Georgia Tech Research Institute

Comprehensive Risk Assessment Methodology for Extended Product Lifecycles

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Introduction

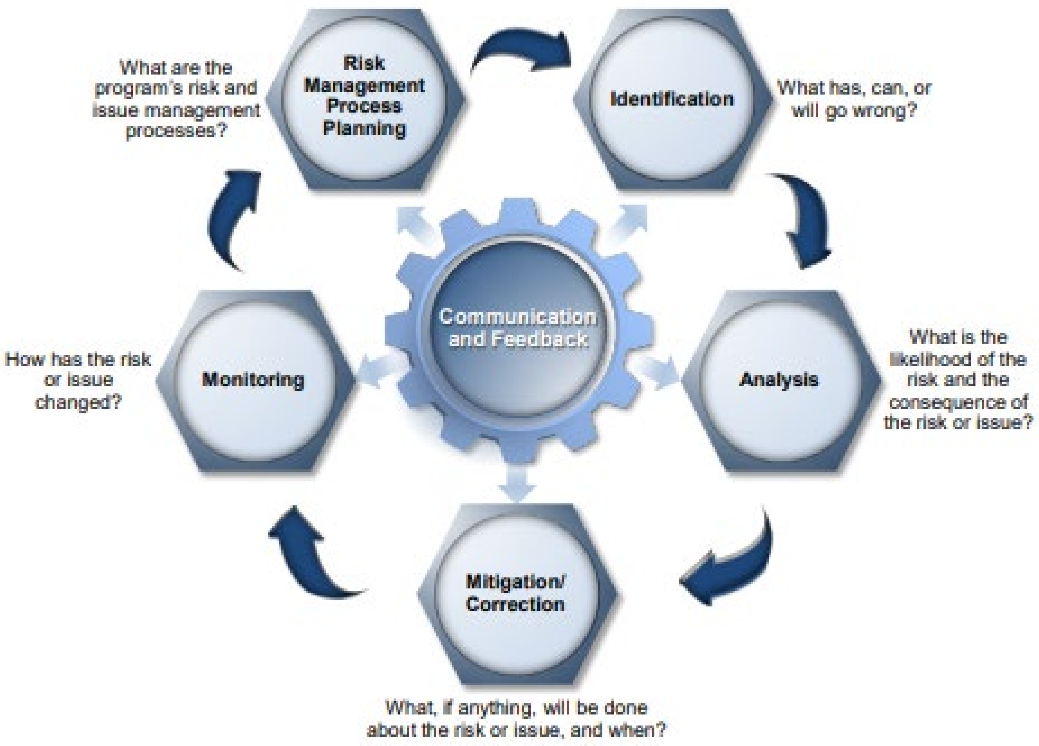
Georgia Tech Research Institute (GTRI) is celebrating its 90th Anniversary!

- As a University Affiliated Research Center (UARC) we provide “white hat” support for the Defense community through a wide spectrum of research initiatives.
- Part of GTRI's mission is to advance technology and provide innovative solutions to benefit national security
  - Our Division provides Systems Engineering Research support to decision makers for a variety of US Defense Programs
- Research Engineer in the Systems Engineering Research Division
  - Focus on enterprise architecting, model-based mission engineering
- Managing Risk is an essential role of the Systems Engineer, but understanding Risk is essential to all stakeholders
  - Translating Risks across domains is critical to providing decision makers at all levels of the enterprise the ability to ensure mission success

Overview

Risk is inherent in every product development cycle

- The Defense Community has a well understood process for identifying, assessing and managing risk in system acquisitions, however it doesn’t translate well across domains
- In Systems Engineering, we talk mostly about the roles of the Acquirer and Supplier
  - For this brief I will refer to these roles collectively as the Developer
- From an Operator's perspective, the definition of Risk is much different
- In both cases, Risk should ideally be projected over the full product lifecycle in order to prioritize decisions in a timely manner

