requirements, system properties, and test cases.**



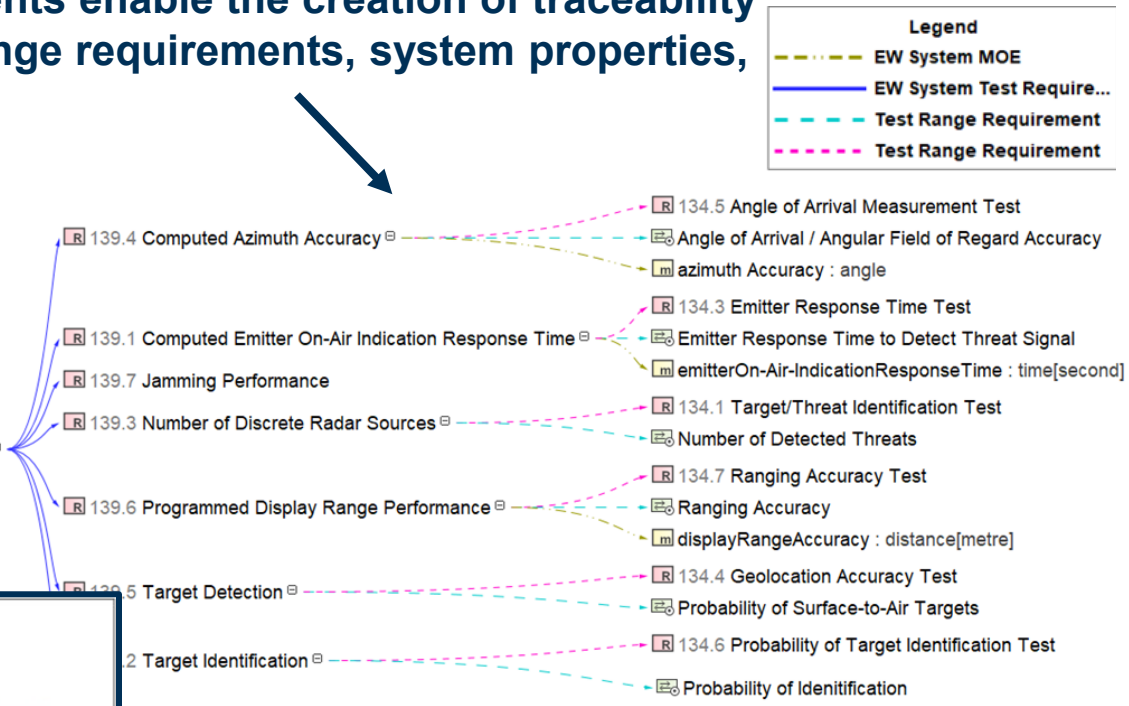
Testing Requirements



Test Range Requirements



EW System Requirements



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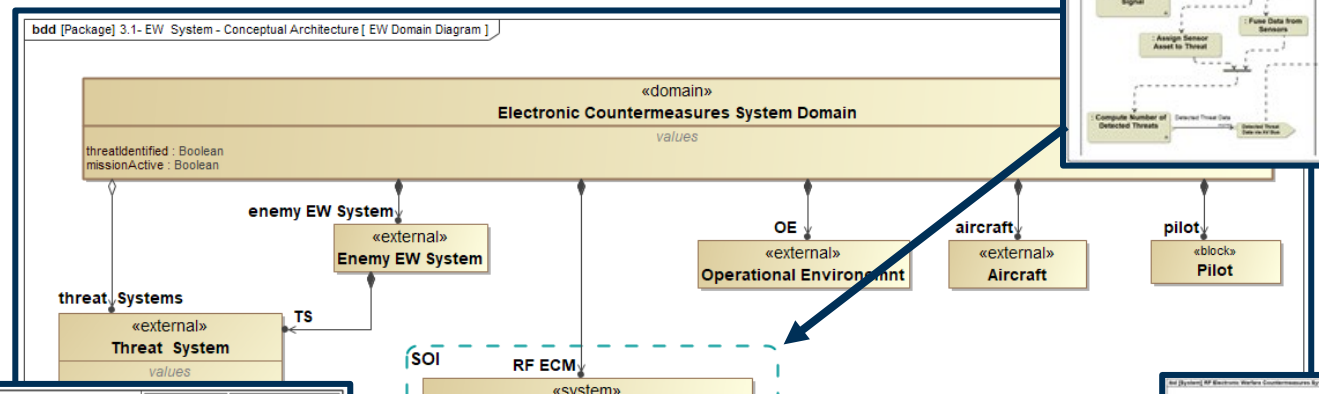
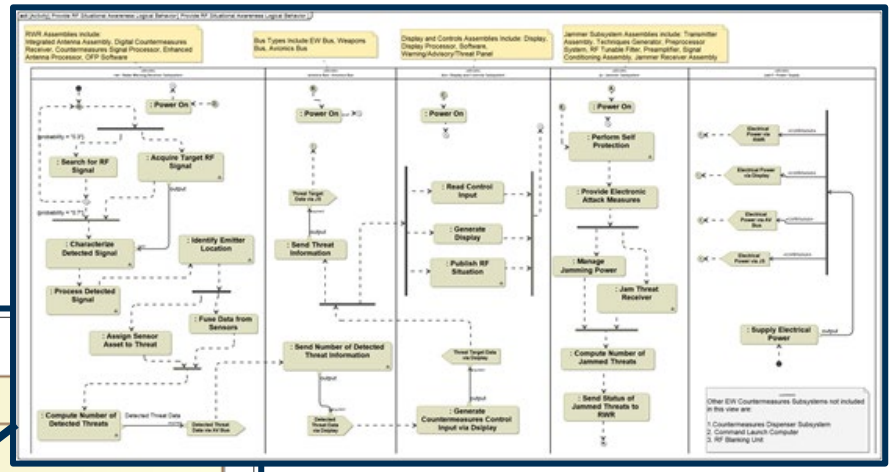
Create a system model to capture system-level properties and capabilities of the weapon system.

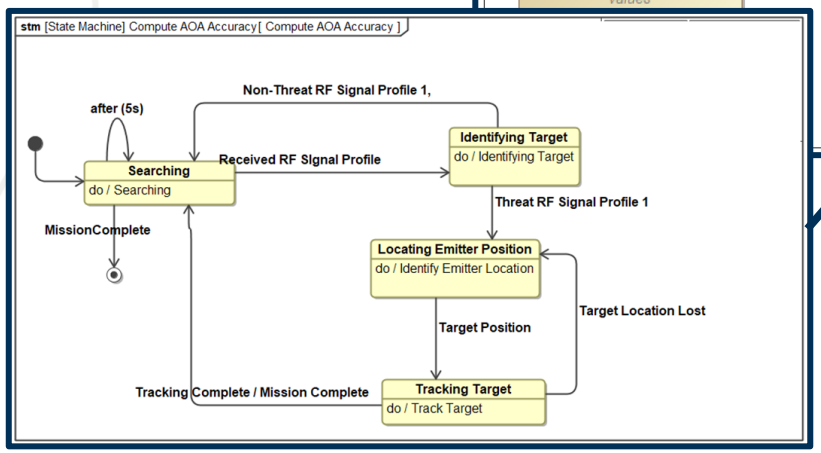
- The EW System Model captures all relevant system properties and capabilities that inform quick decision making and visibility at the program level.
- Abstractions, simplifications and intended limitations of the system structure, data, behavior, parametric, and traceability views can be exploited based on project requirements.

