Battle of Hoth Example for Mission Engineering

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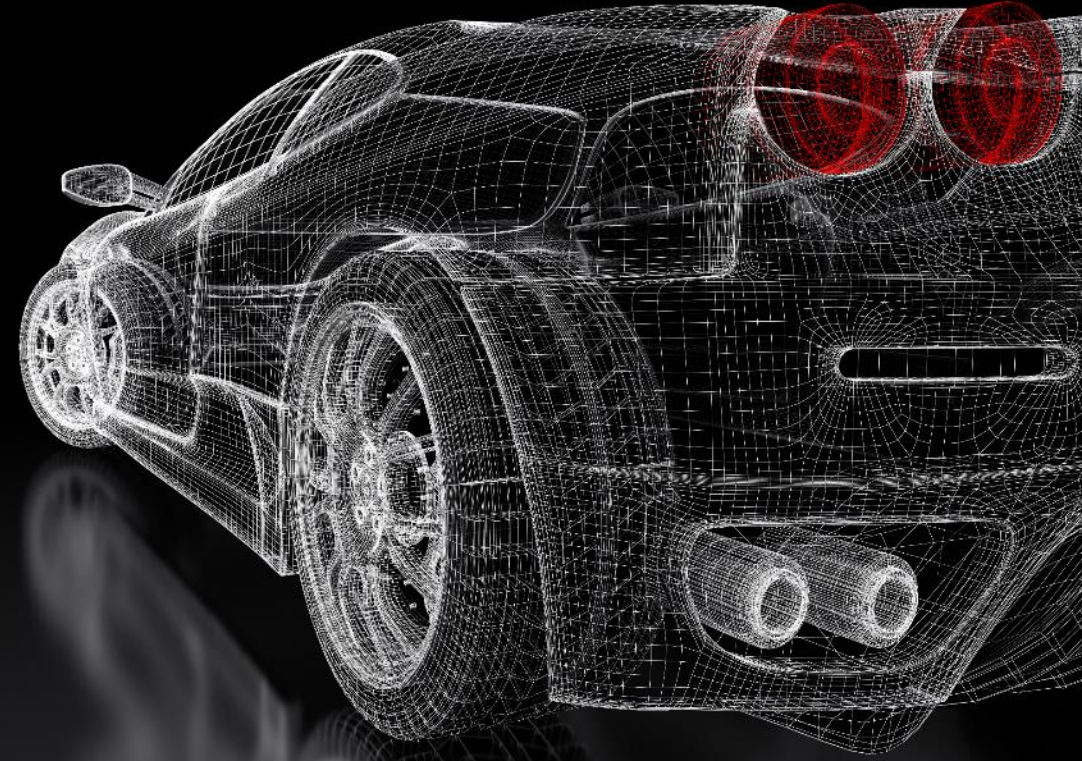
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- As a means of exploring how to identify potential capability gaps within its air, land, and seas forces, the U.S. Department of Defense developed the Mission Engineering Guide to help define key terms and relationships between mission-related elements.

- This paper shows how UAF can be extended to leverage the concepts in the Mission Engineering Guide and use them to model missions and the resources used to execute them, while referencing a widely known Star Wars battle as an example.

- Mission Engineering (ME) as the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects.

- ME is a top-down approach that delivers engineering results to identify enhanced capabilities, technologies, system interdependencies, and architectures to guide development, prototypes, experiments, and SoS to achieve reference missions and close mission capability gaps.

- ME uses systems and SoS in an operational mission context to inform stakeholders about building the right things, not just building things right, by guiding capability maturation to address warfighter mission needs.

Mission Engineering Guide.
Available online at https://ac.cto.mil/wp-content/uploads/2020/12/MEG-v40_20201130_shm.pdf

- **Mission:** The task, together with the purpose, that clearly indicates the action to be taken and the reason thereby. More simply, a mission is a duty assigned to an individual or unit.

- **Mission Thread (MT):** An end-to-end sequence of tasks, activities, and events to execute a mission.

- **Mission Engineering Thread (MET):** Mission threads that include technical details of the capabilities and systems required and utilized to execute the tasks and activities for a mission.

The Unified Architecture Framework Grid

Standard means of expression – model kinds/aspects

	Taxonomy	Structure & Connectivity	Behavior	Information	Parameters	Constraints	Roadmap	Traceability
Strategic	Business View				g, Monetizing, In			
Operational	Usage View, Understa				oS from Operation		As-Is To-Be	Traceability across all levels
Services	Functional View, D				dentifying Cognitive			
Personnel & Resources	Implementation View			Data in all forms	nalytics and Edge A Behavior		Planning	
Security	Cy				rity Analysis		Continuous Availability	
Projects	Understand				velopment milesto			
Standards					ompliance			
	Requirements							

Different Domains

5   3/21/2024

Mission Engineering Views in UAF

UAF OMG Unified Architecture Framework	Motivation Mv	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Sequences Sq	Information If	Parameters Pm	Constraints Ct	Roadmap Rm	Traceability Tr
Architecture Management Am	Architecture Principles Am-Mv	Architecture Extensions Am-Tx	Architecture Views Am-Sr	Architectural References Am-Cn	Architecture Development Method Am-Pr	-	-	Dictionary Am-If	Architecture Parameters Am-Pm	Architecture Constraints Am-Ct	Architecture Roadmap Am-Rm	Architecture Traceability Am-Tr
					Summary & Overview Sm-Ov							
Strategic St	Strategic Motivation St-Mv	Strategic Taxonomy St-Tx	Strategic Structure St-Sr	Strategic Connectivity St-Cn	Strategic Processes St-Pr	Strategic States St-St	-	Strategic Information St-If	Environment and Measurements Me-Pm	Strategic Constraints St-Ct	Strategic Roadmaps: Deployment, Phasing St-Rm-D, -P	Strategic Traceability St-Tr
Operational Op	Requirements Rq-Mv	Operational Taxonomy Op-Tx	Operational Structure Op-Sr	Operational Connectivity Op-Cn	Operational Processes Op-Pr	Operational States Op-St	Operational Sequences Op-Sq	Operational Information Model Op-If		Operational Constraints Op-Ct	-	Operational Traceability Op-Tr
Services Sv		Services Taxonomy Sv-Tx	Services Structure Sv-Sr	Services Connectivity Sv-Cn	Services Processes Sv-Pr	Services States Sv-St	Services Sequences Sv-Sq			Services Constraints Sv-Ct	Services Roadmap Sv-Rm	Services Traceability Sv-Tr
Personnel Ps		Personnel Taxonomy Ps-Tx	Personnel Structure Ps-Sr	Personnel Connectivity Ps-Cn	Personnel Processes Ps-Pr	Personnel States Ps-St	Personnel Sequences Ps-Sq			Competence Drivers Performance Measurements Ps-Ct-C, -D, -P		
Resources Rs		Resources Taxonomy Rs-Tx	Resources Structure Rs-Sr	Resources Connectivity Rs-Cn	Resources Processes Rs-Pr	Resources States Rs-St	Resources Sequences Rs-Sq	Resources Information Model Rs-If	and Risks Rk-Pm	Resources Constraints Rs-Ct	Resources Roadmaps: Evolution, Forecast Rs-Rm-E, -F	Resources Traceability Rs-Tr
Security Sc	Security Controls Sc-Mv	Security Taxonomy Sc-Tx	Security Structure Sc-Sr	Security Connectivity Sc-Cn	Security Processes Sc-Pr	-	-			Security Constraints Sc-Ct		
Projects Pj	-	Projects Taxonomy Pj-Tx	Projects Structure Pj-Sr	Projects Connectivity Pj-Cn	Projects Processes Pj-Pr	-	-	-		-		
Standards Sd		Standards Sd-Sr	-	-	-			-		-	Standards Roadmap Sd-Rm	Standards Traceability Sd-Tr
Actual Resources Ar	-	-	Actual Resources Structure, Ar-Sr	Actual Resources Connectivity, Ar-Cn		Simulation		-	-	Parametric Execution/ Evaluation	-	-

Capabilities & Threats

Mission Threads

MOE's & MOP's

Mission Engineering Threads

Roadmaps

Services

Personnel

Security

Projects

Other Areas for ME?