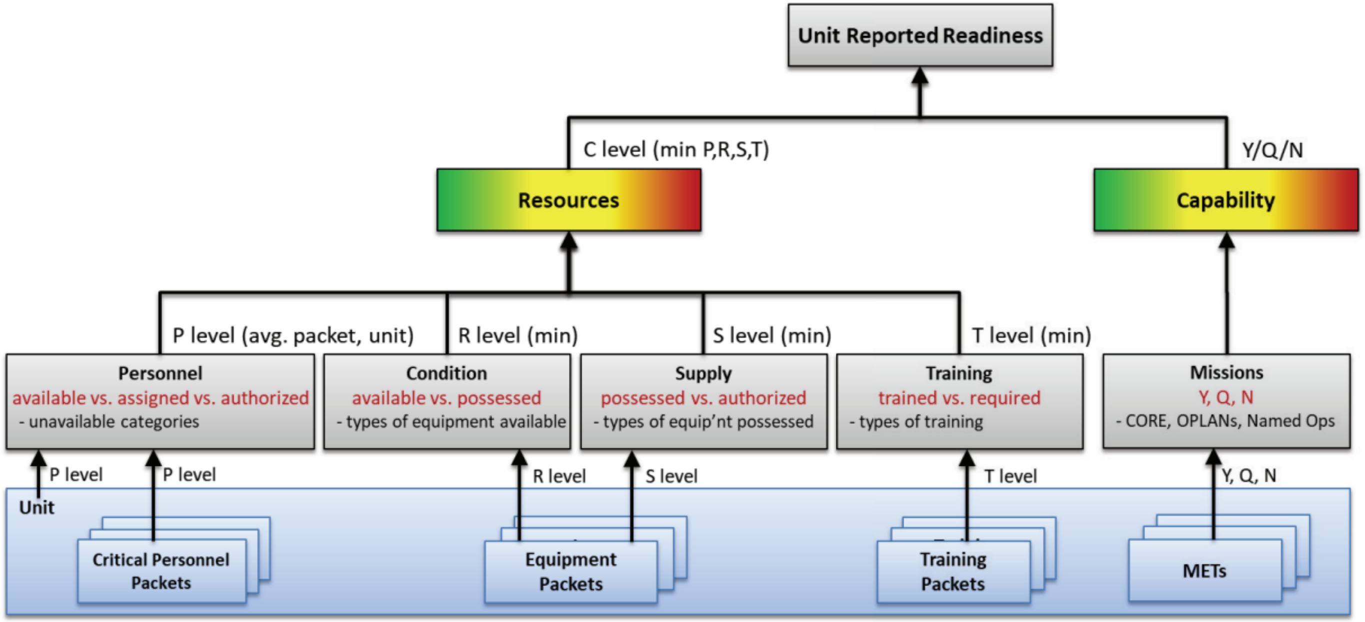

What are the program's risk and issue management processes?
Risk Management Process Planning
Identification
What has, can, or will go wrong?
Communication and Feedback
How has the risk or issue changed?
Monitoring
Analysis
What is the likelihood of the risk and the consequence of the risk or issue?
Mitigation/ Correction
What, if anything, will be done about the risk or issue, and when?

Challenges

The traditional approach to Risk Management focuses mainly on the role of the Developer: Cost, Schedule, Technical Performance

Operators (Users) focus on their ability to successfully execute their Mission (Task)

- Defined by Readiness, Effectiveness, Survivability, Maintainability, Safety, etc.
- Projections of these measures are based on needs communicated to Developers and their anticipated timelines for realization of new capabilities

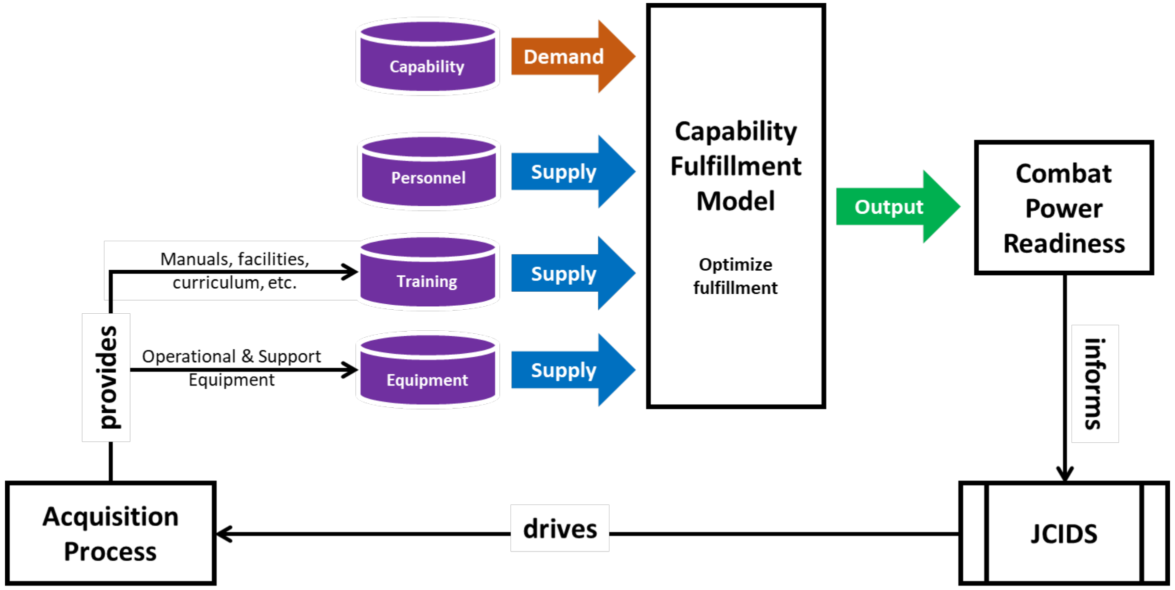


SOURCE: RAND analysis of DRRS-S information.
NOTE: C = resource readiness level; min = minimum; P = personnel; R = equipment condition; S = supplies on hand; T = training of personnel; Y = yes; Q = qualified yes; N = no; CORE = Core Mission Essential Task List; OPLAN = operation plan; ops = operations.

Correlating Operator Risk to Developer Risk

Operators are the key to generating Demand for new Systems

- When Operations identifies a new Threat (i.e. capability need), this will create a gap in their Readiness (i.e. ability to execute their mission) and create a Demand
- This Demand will begin a process to identify requirements for a new Development effort
- The Demands from Operators can change throughout the Product Lifecycle and have a tremendous impact on System Requirements
- Similarly, if the Developer identifies a Risk, it must feed forward into the Operator's Readiness analysis to inform decisions on capability deployment
- This process is analogous to many Demand/Supply cycles found in commercial industries