EW System (Conceptual) view

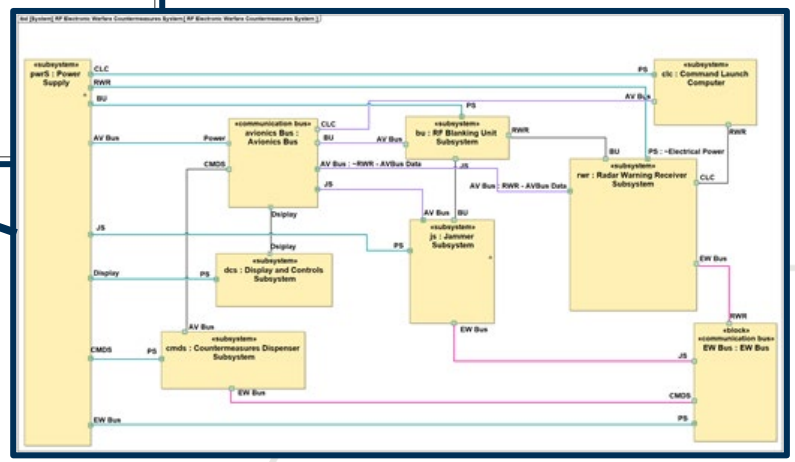




EW System Logical Architecture sectional view



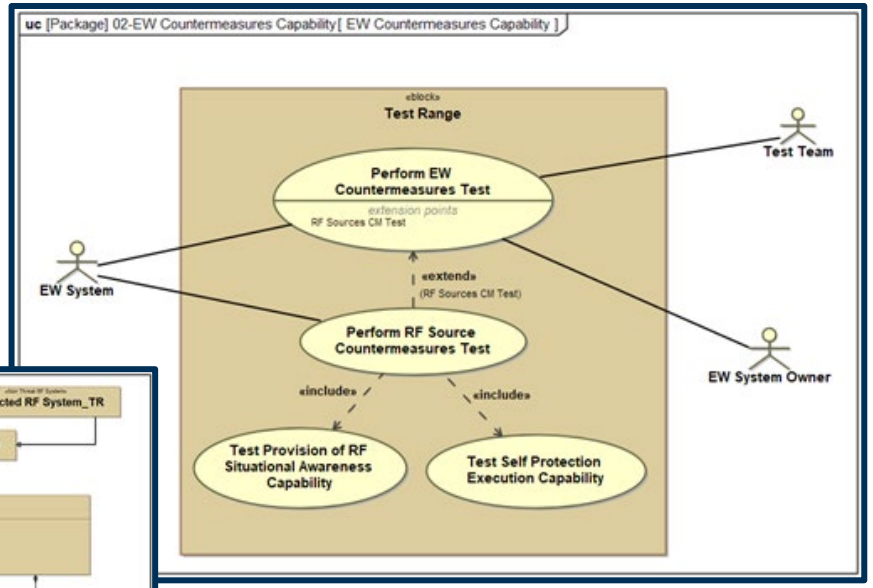
EW System RWR behavior view

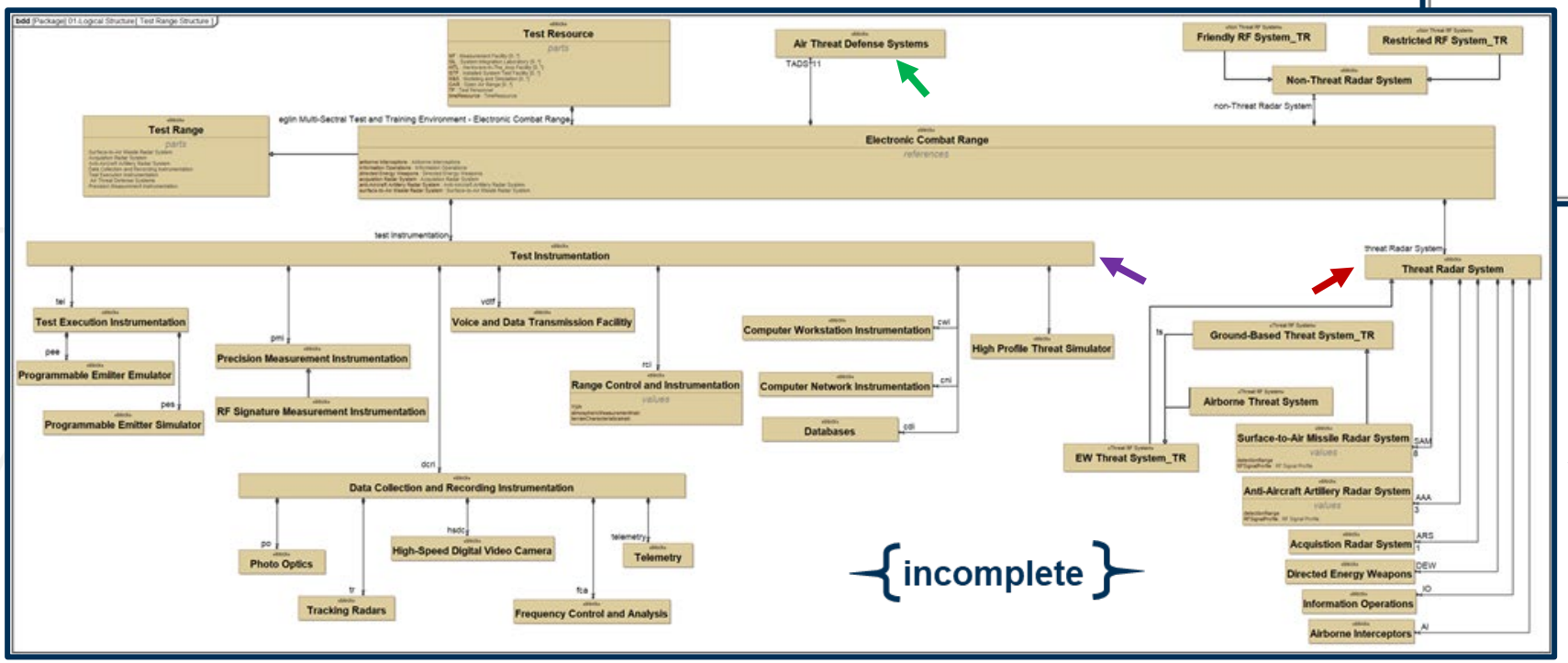


EW Subsystems configuration view

Develop a model-based representation of the testing capabilities required to test the weapon system.[1]

- **The notional Test Range Model (patterned after Eglin Test & Training Complex) include**:
  - Threat Systems
  - Threat Defense Systems
  - Test Instrumentation Systems
  - Operational Environment
  - Test Range Capabilities – Eglin lists 47 test and training capabilities
  - Training Resources etc.