- **Strategic Capability and Enterprise Concepts:**
  - Defines the "why" and "what" and "when" before the "how".
  - For ME, these are used to define the mission goals, purpose, timescales, structure, architecture, quantitative metrics, and temporal and physical mission structures.

- **Operational Logical Architecture:**
  - Defines the enterprise architecture in a solution in-dependent form including behavior and structure.
  - These views define all aspects of the MT.

- **Security:**
  - Identifying risk, its mitigation, and integrating security into the architecture.
  - Mission risks and mitigation can be defined and quantified to increase mission success.

- **Standards:**
  - Definition of and compliance with standards in the architecture. Standards correspond to guidance, rules of engagement, doctrine, etc.
  - For specific elements of doctrine, the standard can be imported into the model, defined as types of requirements, and linked to model elements.

- **Resources/Systems:**
  - Systems, software, technologies, etc that will implement the solution by implementing the operational or logical elements.
  - These views and elements form the MET that implements the ME.
  - UAF also provides temporal concepts to show how the systems evolve over time as well as variations and trade off analysis between candidate solution architectures.
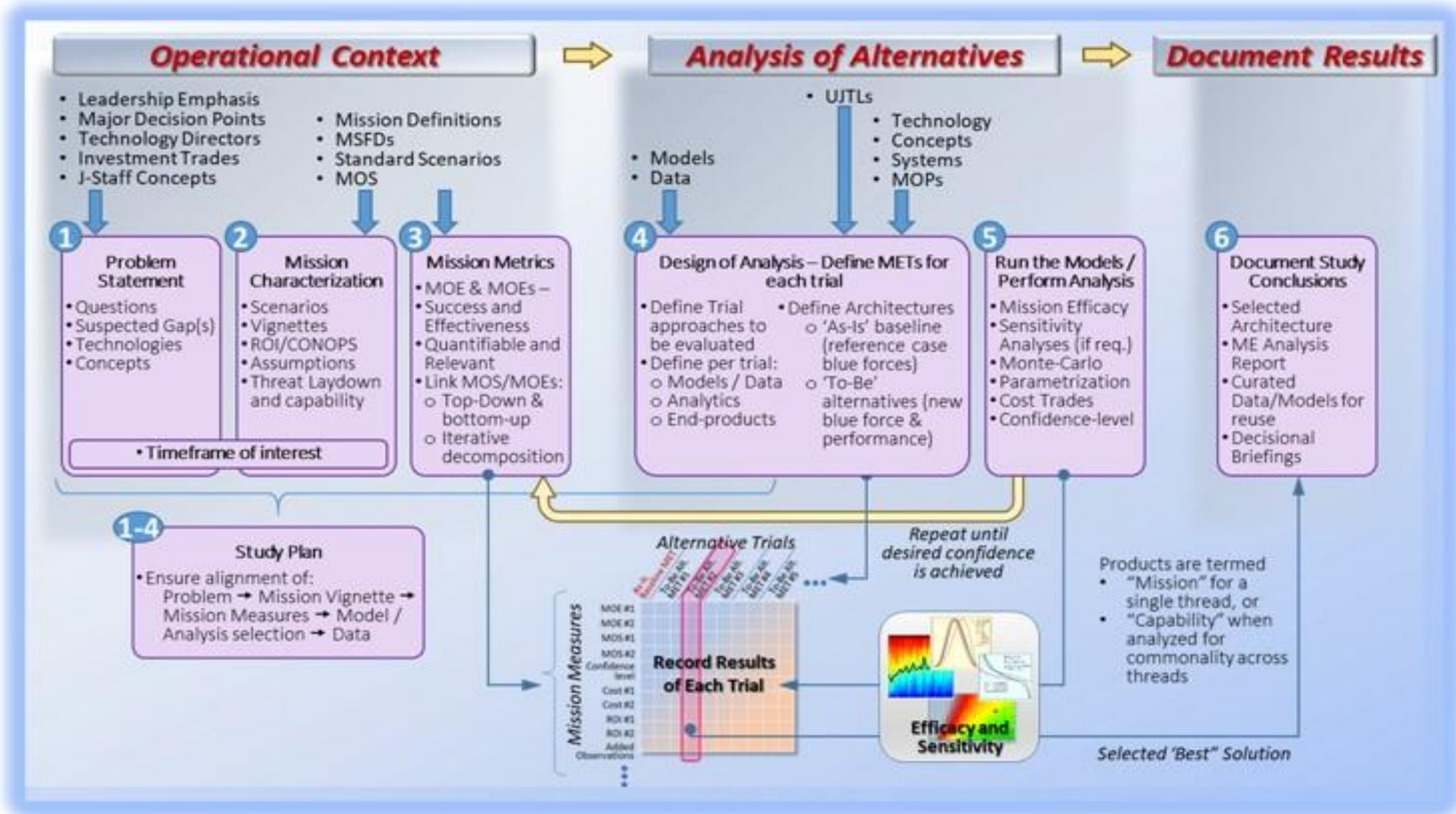
- **Personnel/ Human Factors:**
  - How people and systems interact, and their expected knowledge & skills.
  - These are the organizational structures, configurations, equipment, behavior, etc. pertaining to the MET.
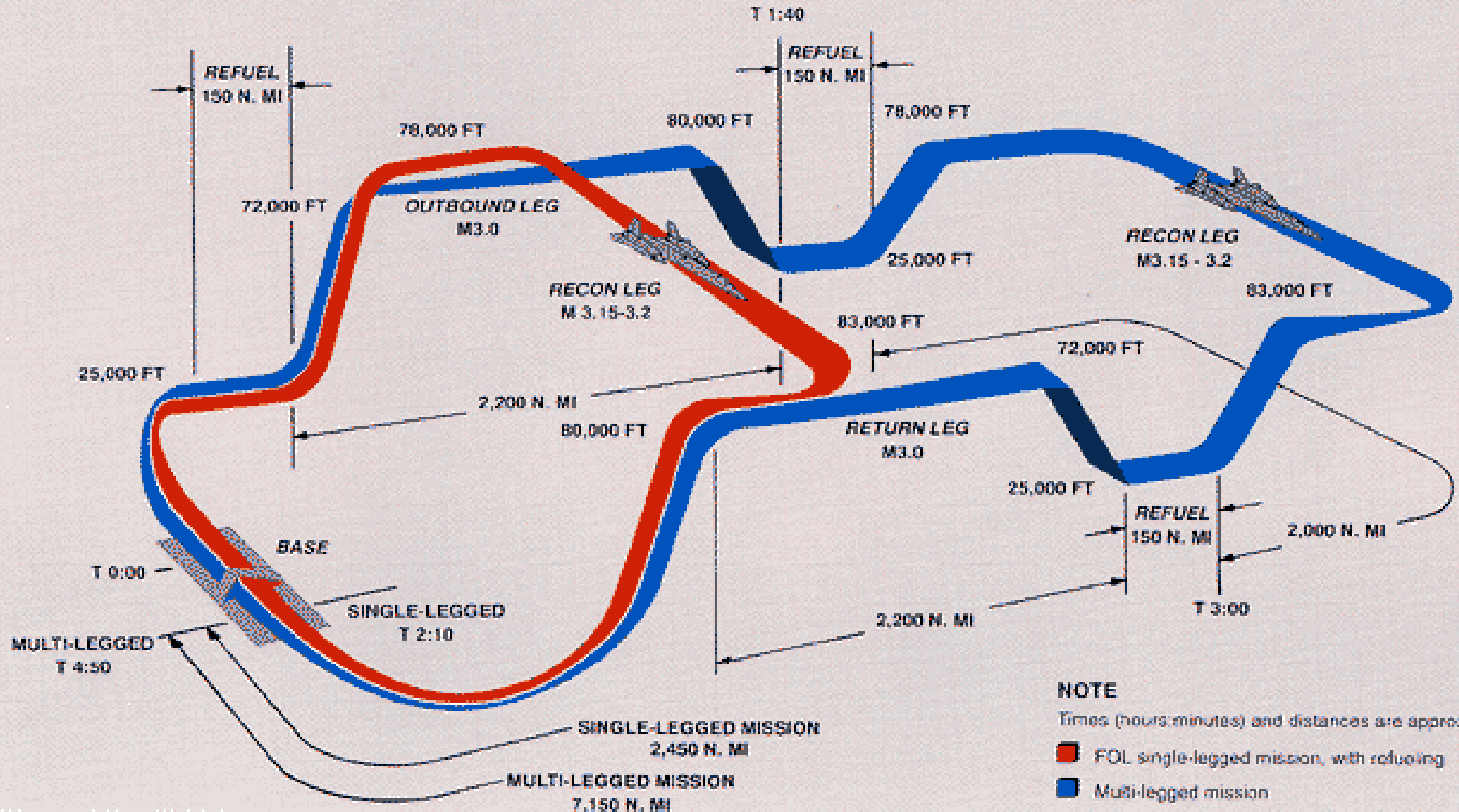
- **Built-in Traceability:**
  - Between Multiple Views as well as Between Layers and Across Layers
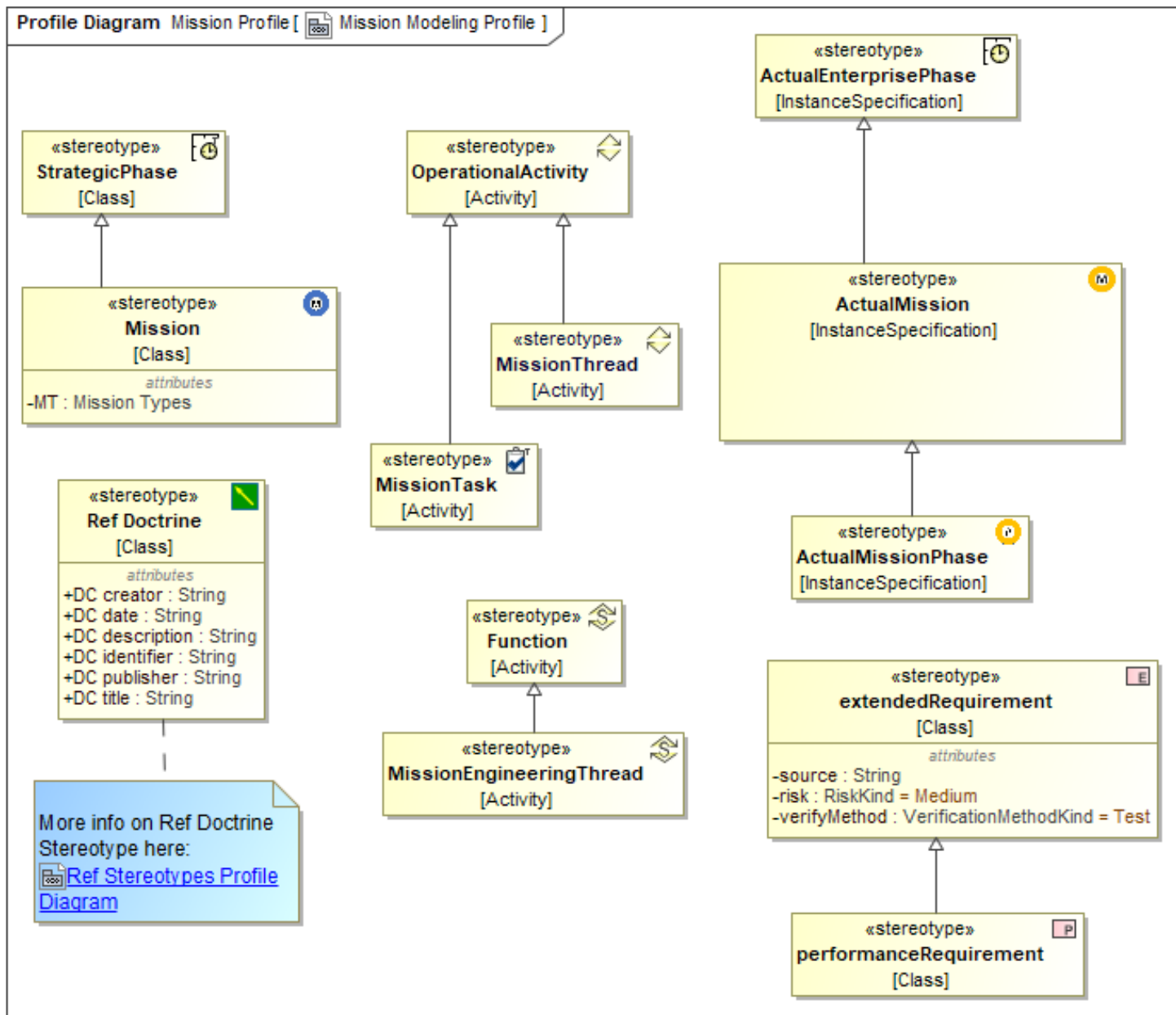 - These demonstrate that capability and mission goals have been met.