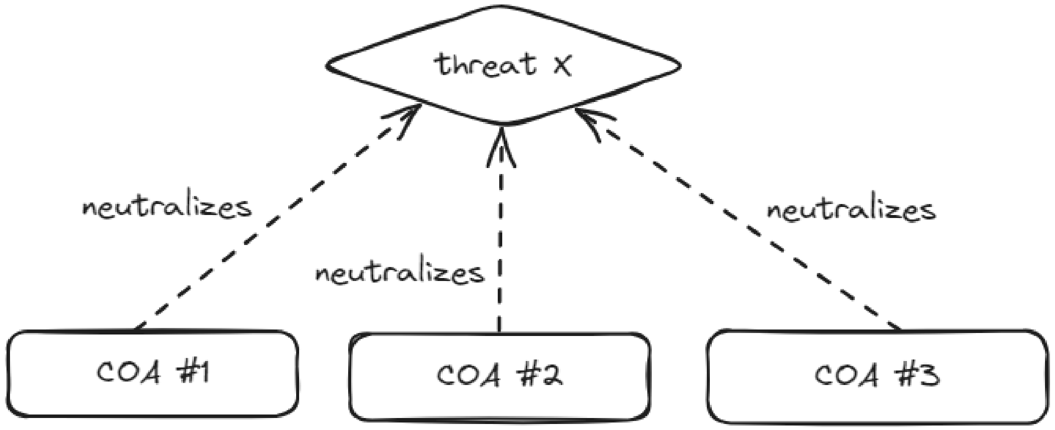


Based on https://www.rand.org/pubs/research_reports/RRA315-1.html

Operations Planning

Further complicating matters, Operators often create multiple strategies for neutralizing potential Threats

- Developing multiple potential Courses of Action (COA) ultimately reduces the overall risk for Mission success
- Potential COAs may include:
  1. Develop a new Capability
     - Most Risk due to Expense & Schedule
  2. Modify an existing Capability
     - Moderate Risk since some of the SoI is already available
  3. Produce more of an existing Capability (i.e. brute force method)
     - Least Risk but the Least Elegant solution
- Each COA drives new requirements to different Development teams



	descr	dev risk	ops risk
COA#1	make	high	low
COA#2	modify	moderate	moderate
COA#3	buy	low	high

Our exemplar

- The appearance of the Borg highlighted a gap in Starfleet capabilities
  - The existing fleet could not rapidly amass to respond to a sudden threat
- Existing ships could not fill the gap
  - Resource-intensive to produce and upkeep
  - Massive crews
- A new class of ship was needed - the Defiant Class
  - Weaponry equivalent to the largest Starfleet ships, in a hull ~1/20th the volume
  - Highly performant propulsion, enabling rapid response without large numbers of ships
  - Only combat-related systems, reducing crew compliment ~90%
  - Small size, reducing the burden of production and sustainment

STAR TREK
DEEP SPACE NINE
DEFIANT DEVELOPMENT
ANTARES FLEET YARDS
U.S.S. DEFIANT
NX-74205

NX-74205
U.S.S. DEFIANT
DEFIANT CLASS

TYPE: ESCORT
ACTIVE: 2370S
LENGTH: 119.5 METERS
BEAM: 90.3 METERS
HEIGHT: 25.5 METERS
MASS: 355,000 METRIC TONS
CREW COMPLEMENT: ~50
SPEED: WARP 9.5
ARMAMENT: 4 PHASER CANNONS,
AT LEAST 3 PHASER EMITTERS,
AT LEAST 4 FORWARD TORPEDO (PHOTON
AND QUANTUM TORPEDO) LAUNCHERS,
AT LEAST 2 AFT TORPEDO LAUNCHERS
DEFENSES: DEFLECTOR SHIELDS, ABLATIVE
ARMOR, CLOAKING DEVICE
(USS DEFIANT ONLY)

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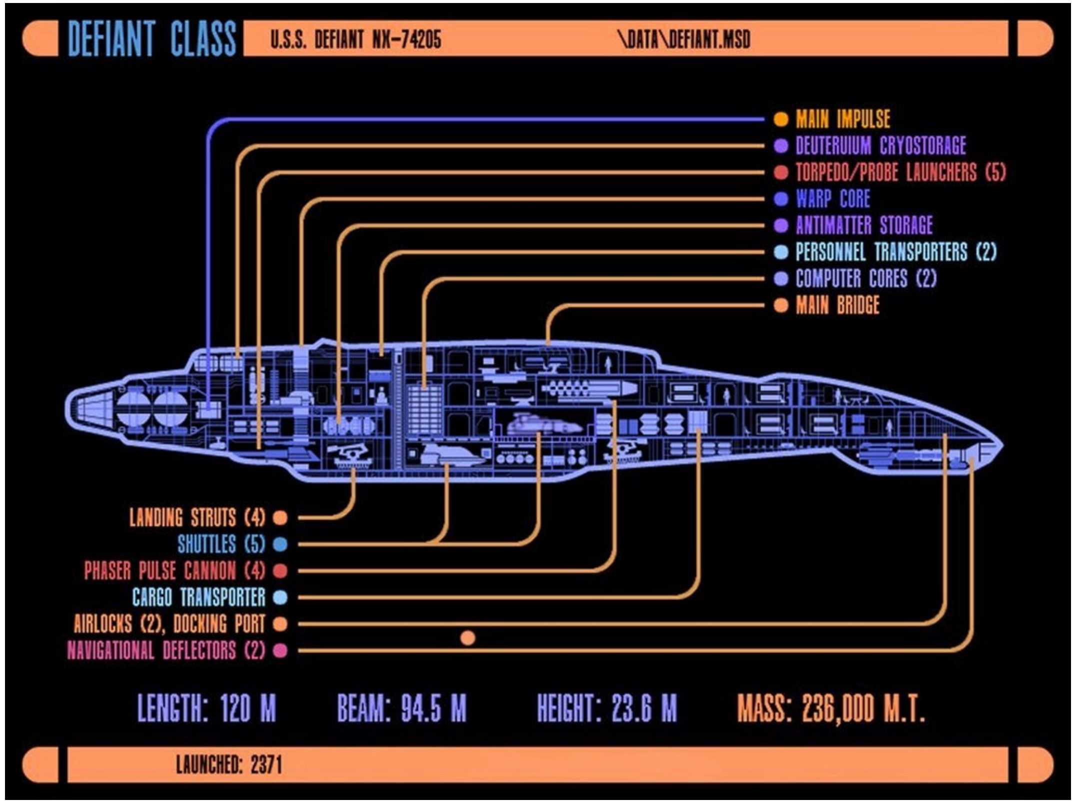
Developer vs Operator Risk examples