Use case diagram captures the "Perform EW Countermeasures Test Capability"

A High-Level Test Range Structural view

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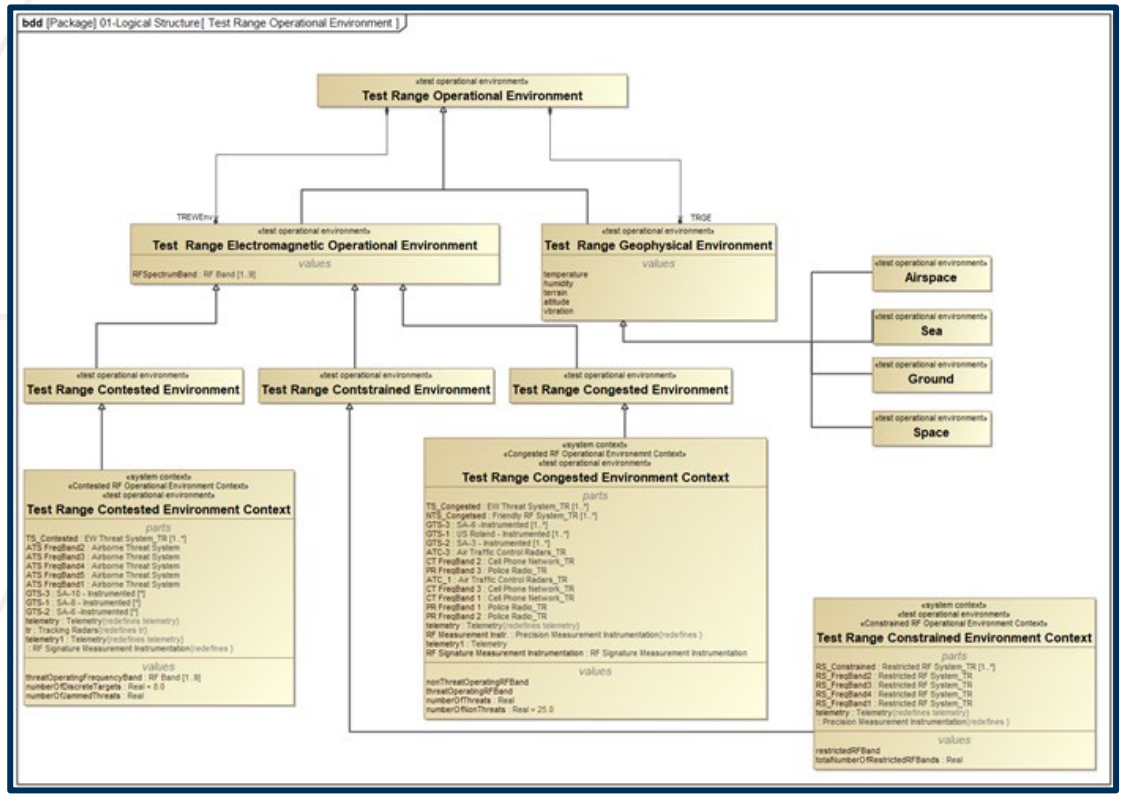
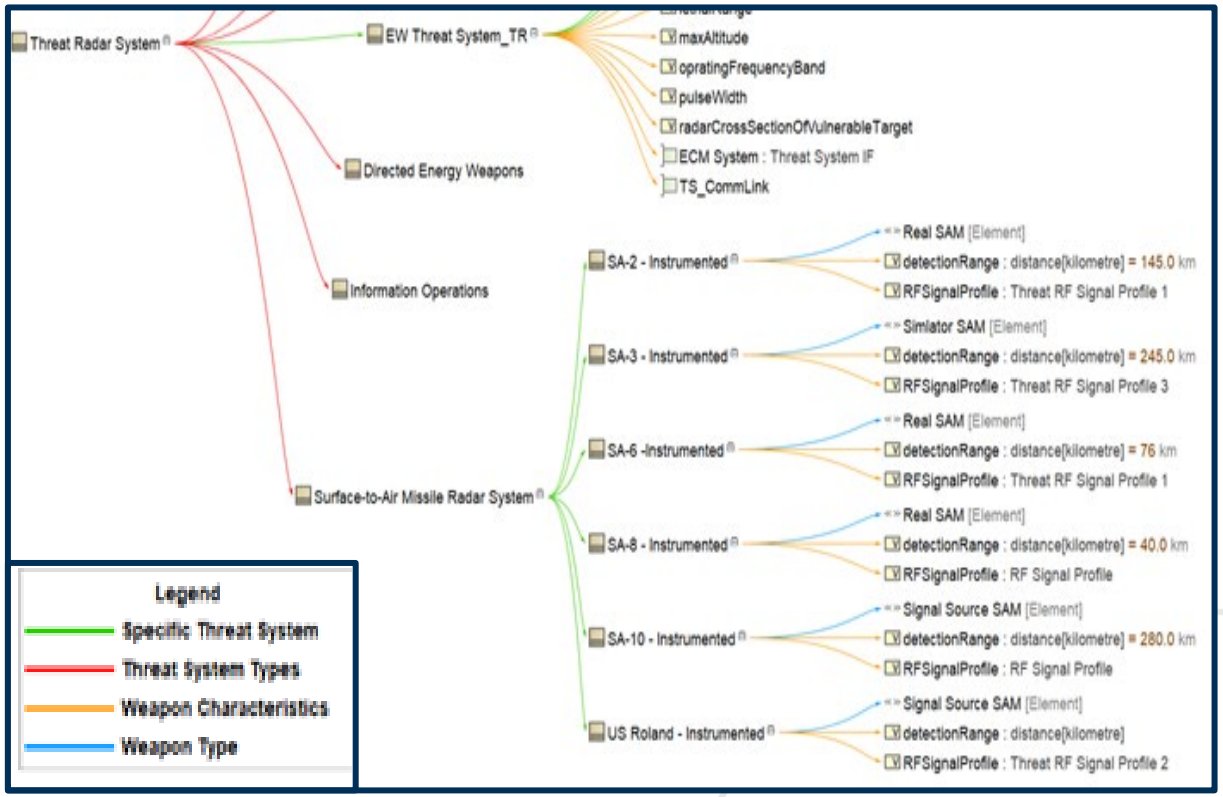
Develop a model-based representation of the testing capabilities required to test the weapon system.[2]

Test Range Operating Environments defined for testing the EW system include:

- Contested Operational Environment – Threat radar systems
- Congested Operational Environment – Threat and non-threat radar systems
- Constrained Operational Environment – Restricted radar systems



Partial view of the Threat Radar Systems defined as part of the Test Range Architecture.

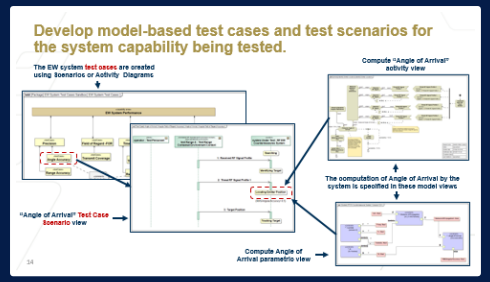


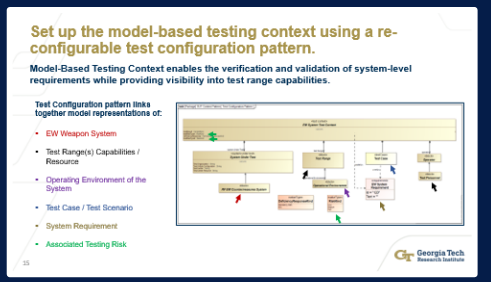
Perform Model-Based Testing of evaluable weapon system properties and capabilities.