- We took a minimalist approach: only add what was absolutely necessary.

- Simple extensions to add some of the concepts to be implemented in UAF 1.3
  - Mission
  - Actual Mission Phase
  - Mission Thread
  - Mission Task
  - Mission Engineering Thread
  - Ref Doctrine
  - Extensions to the UAF diagrams.

Profile Diagram Mission Profile [Mission Modeling Profile]

«stereotype»
ActualEnterprisePhase
[InstanceSpecification]

«stereotype»
StrategicPhase
[Class]

«stereotype»
OperationalActivity
[Activity]

«stereotype»
Mission
[Class]
attributes
-MT : Mission Types

«stereotype»
MissionThread
[Activity]

«stereotype»
ActualMission
[InstanceSpecification]

«stereotype»
MissionTask
[Activity]

«stereotype»
Ref Doctrine
[Class]
attributes
+DC creator : String
+DC date : String
+DC description : String
+DC identifier : String
+DC publisher : String
+DC title : String

«stereotype»
Function
[Activity]

«stereotype»
ActualMissionPhase
[InstanceSpecification]

«stereotype»
extendedRequirement
[Class]
attributes
-source : String
-risk : RiskKind = Medium
-verifyMethod : VerificationMethodKind = Test

More info on Ref Doctrine Stereotype here:
Ref Stereotypes Profile Diagram

«stereotype»
MissionEngineeringThread
[Activity]

«stereotype»
**performanceRequirement**
[Class]

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- The Battle of Hoth was a major battle fought in 3 ABY and was considered a major victory for the Galactic Empire and the single worst battlefield defeat suffered by the Rebel Alliance during the Galactic Civil War.

  ❏ The battle was an Imperial invasion led by Darth Vader, aimed at destroying the Rebel Alliance's Echo Base hidden on the remote ice world Hoth and capturing Luke Skywalker.