Throughout the storied history of the USS Defiant, the Core Mission (i.e. Operational Need) changed dramatically over its lifecycle:

- Originally designed to address the Borg (ca. 2366)
- Repurposed for Dominion Conflict (ca. 2371)
- Redirected to battle the Klingons (ca. 2372)
- Deployed for the resurgency of the Borg (ca. 2373)

Similarly, Developer Risk also evolves over time:

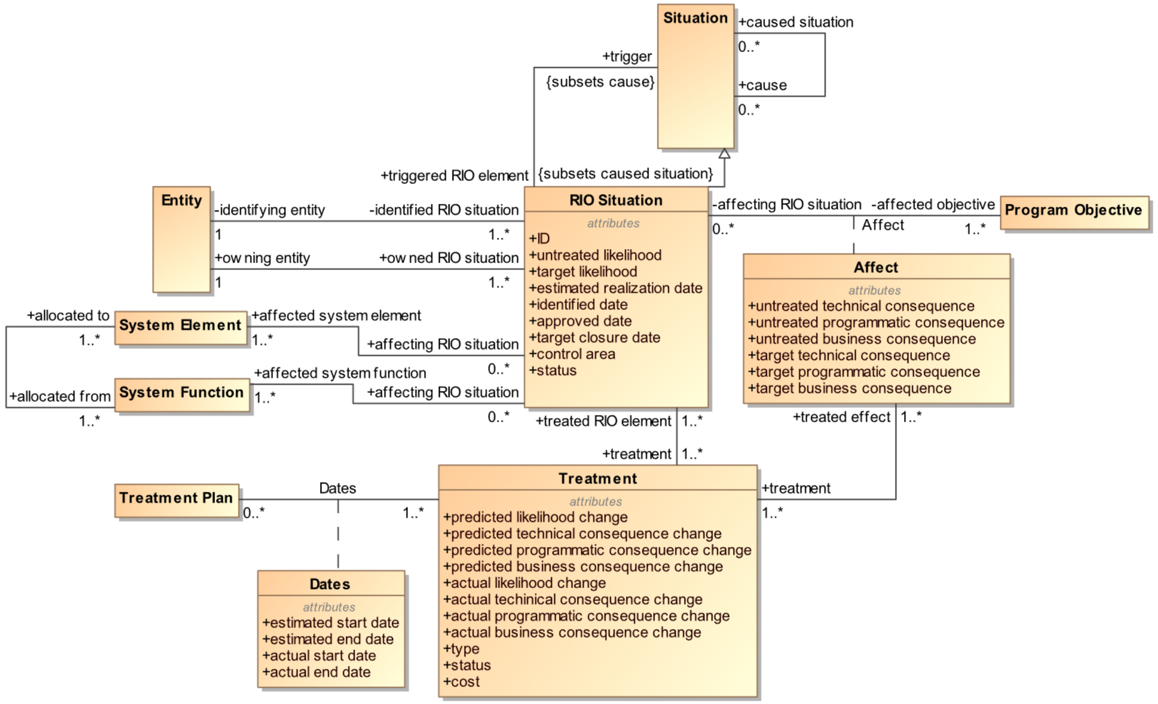
- During initial testing, the Defiant exhibited some Structural Integrity issues
  - These issues rendered the Warp Drive effectively useless and ultimately led to the ship being mothballed
- Ablative Armor (low TRL) was installed without widespread adoption by the Fleet
- A Romulan Cloaking Device was integrated but due to the ship's normal power consumption never worked properly



Ontology

A fit-for-purpose Ontology had to be created to enable this capability in a model-based (i.e. SysML) format

- This ontology is largely based on the DoD's Risk, Issues & Opportunities (RIO) Guide, however some liberties had to be taken to reduce ambiguity
- Considered using Risk Analysis and Assessment Modeling Language (RAAML)
- Key Features include:
  - Identifies both risks (i.e. negative outcomes) and opportunities (i.e. positive outcomes)
  - Treatments (i.e. mitigations) are bundled into Plans to enable Trades & Reuse
  - Tracks Predictions & Actual Outcomes
- This is still very much a work in progress
  - Several additional properties will be added as research continues