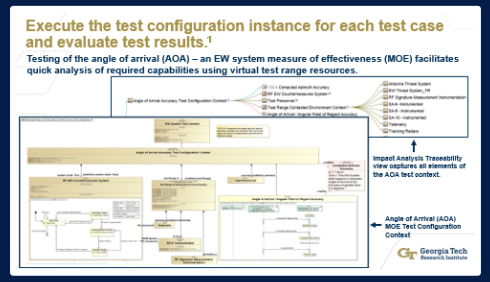
2

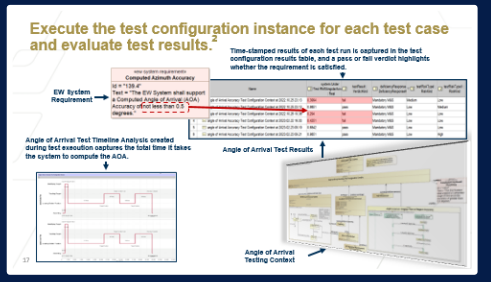
Test Configuration Development

Develop Test Cases and Test Configuration









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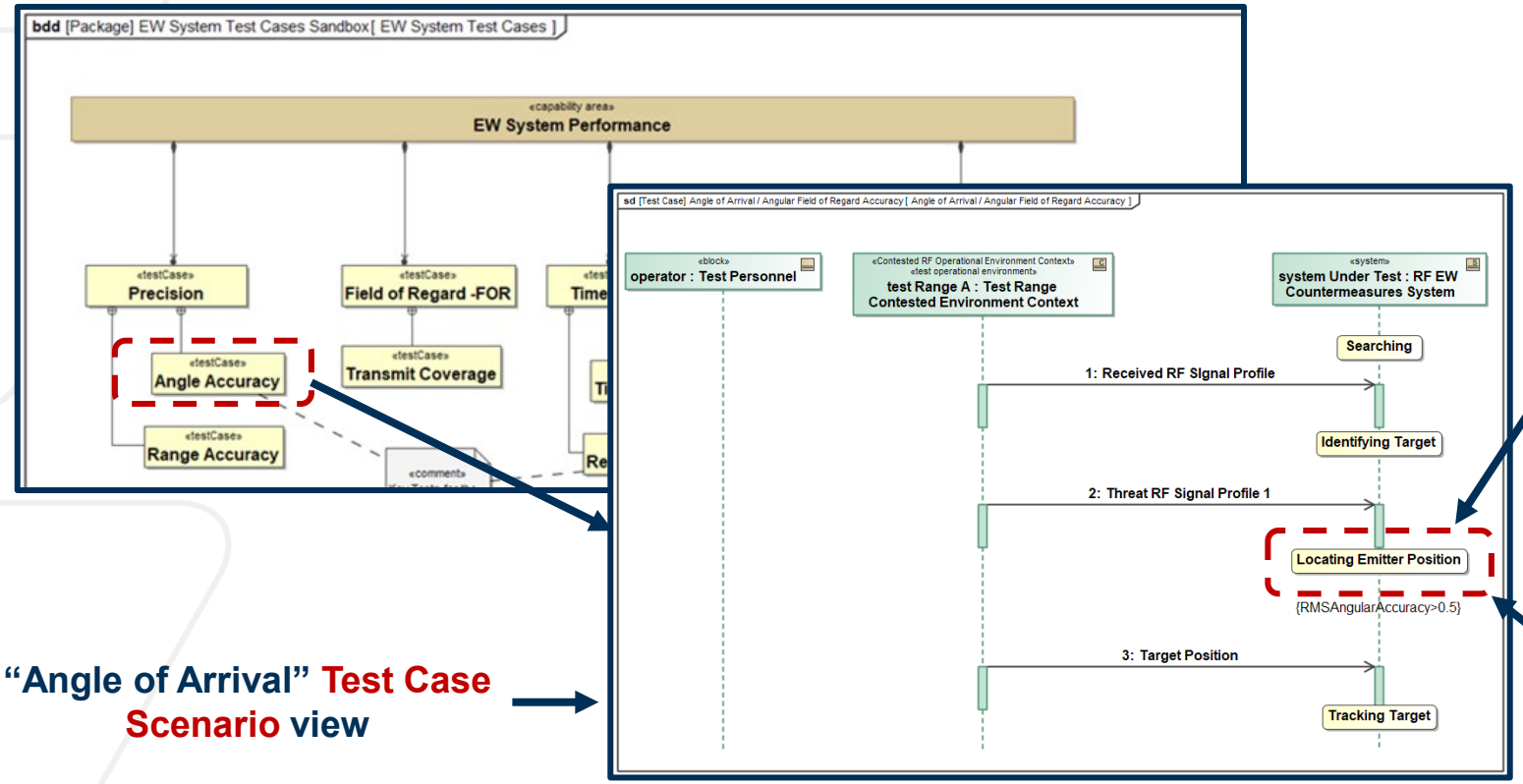
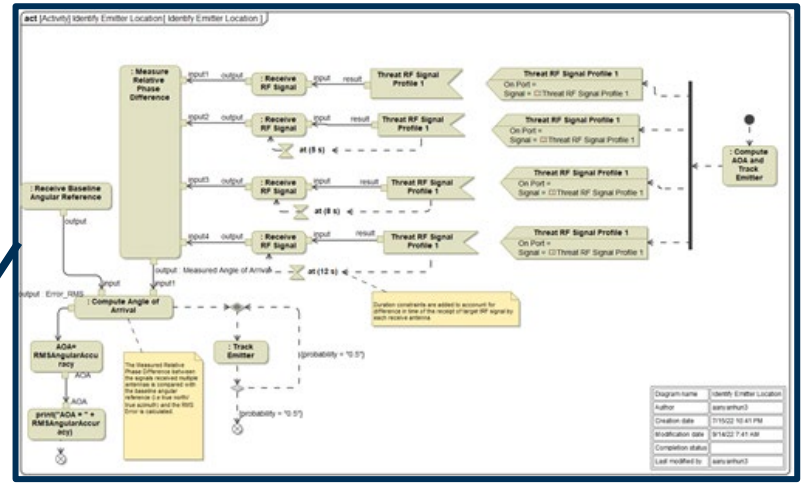
Develop model-based test cases and test scenarios for the system capability being tested.