  ❏ The base's location was discovered when a Viper probe droid, deployed by Darth Vader's Death Squadron, landed on the planet - prompting the Rebels to begin an evacuation of Hoth.

https://starwars.fandom.com/wiki/Star_Wars:_Episode_V_The_Empire_Strikes_Back#The_Battle_of_Hoth

- The example used in this paper is the Battle of Hoth from the second Star Wars movie, "The Empire Strikes Back".

  ❑ We are using this as an example because it is well known, contains a rich source of systems, strategies, missions, and behavior as well as illustrates joint operations.

  ❑ As it is based on a movie, there are no issues of classified materials or problems relating to the release of information.

  ❑ The actual model created to describe the complete mission would be a large undertaking requiring several diagrams.

  ❑ For reasons of space and time, we have limited this to a set of example diagrams to express the main concepts covered.

- The Empire Mission structure shown illustrate the complexity required to model missions.

- Empire doctrine proscribes that every military mission has two phases to it: Planning and Execution.

- A Planetary Invasion Mission is comprised of separate Scout, Landing, and Attack Missions each with their own Planning and Execution Phases.

- These are all types of Invasion Missions.

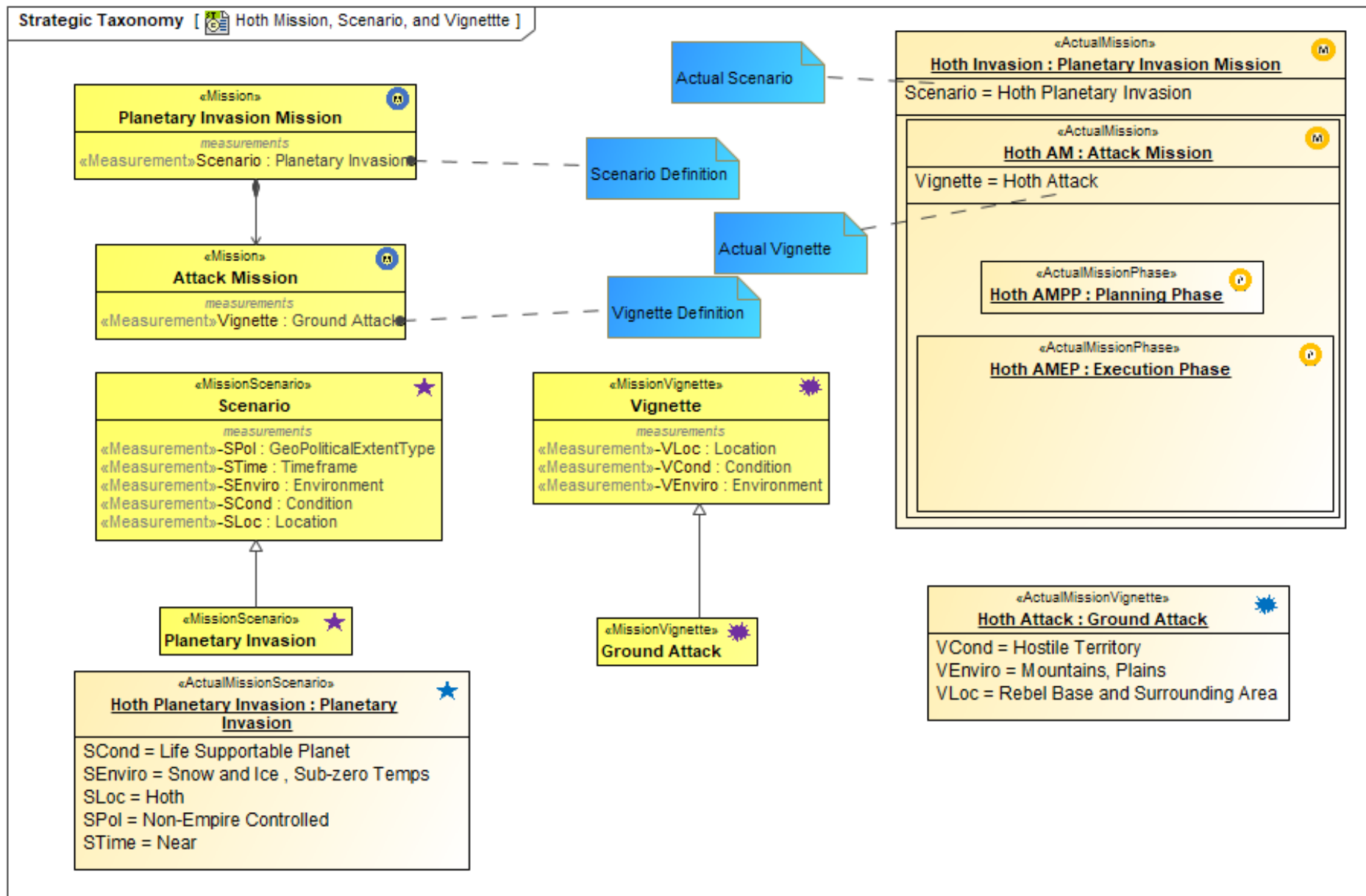- The Execution and Planning Phases both inh Mission Tempo and Phase attributes.
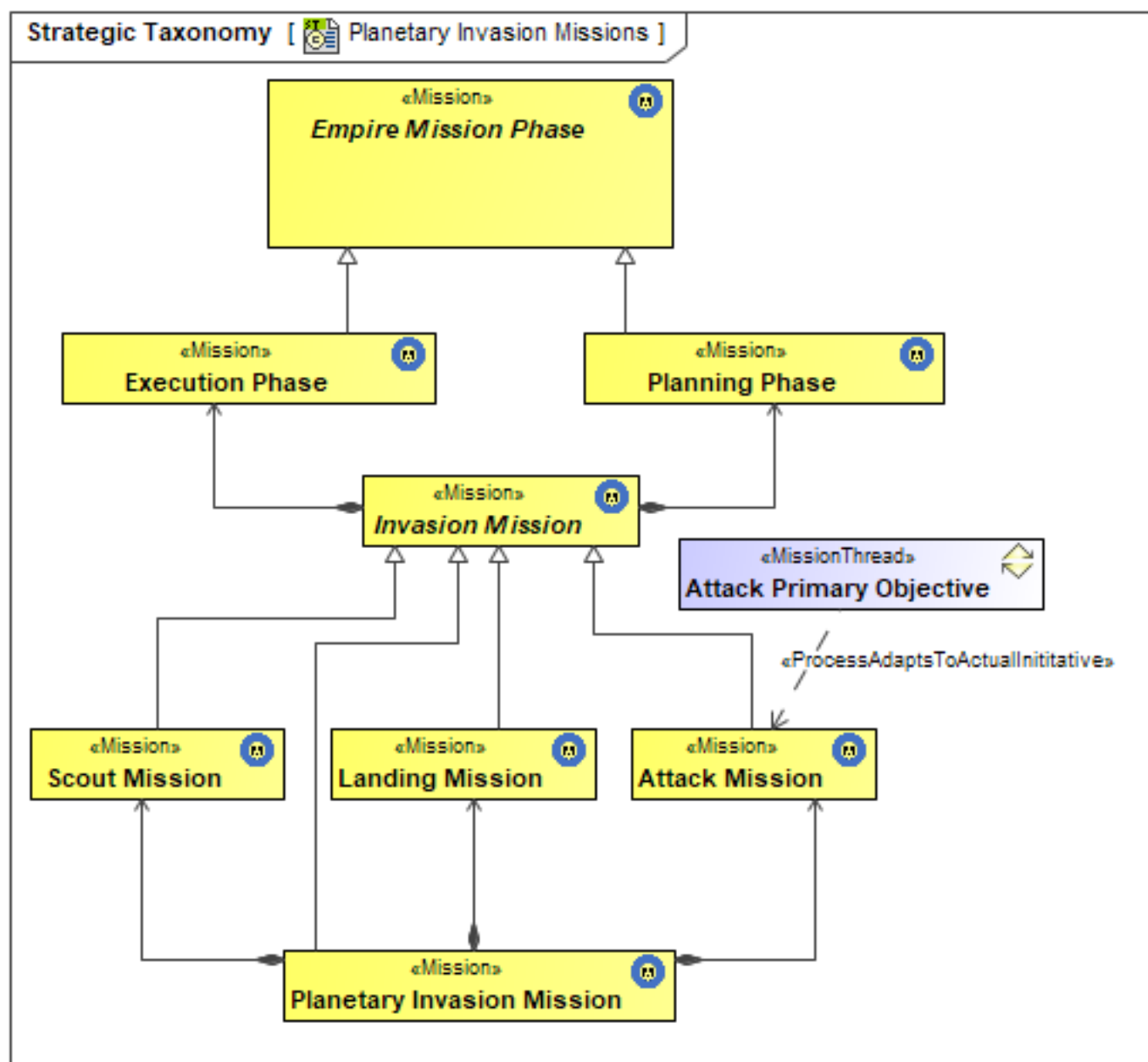
Strategic Taxonomy [Planetary Invasion Missions]