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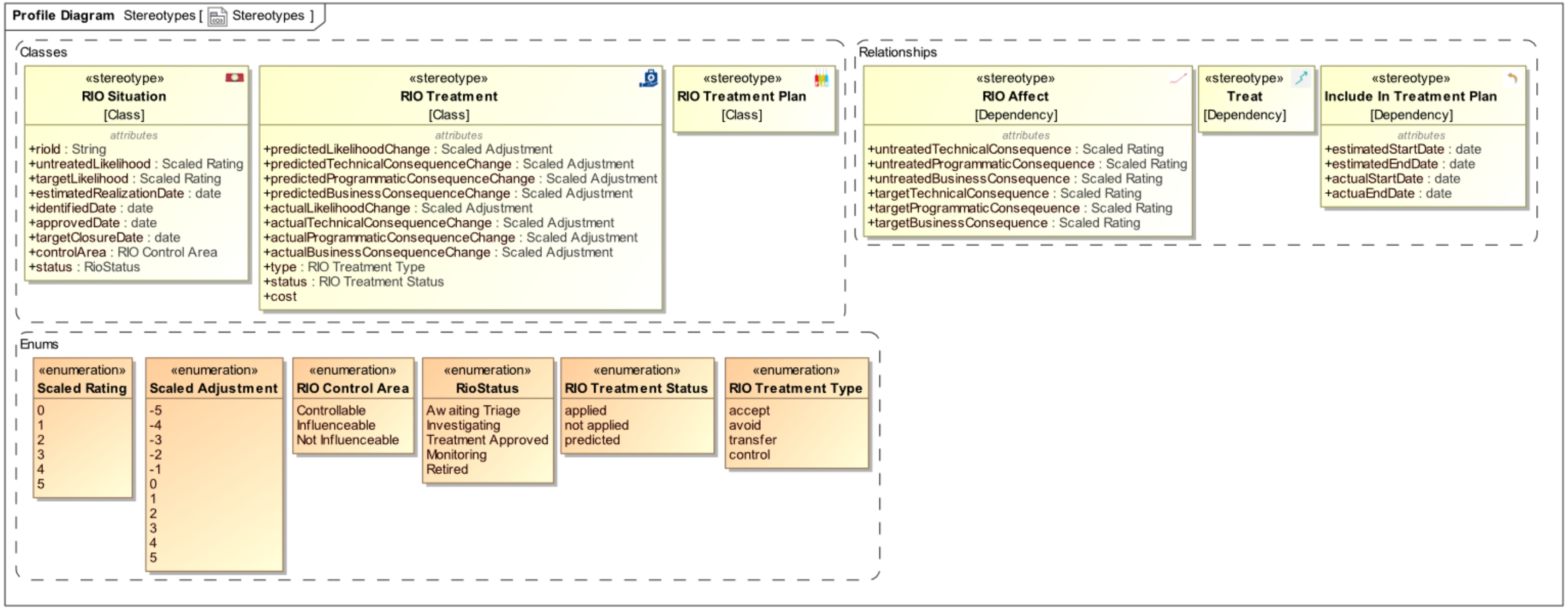
Custom Risk Profile

Common, reusable and shareable implementation throughout a set of models

- Scaled rating system which can trace to specific or calculated impacts
- Created from UML to support multiple modeling languages, including UAF



Profile Diagram Stereotypes [Stereotypes]

Classes

«stereotype»
RIO Situation
[Class]
attributes
+riold : String
+untreatedLikelihood : Scaled Rating
+targetLikelihood : Scaled Rating
+estimatedRealizationDate : date
+identifiedDate : date
+approvedDate : date
+targetClosureDate : date
+controlArea : RIO Control Area
+status : RioStatus

«stereotype»
RIO Treatment
[Class]
attributes
+predictedLikelihoodChange : Scaled Adjustment
+predictedTechnicalConsequenceChange : Scaled Adjustment
+predictedProgrammaticConsequenceChange : Scaled Adjustment
+predictedBusinessConsequenceChange : Scaled Adjustment
+actualLikelihoodChange : Scaled Adjustment
+actualTechnicalConsequenceChange : Scaled Adjustment
+actualProgrammaticConsequenceChange : Scaled Adjustment
+actualBusinessConsequenceChange : Scaled Adjustment
+type : RIO Treatment Type
+status : RIO Treatment Status
+cost

«stereotype»
RIO Treatment Plan
[Class]

Relationships

«stereotype»
RIO Affect
[Dependency]
attributes
+untreatedTechnicalConsequence : Scaled Rating
+untreatedProgrammaticConsequence : Scaled Rating
+untreatedBusinessConsequence : Scaled Rating
+targetTechnicalConsequence : Scaled Rating
+targetProgrammaticConseqeuence : Scaled Rating
+targetBusinessConsequence : Scaled Rating

«stereotype»
Treat
[Dependency]

«stereotype»
Include In Treatment Plan
[Dependency]
attributes
+estimatedStartDate : date
+estimatedEndDate : date
+actualStartDate : date
+actuaEndDate : date

Enums

«enumeration»
Scaled Rating
0
1
2
3
4
5

«enumeration»
Scaled Adjustment
-5
-4
-3
-2
-1
0
1
2
3
4
5

«enumeration»
RIO Control Area
Controllable
Influenceable
Not Influenceable

«enumeration»
RioStatus
Awaiting Triage
Investigating
Treatment Approved
Monitoring
Retired

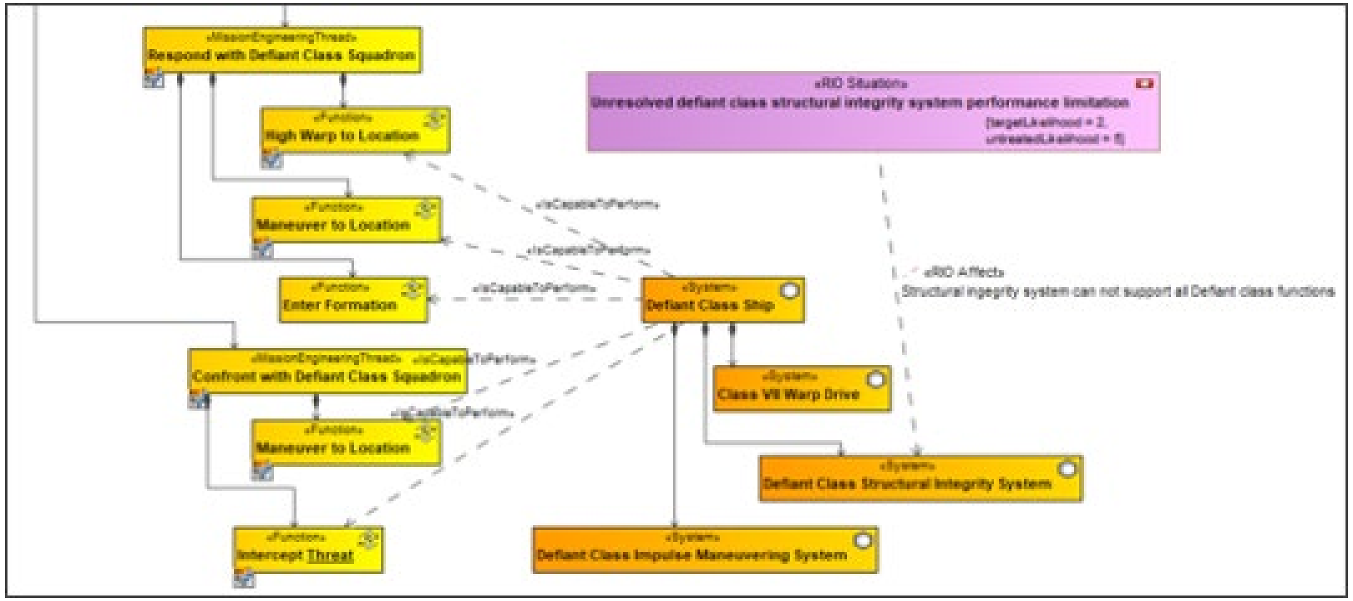
«enumeration»
RIO Treatment Status
applied
not applied
predicted