The EW system test cases are created using Scenarios or Activity Diagrams



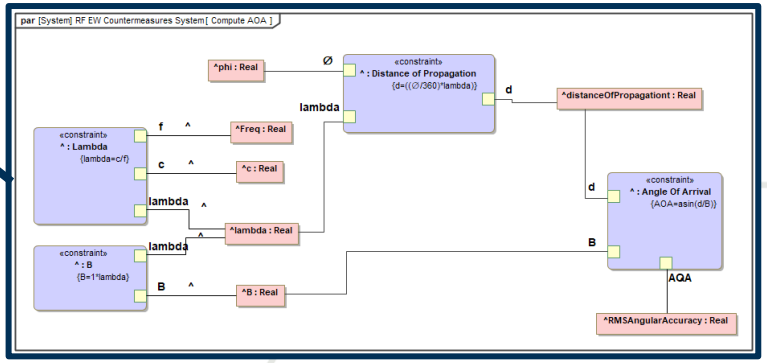
"Angle of Arrival" Test Case Scenario view

Compute "Angle of Arrival" activity view



The computation of Angle of Arrival by the system is specified in these model views

Compute Angle of Arrival parametric view

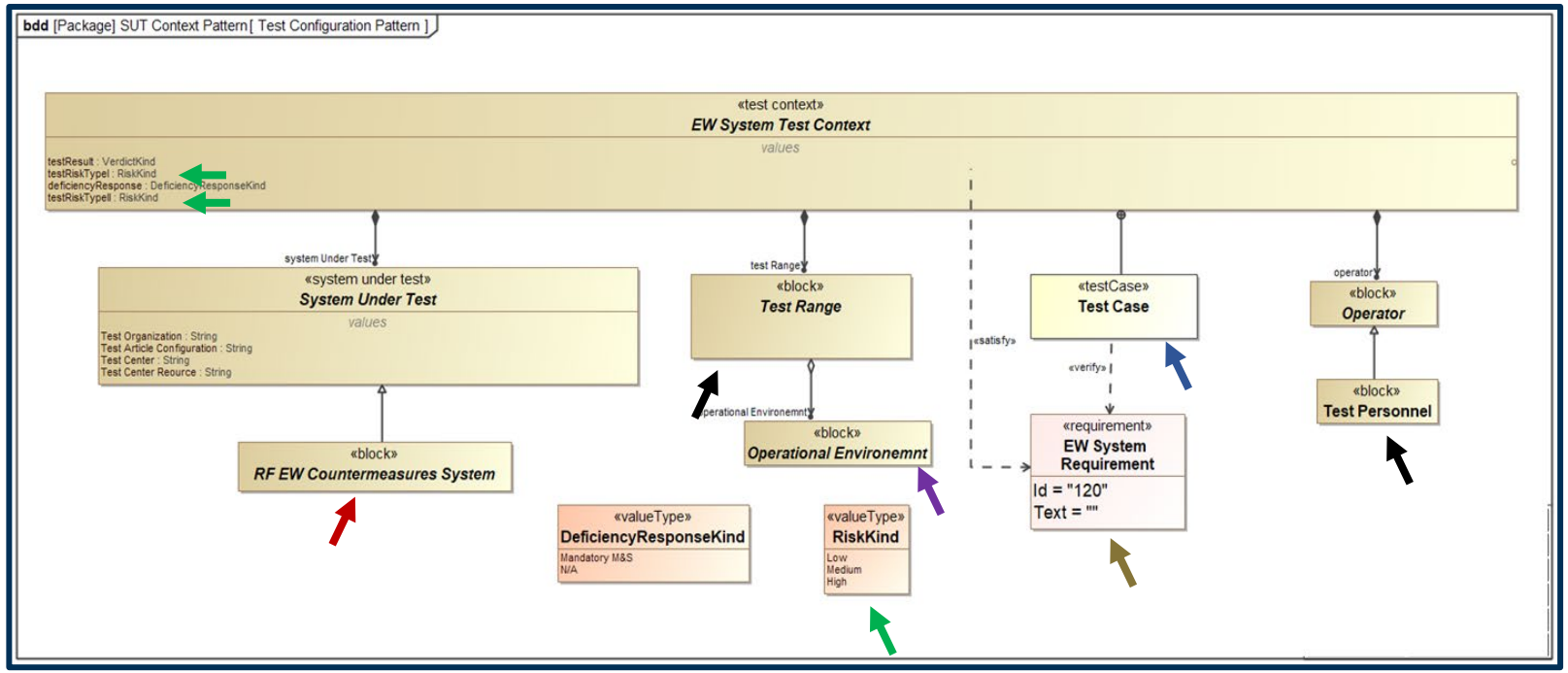


Set up the model-based testing context using a re-configurable test configuration pattern.

Model-Based Testing Context enables the verification and validation of system-level requirements while providing visibility into test range capabilities.

Test Configuration pattern links together model representations of:

- EW Weapon System
- Test Range(s) Capabilities / Resource
- Operating Environment of the System
- Test Case / Test Scenario
- System Requirement
- Associated Testing Risk



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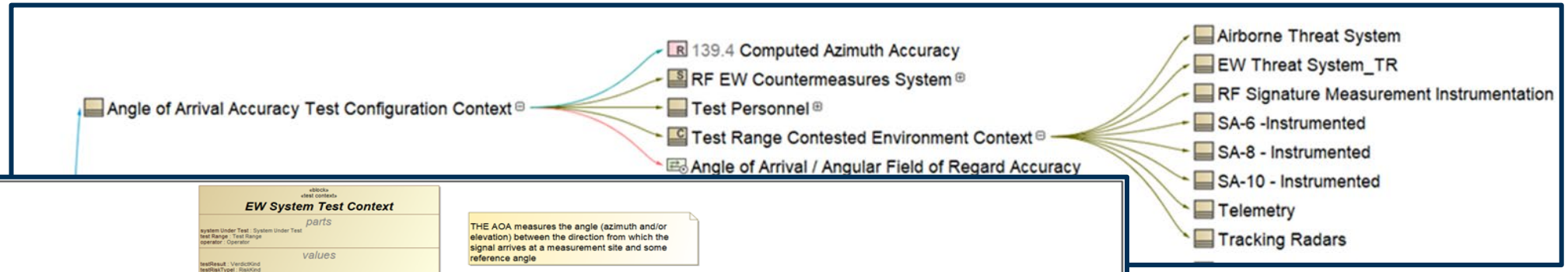
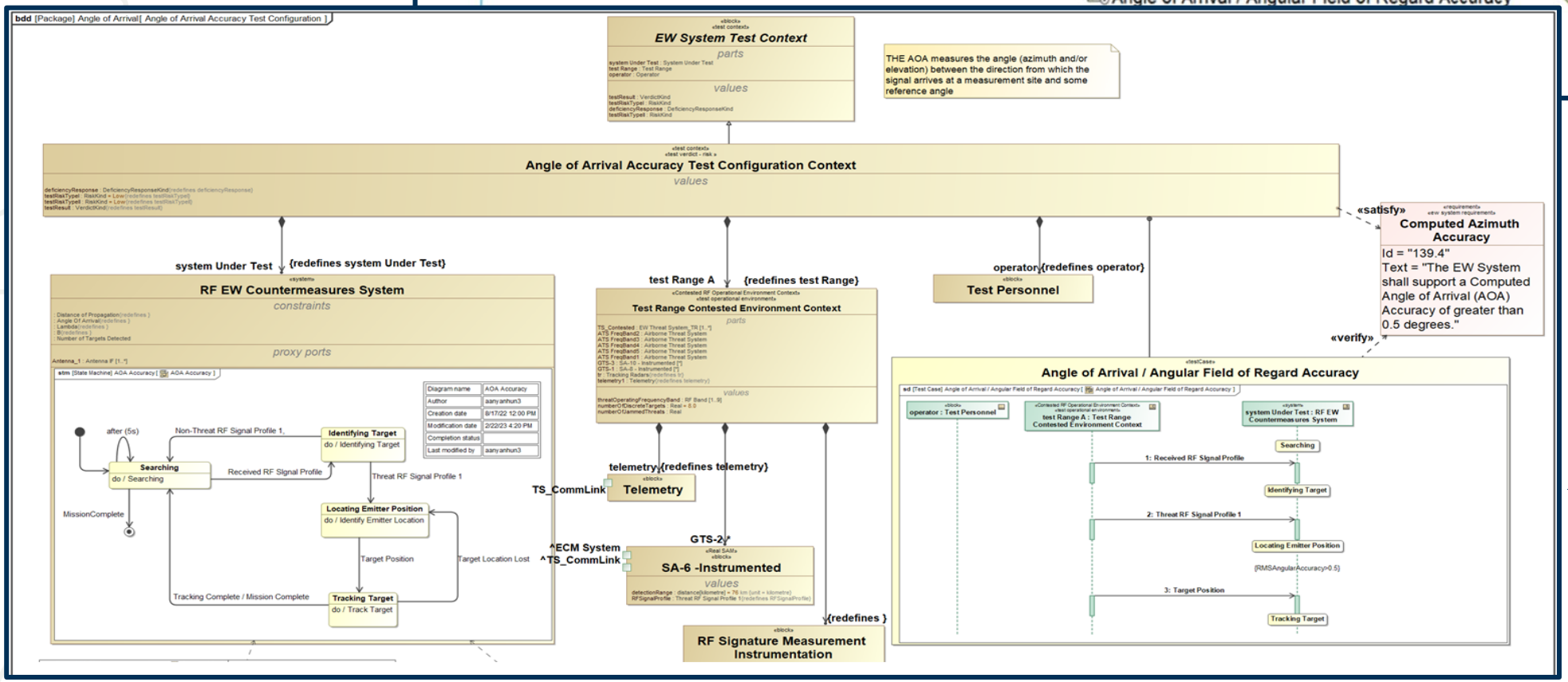
Execute the test configuration instance for each test case and evaluate test results.[1]