- The Hoth Invasion is an instance of the Planetary Invasion Mission

- This Actual Mission is made up of the Planning and Execution Phase as well as the Landing Mission, Attack Mission, and Scout mission.

- These Missions each have Planning and Execution Phases.

- The Execution phases all have Mission Threads and Mission Engineering Threads mapped to them.

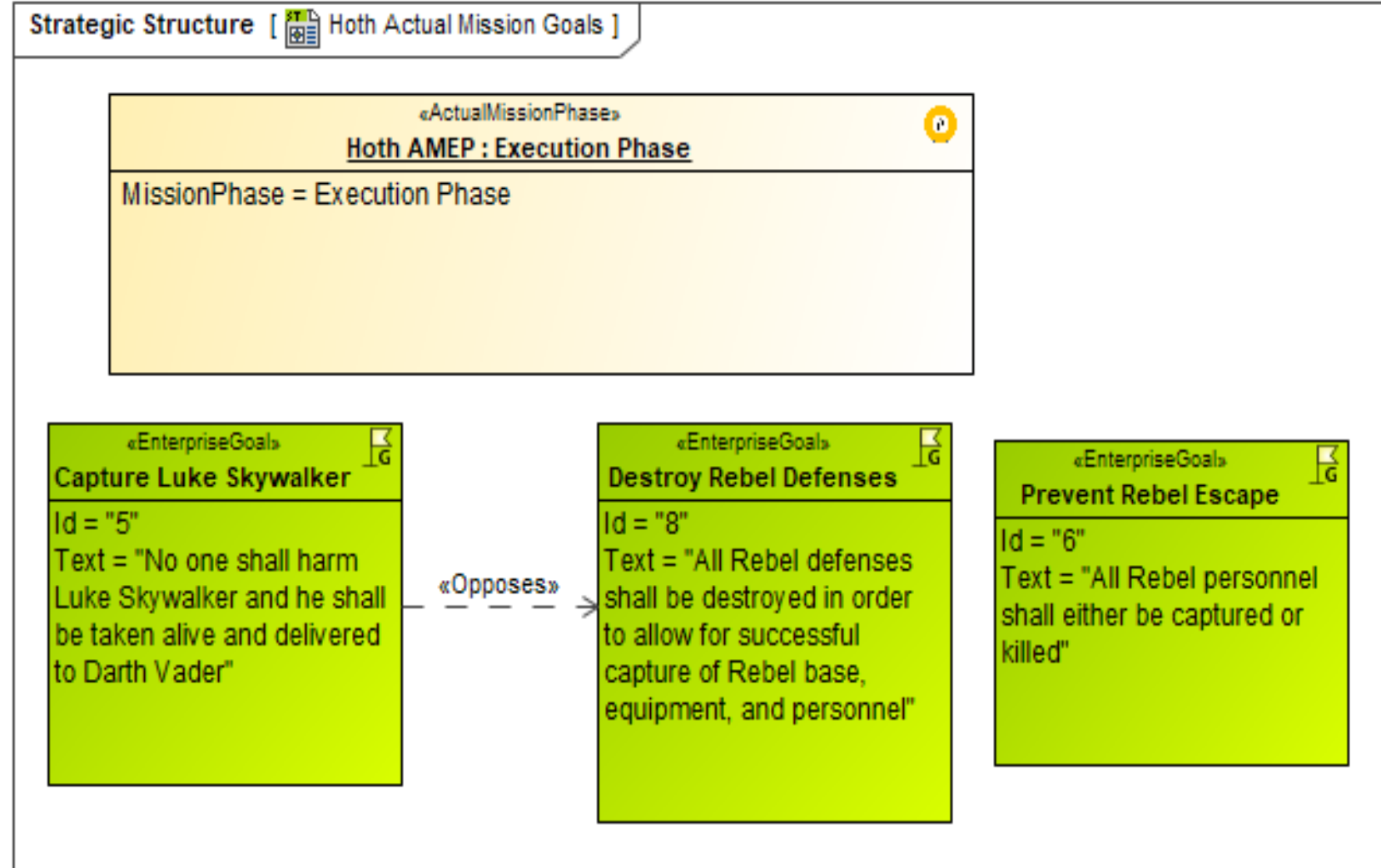- The Hoth AMEP Execution Phase has defined goals as well as Operational and Resource Architecture.

Strategic Taxonomy [Hoth Invasion Missions]

«ActualMission»
Hoth Invasion : Planetary Invasion Mission

AM = Hoth AM
invasion Execution Phase = Hoth EP
invasion Planning Phase = Hoth PP
LM = Hoth LM
Scenario = Hoth Planetary Invasion
SM = Hoth SM

«MissionEngineeringThread»
Execute Hoth Planetary Invasion

«ProcessAdaptsToActualInititative»

«ActualMissionPhase»
Hoth PP : Planning Phase

«ActualMissionPhase»
Hoth EP : Execution Phase

«ActualMission»
Hoth LM : Landing Mission

invasion Execution Phase = Hoth LMEP
invasion Planning Phase = Hoth LMPP

«ActualMission»
Hoth AM : Attack Mission

invasion Execution Phase = Hoth AMEP
invasion Planning Phase = Hoth AMPP
Vignette = Hoth Attack

«ActualMission»
Hoth SM : Scout Mission

invasion Execution Phase = Hoth SMEP
invasion Planning Phase = Hoth SMPP

«ActualMissionPhase»
Hoth LMPP : Planning Phase

MissionPhase = Planning Phase

«ActualMissionPhase»
Hoth AMPP : Planning Phase

MissionPhase = Planning Phase

«ActualMissionPhase»
Hoth SMPP : Planning Phase

MissionPhase = Planning Phase

«ActualMissionPhase»
Hoth LMEP : Execution Phase

MissionPhase = Execution Phase

«ActualMissionPhase»
Hoth AMEP : Execution Phase

Goal =
  G Destroy Rebel Defenses
  G Capture Luke Skywalker
  G Prevent Rebel Escape
MissionPhase = Execution Phase

«ActualMissionPhase»
Hoth SMEP : Execution Phase

MissionPhase = Execution Phase

«ProcessAdaptsToActualInititative»

«ProcessAdaptsToActualInititative»

«ProcessAdaptsToActualInititative»

«MissionEngineeringThread»
Deploy Attack Force

«MissionEngineeringThread»
Destroy Key Rebel Hoth Defenses

«MissionEngineeringThread»
Scout Hoth Surface

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- The scenario & vignette elements are types of condition which means that they can define single conditions as well as sets of conditions.