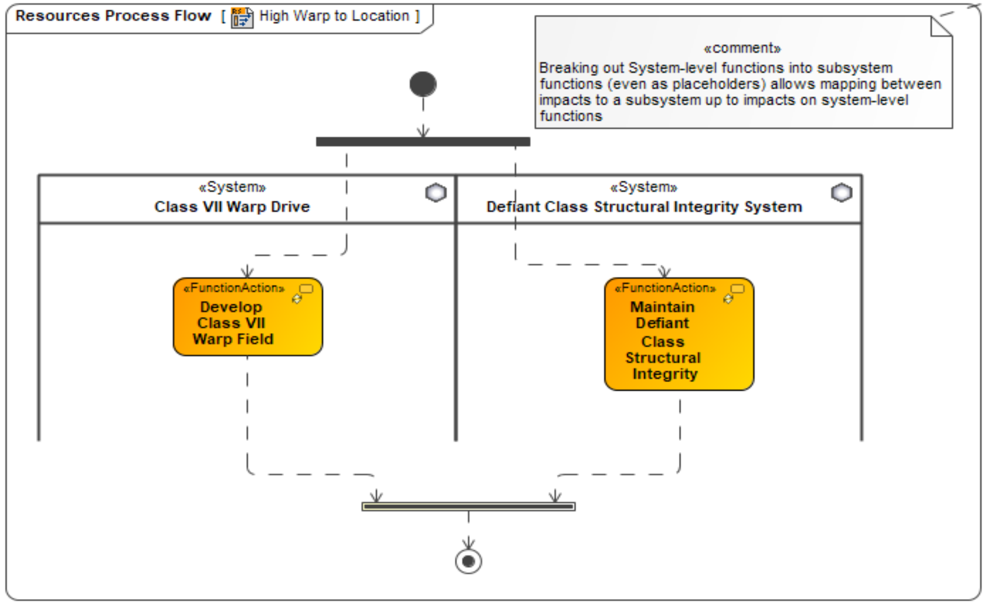
«enumeration»
RIO Treatment Type
accept
avoid
transfer
control

Risk Viewpoints

Common views within the model will communicate to different stakeholders

- Diagrams were created to address specific relationships between Functional Elements, System Elements, and discrete RIO Situations
- Understanding the relationships between like elements is also critical





Resources Process Flow [High Warp to Location]
«System»
Class VII Warp Drive
«System»
Defiant Class Structural Integrity System
«FunctionAction»
Develop Class VII Warp Field
«FunctionAction»
Maintain Defiant Class Structural Integrity

«comment»
Breaking out System-level functions into subsystem functions (even as placeholders) allows mapping between impacts to a subsystem up to impacts on system-level functions