Testing of the angle of arrival (AOA) – an EW system measure of effectiveness (MOE) facilitates quick analysis of required capabilities using virtual test range resources.





Impact Analysis Traceability view captures all elements of the AOA test context.

Angle of Arrival (AOA) MOE Test Configuration Context

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Execute the test configuration instance for each test case and evaluate test results.[2]

Time-stamped results of each test run is captured in the test configuration results table, and a pass or fail verdict highlights whether the requirement is satisfied.

EW System Requirement

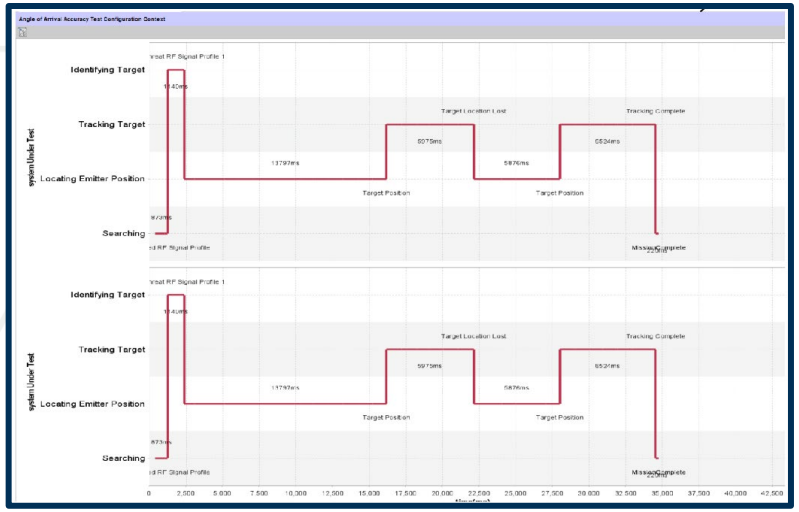
«ew system requirement»
Computed Azimuth Accuracy

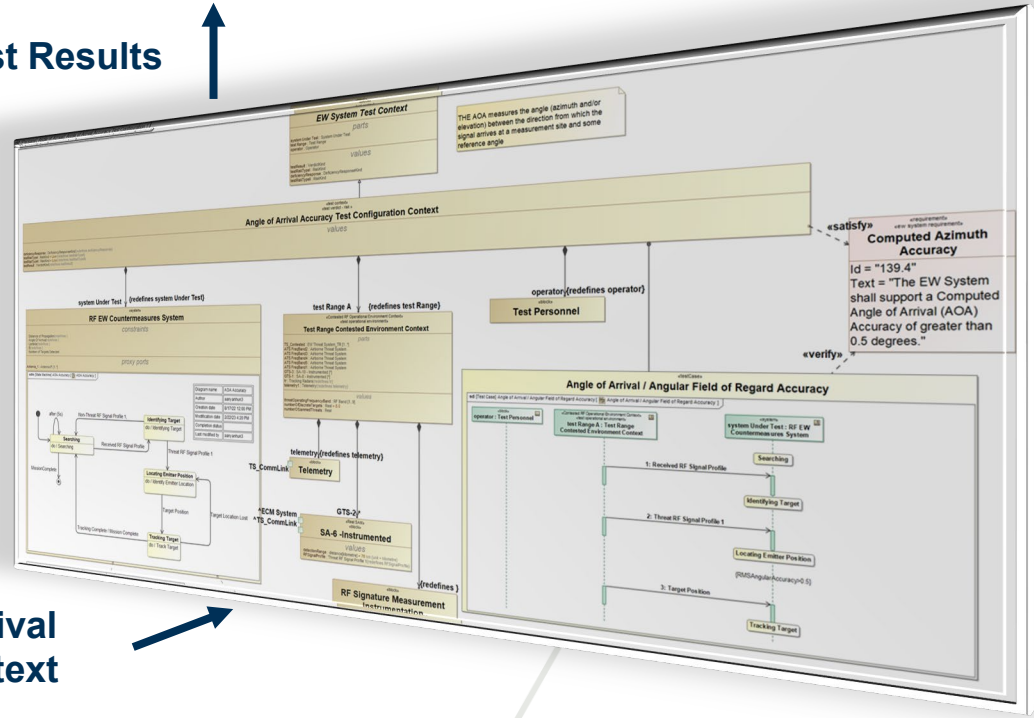
Id = "139.4"
Text = "The EW System shall support a Computed Angle of Arrival (AOA) Accuracy of not less than 0.5 degrees."