- The scenario defines the conditions for the mission and the vignette for the mission phase.

- The actual scenarios and vignettes do the same for the actual mission and mission phase.
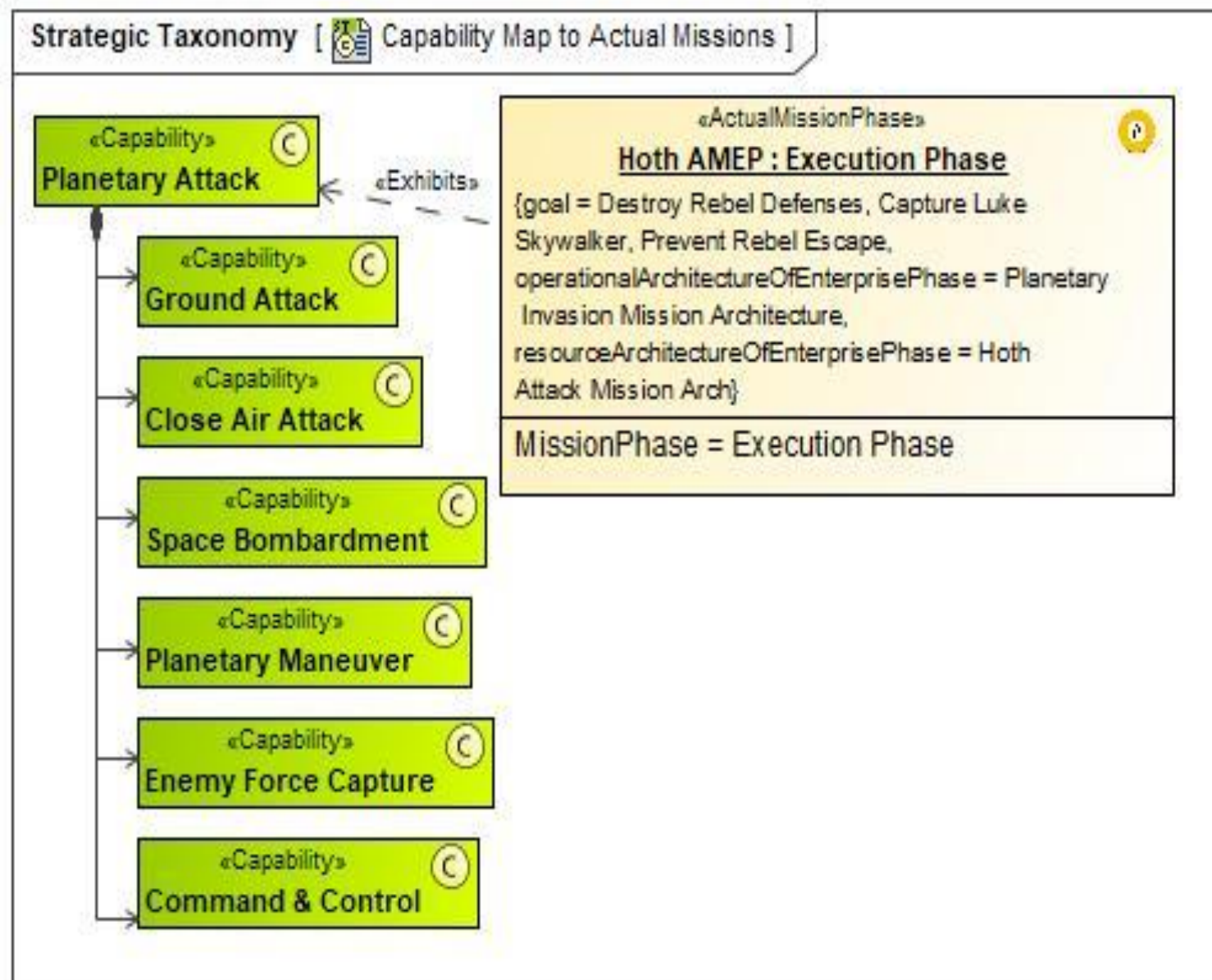
- As they are actuals, the define the precise conditions

Strategic Taxonomy [Hoth Mission, Scenario, and Vignettte]

«Mission»
Planetary Invasion Mission
measurements
«Measurement»Scenario : Planetary Invasion

«Mission»
Attack Mission
measurements
«Measurement»Vignette : Ground Attack

Actual Scenario

Scenario Definition

Actual Vignette

Vignette Definition

«MissionScenario»
Scenario
measurements
«Measurement»-SPol : GeoPoliticalExtentType
«Measurement»-STime : Timeframe
«Measurement»-SEnviro : Environment
«Measurement»-SCond : Condition
«Measurement»-SLoc : Location

«MissionVignette»
Vignette
measurements
«Measurement»-VLoc : Location
«Measurement»-VCond : Condition
«Measurement»-VEnviro : Environment

«MissionScenario»
Planetary Invasion

«MissionVignette»
Ground Attack

«ActualMissionScenario»
Hoth Planetary Invasion : Planetary Invasion
SCond = Life Supportable Planet
SEnviro = Snow and Ice , Sub-zero Temps
SLoc = Hoth
SPol = Non-Empire Controlled
STime = Near

«ActualMission»
Hoth Invasion : Planetary Invasion Mission
Scenario = Hoth Planetary Invasion

«ActualMission»
Hoth AM : Attack Mission
Vignette = Hoth Attack

«ActualMissionPhase»
Hoth AMPP : Planning Phase

«ActualMissionPhase»
Hoth AMEP : Execution Phase

«ActualMissionVignette»
Hoth Attack : Ground Attack
VCond = Hostile Territory
VEnviro = Mountains, Plains
VLoc = Rebel Base and Surrounding Area

- Prior to planning the Mission Thread and Mission Engineering Thread, the Goals of the Mission are defined.

- These are to Destroy Rebel Defenses, Prevent Rebel Escape, and Capture Luke Skywalker.

- The constraint imposed by Capturing Luke Skywalker alive and unharmed is what causes the Mission to fail.

- The Empire normally executes their missions with extreme violence. This constraint, prevented this.

Strategic Structure [📄 Hoth Actual Mission Goals]

«ActualMissionPhase»
Hoth AMEP : Execution Phase

MissionPhase = Execution Phase

«EnterpriseGoal»
Capture Luke Skywalker

Id = "5"
Text = "No one shall harm Luke Skywalker and he shall be taken alive and delivered to Darth Vader"

«Opposes»

«EnterpriseGoal»
Destroy Rebel Defenses

Id = "8"
Text = "All Rebel defenses shall be destroyed in order to allow for successful capture of Rebel base, equipment, and personnel"

«EnterpriseGoal»
Prevent Rebel Escape

Id = "6"
Text = "All Rebel personnel shall either be captured or killed"

- The Planetary Attack capability hierarchy is shown on the left.

- This includes Ground Attack, Close Air Attack, etc.

- Linking the mission to the highest-level capability reduces the coupling of the two structures.

- These capabilities along with the associated metrics will form the basis for trade-off analysis of the candidate architectures and systems.

Strategic Taxonomy [Capability Map to Actual Missions]

«Capability» C Planetary Attack «Exhibits»

«Capability» C Ground Attack

«Capability» C Close Air Attack

«Capability» C Space Bombardment

«Capability» C Planetary Maneuver

«Capability» C Enemy Force Capture

«Capability» C Command & Control

«ActualMissionPhase»
Hoth AMEP : Execution Phase
{goal = Destroy Rebel Defenses, Capture Luke Skywalker, Prevent Rebel Escape, operationalArchitectureOfEnterprisePhase = Planetary Invasion Mission Architecture, resourceArchitectureOfEnterprisePhase = Hoth Attack Mission Arch}

MissionPhase = Execution Phase

- Automatically generated table showing details of the Actual Missions and Phases.