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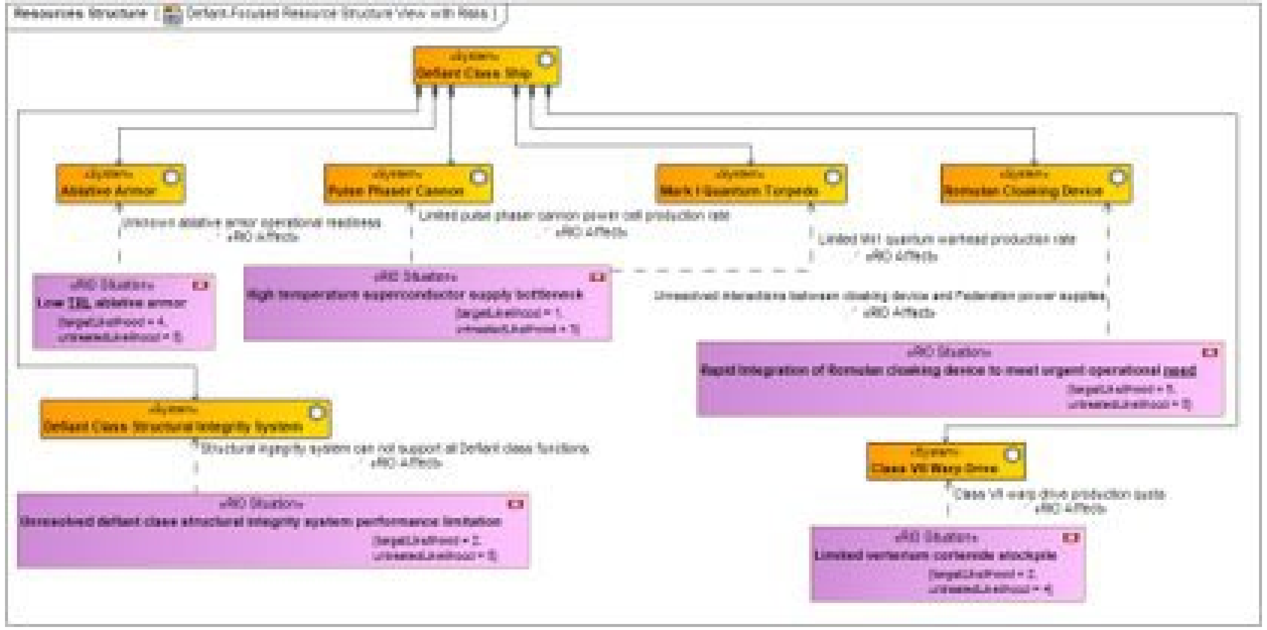
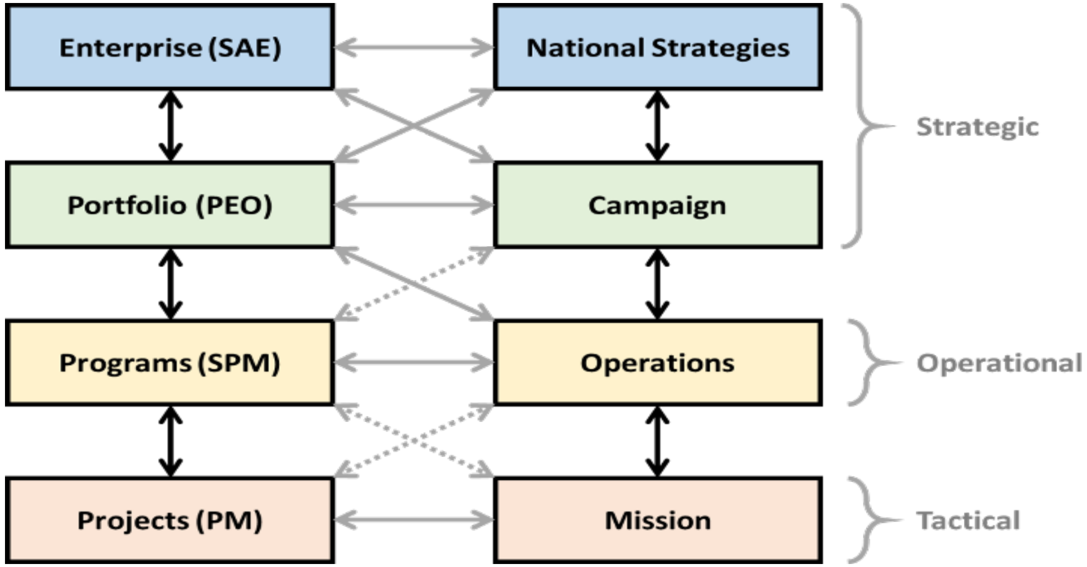
Aggregation

To achieve a Comprehensive Risk Methodology, all risks must be aggregable

- RIO Situations can be aggregated within the SoI's WBS hierarchy
- Different levels of aggregation speak to different levels of hierarchy within the stakeholders' organizations