	Name	system Under Test.RMSAngularAccu : Real	testResult : VerdictKind	deficiencyResponse : DeficiencyResponseK	testRiskTypeI : RiskKind	testRiskTypeII : RiskKind
	gle of Arrival Accuracy Test Configuration Context at 2022.10.25 23.13	0.3994	fail	Mandatory M&S	Medium	Low
	gle of Arrival Accuracy Test Configuration Context at 2022.10.25 23.12	0.9851	pass	Mandatory M&S	Low	Medium
	gle of Arrival Accuracy Test Configuration Context at 2022.10.26 10.38	0.294	fail	Mandatory M&S	Low	Low
4	angle of Arrival Accuracy Test Configuration Context at 2023.02.22 16.03	0.4251	fail	Mandatory M&S	Low	Low
5	angle of Arrival Accuracy Test Configuration Context at 2023.02.23 09.19	0.6842	pass	Mandatory M&S	Low	Low
6	angle of Arrival Accuracy Test Configuration Context at 2023.02.23 09.21	0.9851	pass	Mandatory M&S	Low	High

Angle of Arrival Test Results

Angle of Arrival Test Timeline Analysis created during test execution captures the total time it takes the system to compute the AOA.





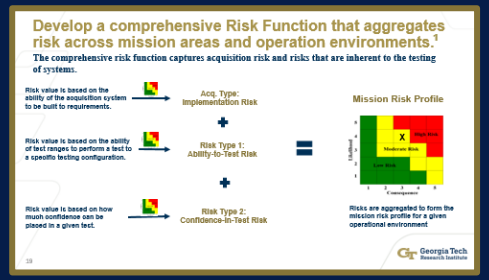
Angle of Arrival Testing Context

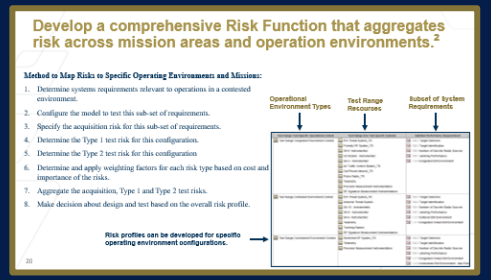
Analyze the risk inherent in testing the weapon systems using its mission-based risk profile.

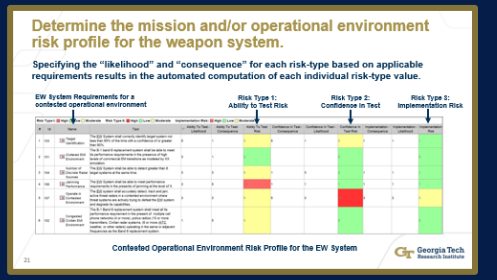
3

Risk Profile Development

Develop Risk Function Model







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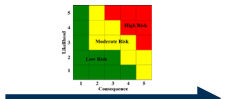
Develop a comprehensive Risk Function that aggregates risk across mission areas and operation environments.[1]

The comprehensive risk function captures acquisition risk and risks that are inherent to the testing of systems.

Risk value is based on the ability of the acquisition system to be built to requirements.



Acq. Type:
Implementation Risk

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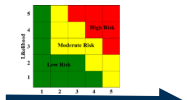
Risk value is based on the ability of test ranges to perform a test to a specific testing configuration.



Risk Type 1:
Ability-to-Test Risk

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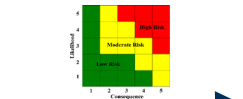
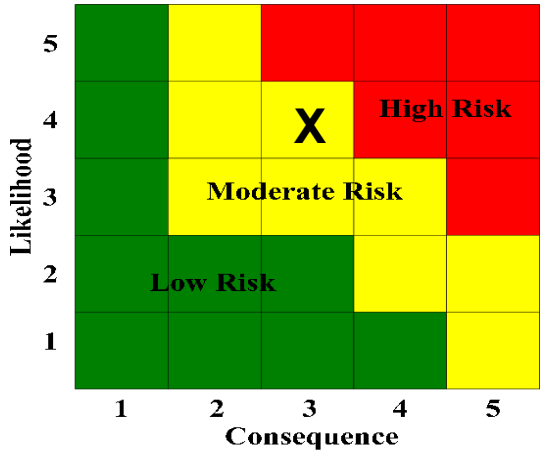
Risk value is based on how much confidence can be placed in a given test.



Risk Type 2:
Confidence-in-Test Risk

Mission Risk Profile



Risks are aggregated to form the mission risk profile for a given operational environment

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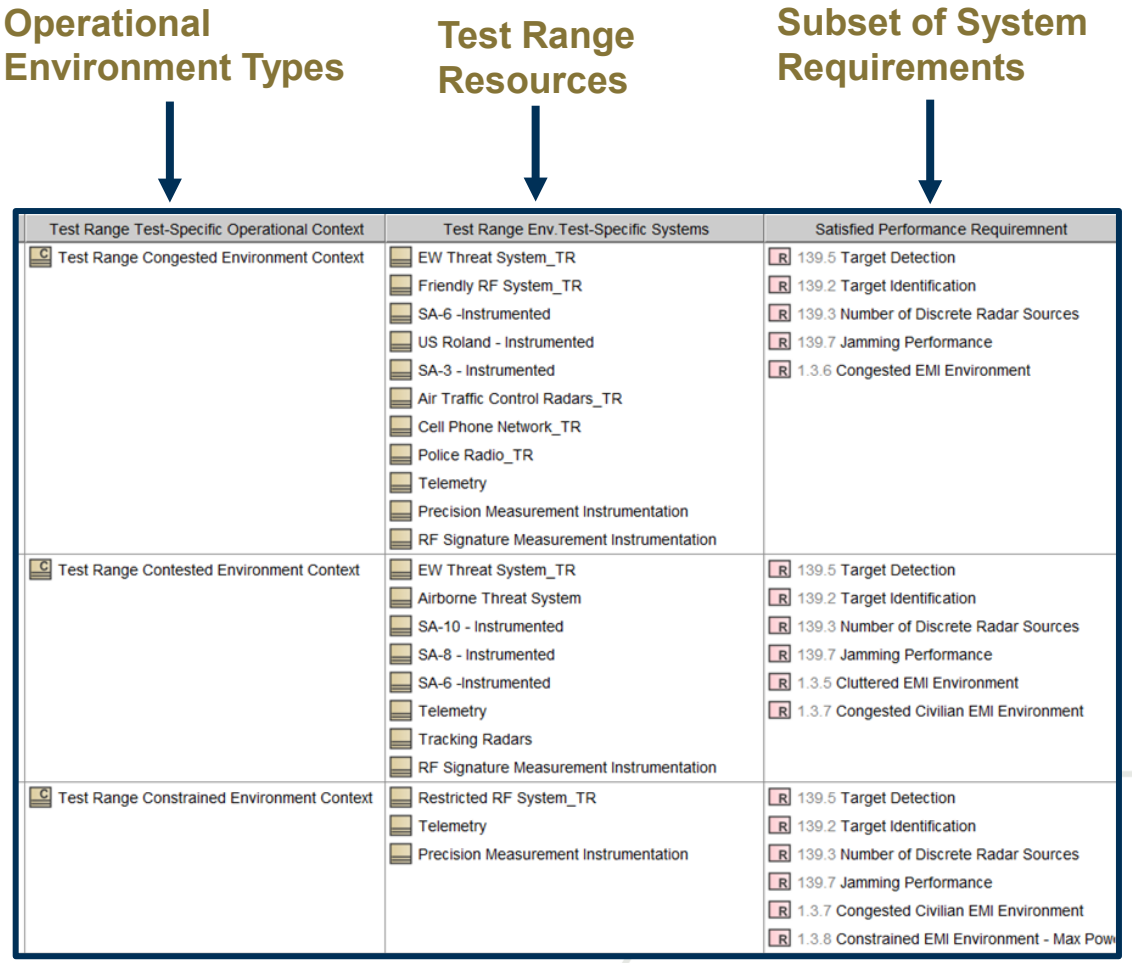
Develop a comprehensive Risk Function that aggregates risk across mission areas and operation environments.[2]

Method to Map Risks to Specific Operating Environments and Missions:

1. Determine systems requirements relevant to operations in a contested environment.
2. Configure the model to test this sub-set of requirements.
3. Specify the acquisition risk for this sub-set of requirements.
4. Determine the Type 1 test risk for this configuration.
5. Determine the Type 2 test risk for this configuration
6. Determine and apply weighting factors for each risk type based on cost and importance of the risks.
7. Aggregate the acquisition, Type 1 and Type 2 test risks.
8. Make decision about design and test based on the overall risk profile.