#	Name	Type	Goal	Operational Architecture Of Enterprise Phase	Resource Architecture Of Enterprise Phase	Exhibits Capability	Slot
1	Execute Hoth Invasion	Execution Phase					MissionTempo = Rapid and Forceful MissionPhase = Execution Phase
2	Hoth AM	Attack Mission					invasion Planning Phase = Hoth AMPP invasion Execution Phase = Hoth AMEP
3	Hoth AMEP	Execution Phase	EG4 Destroy Rebel Defense EG5 Capture Luke Skywalke EG6 Prevent Rebel Escape	Planetary Invasion Mission	Hoth Attack Mission Arch	Planetary Attack	MissionPhase = Execution Phase
4	Hoth AMPP	Planning Phase					MissionPhase = Planning Phase
5	Hoth Attack Mission	Attack Mission					
6	Hoth EP	Execution Phase					
7	Hoth Invasion	Planetary Invasion Mission					LM = Hoth LM AM = Hoth AM SM = Hoth SM invasion Planning Phase = Hoth PP invasion Execution Phase = Hoth EP
8	Hoth Landing Mission	Landing Mission					
9	Hoth LM	Landing Mission					invasion Execution Phase = Hoth LMEP invasion Planning Phase = Hoth LMPP
10	Hoth LMEP	Execution Phase					MissionPhase = Execution Phase
11	Hoth LMPP	Planning Phase					MissionPhase = Planning Phase
12	Hoth PP	Planning Phase					
13	Hoth Screen Mission	Scout Mission					
14	Hoth SM	Scout Mission					invasion Planning Phase = Hoth SMPP invasion Execution Phase = Hoth SMEP
15	Hoth SMEP	Execution Phase					MissionPhase = Execution Phase
16	Hoth SMPP	Planning Phase					MissionPhase = Planning Phase
17	Plan Hoth Invasion Mis	Planning Phase					

- Defines the interactions that will take place at both the Operational and Resource levels.

- Blaster weapons are directed energy weapons, so the transmitted elements are types of energy, a natural resource.
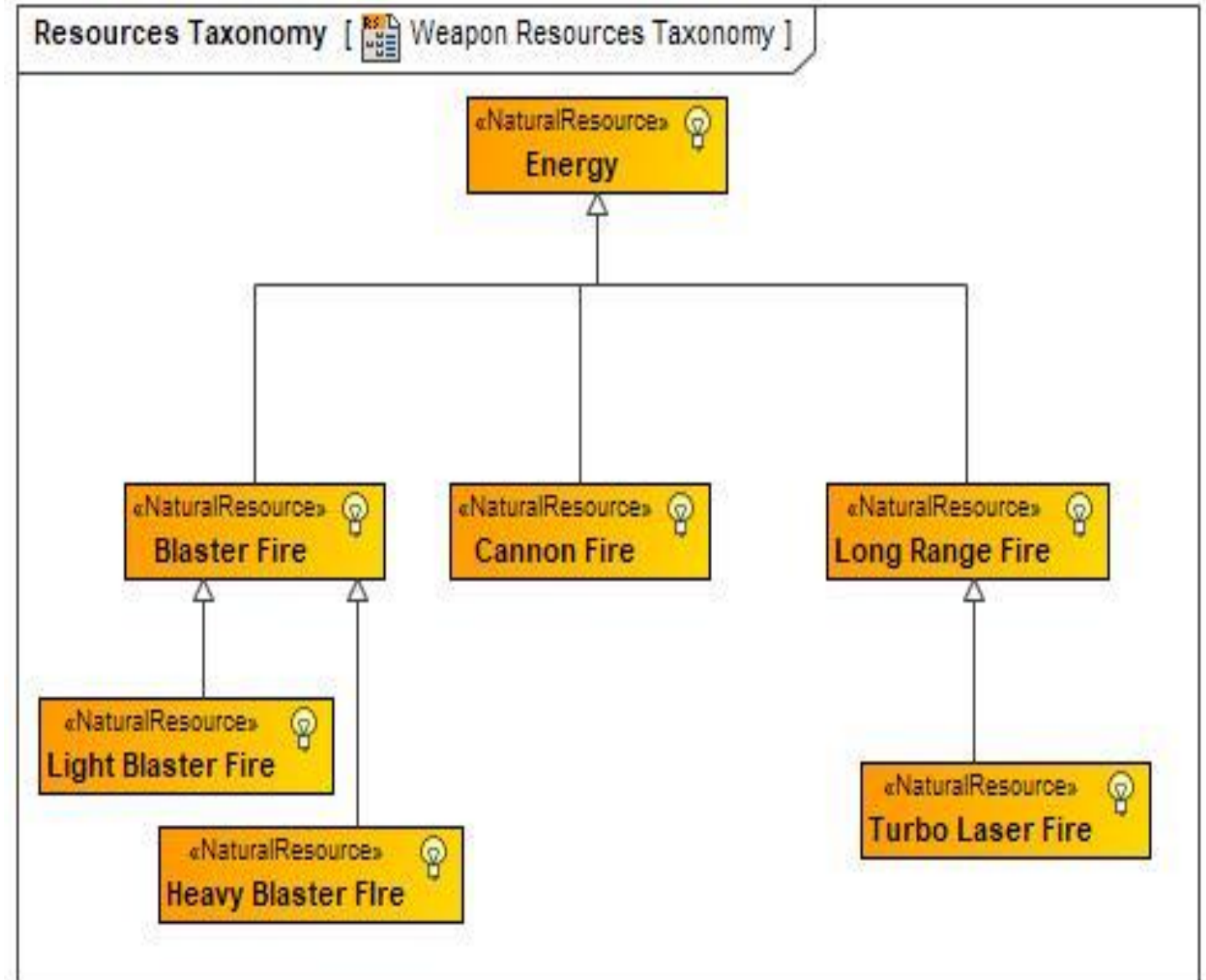
- Initial data model of the information interactions at the Operational level.