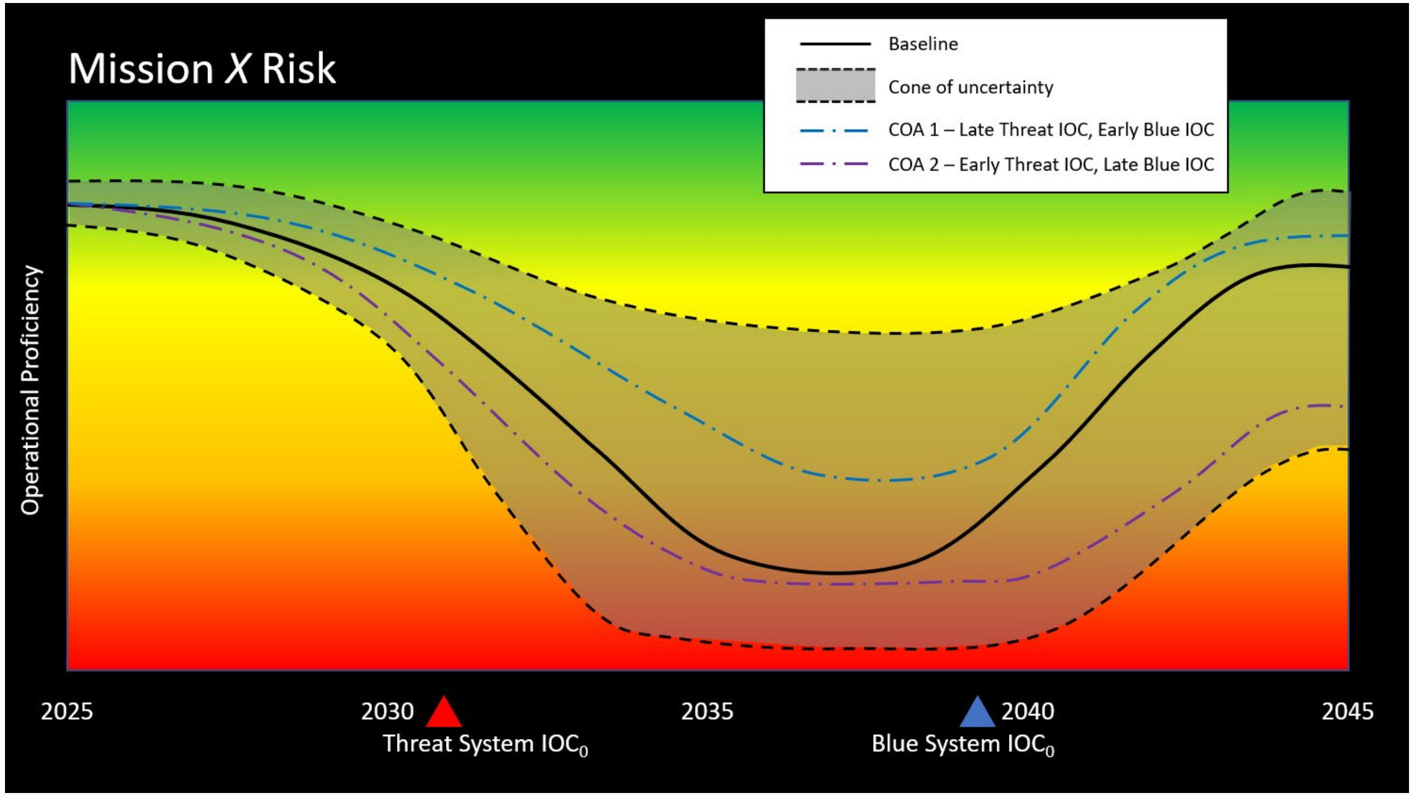

Resources Structure [Defiant-Focused Resource Structure View with Risks]
«System»
Defiant Class Ship
«System»
Ablative Armor
«System»
Pulse Phaser Cannon
«System»
Mark I Quantum Torpedo
«System»
Romulan Cloaking Device
Unknown ablative armor operational readiness
«RIO Affects»
Limited pulse phaser cannon power cell production rate
«RIO Affects»
Limited Mk1 quantum warhead production rate
«RIO Affects»
«RIO Situation»
Low TRL ablative armor
targetLikelihood = 4
unhandledLikelihood = 5
«RIO Situation»
High temperature superconductor supply bottleneck
targetLikelihood = 1
unhandledLikelihood = 5
Unresolved interactions between cloaking device and Federation power supplies
«RIO Affects»
«RIO Situation»
Rapid Integration of Romulan cloaking device to meet urgent operational need
targetLikelihood = 5
unhandledLikelihood = 5
«System»
Defiant Class Structural Integrity System
Structural integrity system can not support all Defiant class functions
«RIO Affects»
«System»
Class VII Warp Drive
Class VII warp drive production quota
«RIO Affects»
«RIO Situation»
Unresolved defiant class structural integrity system performance limitation
targetLikelihood = 2
unhandledLikelihood = 5
«RIO Situation»
Limited verterium cortenide stockpile
targetLikelihood = 2
unhandledLikelihood = 4



Risk Evolves Over Time

Key aspect of this research is to provide a means of characterizing Risk over Time

- Balance the need to make decisions made today vs some day in the future
- Compare multiple COAs and their projected impact on Mission success
- Conceptually, this capability is understood however SysML v1 doesn't handle time-based criteria well
  - SysML v2 has better capabilities for temporal viewpoints



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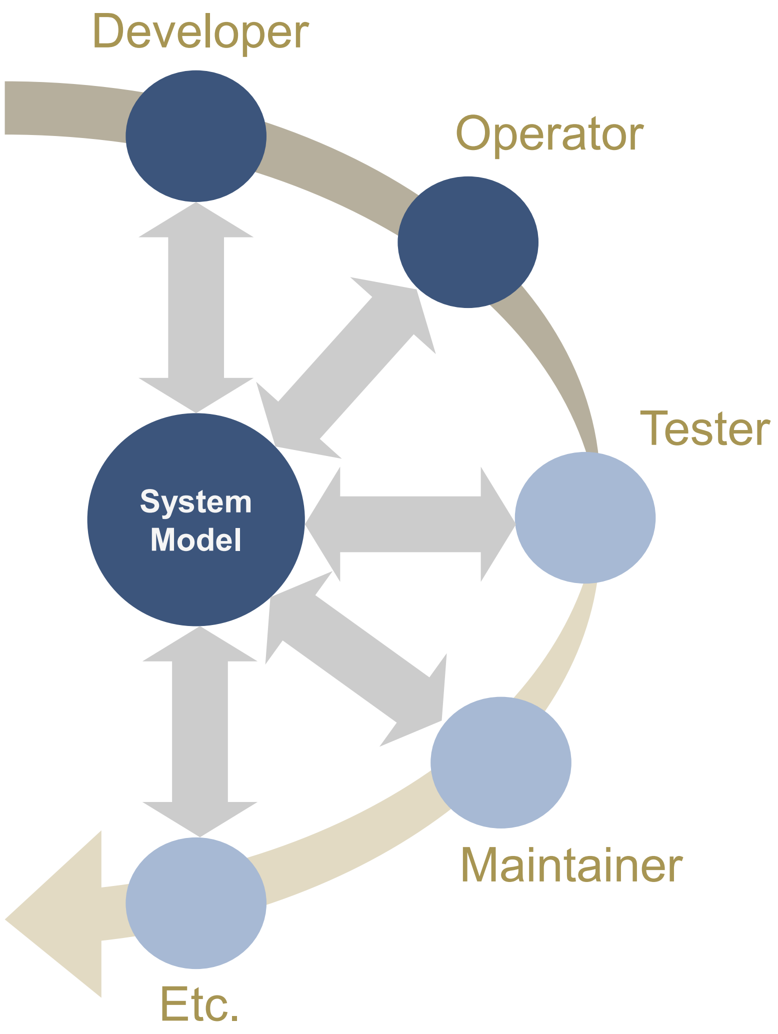
Next Steps

- Develop specific viewpoints to address concerns of the operator
- Integrate temporal assessment functionality
- Create quantifiable relationships to other risk categories
- Implement dynamic views to allow “what-if” tradespace analysis
- Product Program/portfolio viewpoints for each category of risk
- Adapt the methodology to SysML v2 once it is mature enough for widespread use



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