Risk profiles can be developed for specific operating environment configurations.



Determine the mission and/or operational environment risk profile for the weapon system.

Specifying the "likelihood" and "consequence" for each risk-type based on applicable requirements results in the automated computation of each individual risk-type value.

EW System Requirements for a contested operational environment

Risk Type 1: Ability to Test Risk

Risk Type 2: Confidence in Test

Risk Type 3: Implementation Risk

Risk Type I: High Low Moderate Risk Type II: High Low Moderate Implementation Risk: High Low Moderate

#	Id	Name	Text	Ability To Test - Likelihood	Ability To Test- Consequence	Ability To Test Risk	Confidence In Test - Consequence	Confidence In Test - Likelihood	Confidence In Test Risk	Implementation - Consequence	Implementation - Likelihood	Implementation Risk
1	153	R Target Identification	The EW System shall correctly identify target system not less than 95% of the time with a confidence of or greater than 90%.	5	1	5	5	1	5	1	1	1
2	151	R Cluttered EMI Environment	The B-1 band 8 replacement system shall be able to meet its performance requirements in the presence of high levels of commercial EM transitions as modeled by XX simulation.	3	1	3			0			0
3	154	R Number of Discrete Radar Sources	The EW System shall be able to detect greater than 8 target systems at the same time.	3	3	9	1	3	3	1	1	1
4	156	R Jamming Performance	The EW System shall be able to meet performance requirements in the presents of jamming at the level of X.	3	5	15	1	1	1	1	1	1
5	157	R Operate in Contested Environment	The EW system shall accurately detect, track and jam, active threat radars in a contented environment where threat systems are actively trying to defeat the EW system and degrade its capabilities.	3	3	9	5	3	15	3	3	0
6	152	R Congested Civilian EMI Environment	The B-1 Band 8 replacement system shall meet all its performance requirement in the present of multiple cell phone networks (4 or more), police radios (15 or more transmitters, Civilian radar systems, (6 or more (ATC, weather, or other radars) operating in the same or adjacent frequencies as the Band 8 replacement system.	1	5	5			0			0

Contested Operational Environment Risk Profile for the EW System

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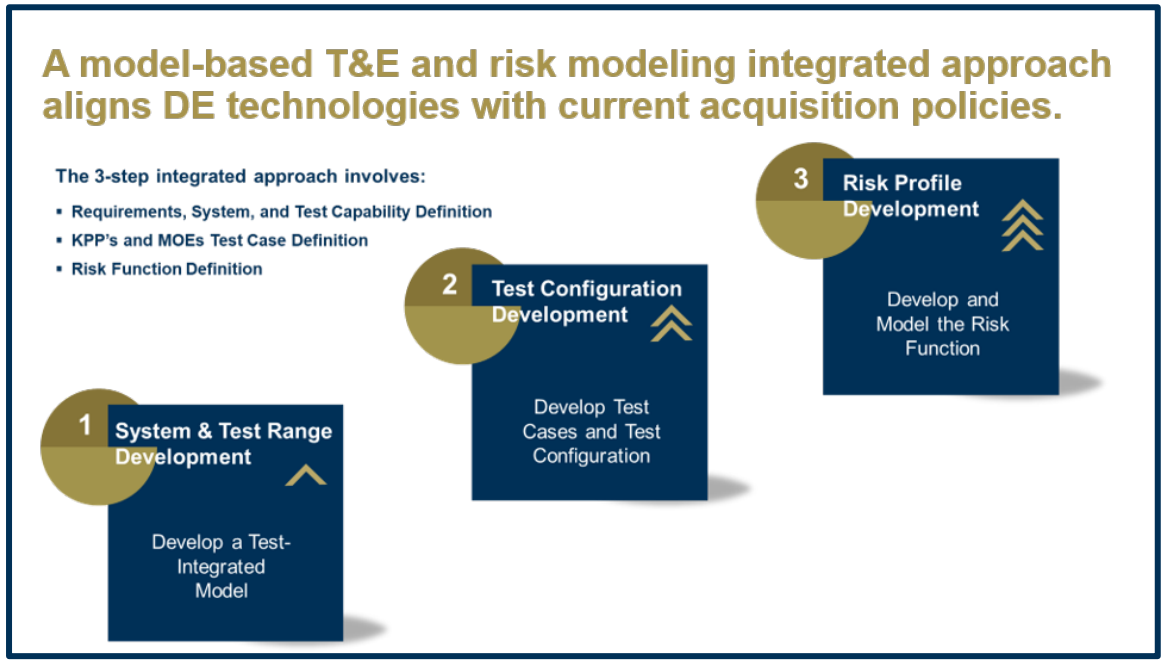
In summary, expanding the use of MBSE to include T&E and risk modeling enables a shift-left in acquisition cycle time.

MBSE and DE accelerate DOD programs through improved visibility and management of program performance.

- *T&E Modeling* allows a program office effectively plan and manage test programs.
- *Risk Function* model addresses risk as a function of a mission's profile and operating environment.
- *MBSE Test & Risk Integrated* model directly links program requirements and system design to test planning, system testing, and risk modeling.



Georgia Tech Research Institute

Shifting Left: Opportunities to Reduce Defense Acquisition Cycle Time by Fully Integrating Test and Evaluation in Model Based Systems Engineering

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Paper Abstract

The reduction in cycle time for acquisition programs, or “Shift Left”, is important to realizing the benefits of digital engineering (DE) as specifically addressed in the DOT&E Strategy update in 2022. Although DE has long held the promise of making programs faster, and achieving goals and priorities more efficiently, its effect on reduced acquisition cycle time is still difficult to identify and quantify. Furthermore, problem discovery during testing and evaluation (T&E) has been identified as a critical driver in the time it takes to develop systems and is said to have significant impact on the acquisition cycle time. Hence, a reduction in acquisition cycle time can be achieved through a systemic approach that positively impacts the time required to test systems while maintaining or reducing risk. Therefore, expanding the use of DE and model-based systems engineering (MBSE) to include test capability models creates the opportunity to improve development and testing of defense systems, as well as reduce the defense acquisition life cycle time. To this end, this paper will present the quantitative results of a project that expands the use of MBSE within the test and evaluation space through the creation of a model-based test integration prototype. The results will show where and how test modeling can be used to impact acquisition decision-making and reduce overall program schedule.