- These should be expanded to include attributes and other elements.
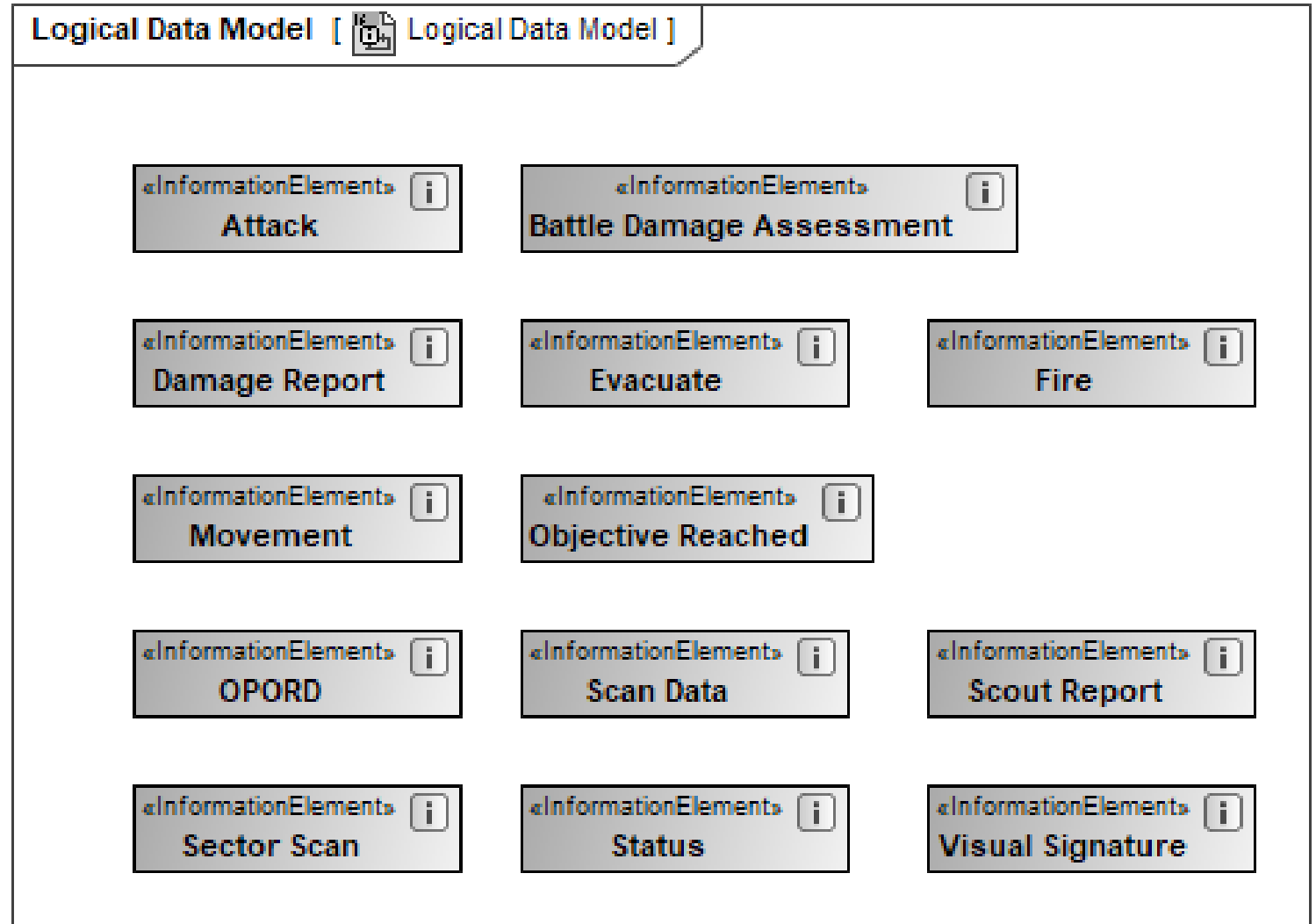
- Defines the Operational Architecture hierarchy of the context in which the Empire (Blue Force) and Rebel Forces (Red Forces) will engage.

- The Empire forces are those which will be deployed as part of their attack strategy. These are the abstract elements, from which Resources will be chosen to implement them.

- The Rebel Forces are less clear. They have been discovered by reconnaissance systems. Additional attributes such as provenance, confidence level, etc. should be added.

- The addition of Friendly, Enemy, and Neutral stereotypes are shown later.

- The Rebel Forces were able to escape as the Empire underestimated the strength of the ground forces cannon which destroyed one of their spaceships.

Operational Taxonomy [📄 Operational Taxonomy]

«OperationalPerformer»
Rebel Shield

«OperationalPerformer»
Rebel Air Defense Forces

«OperationalPerformer»
Rebel Escape Transport

«OperationalPerformer»
Rebel Ground Defense Forces

«OperationalPerformer»
Rebel Command

«OperationalPerformer»
Rebel Forces

«OperationalArchitecture»
Planetary Invasion Mission Architecture

«OperationalPerformer»
Empire Ground Attack Forces

«OperationalPerformer»
Empire Scout Forces

«OperationalPerformer»
Empire Air Transport Forces

«OperationalPerformer»
Empire Space Forces

«OperationalPerformer»
Empire Command

«OperationalPerformer»
Empire Air Attack Forces

«OperationalPerformer»
Empire Forces

- IBD version of the Operational Architecture.

- An abstract/solution independent expression of the proposed battle.

- Interactions include Information Exchanges between troops and commanders, weapons fire, sustained damage, scan data, etc.

Operational Internal Connectivity [Attack Mission Architecture]
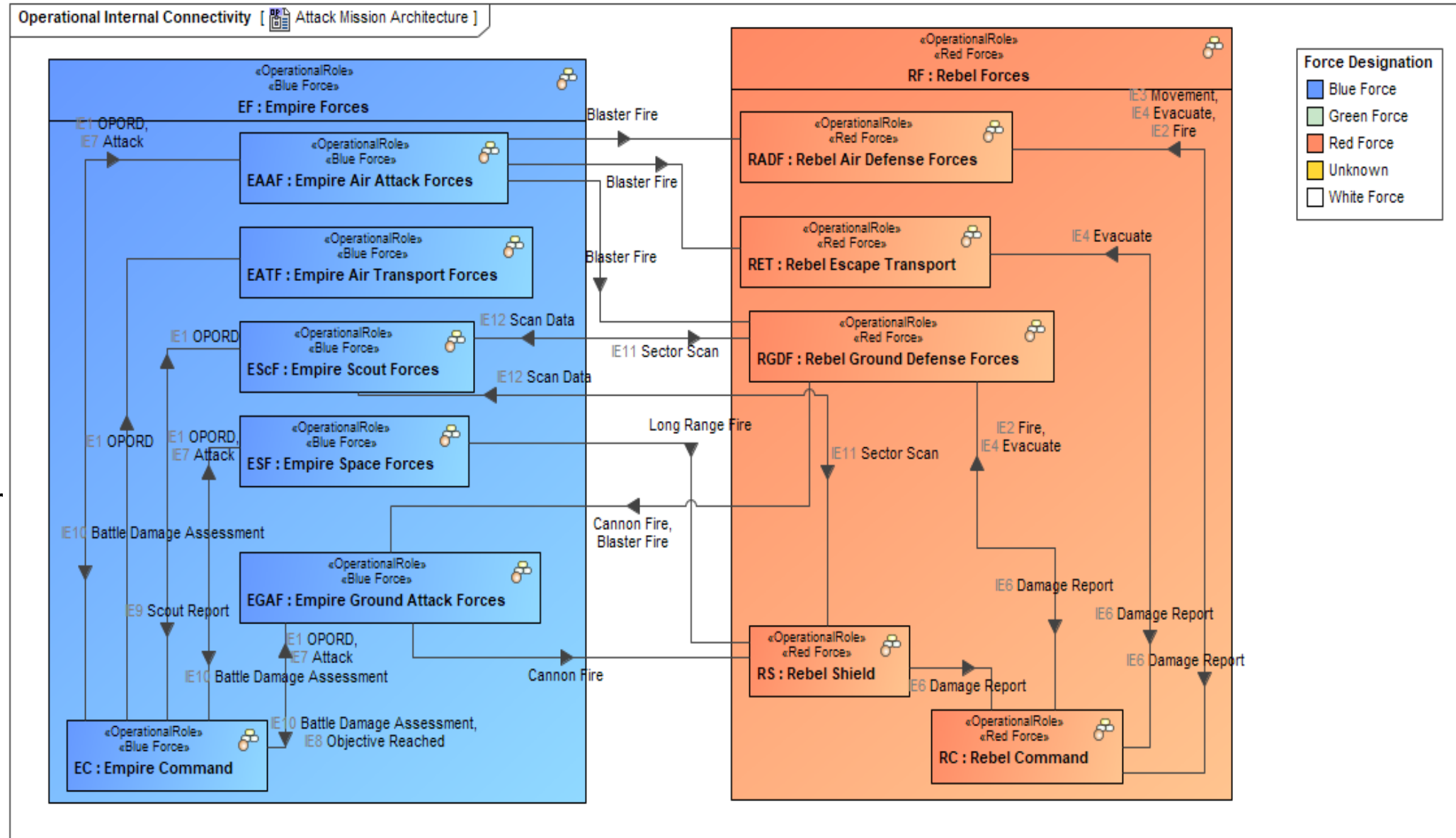
- Automatically generated table.

- Traceability between the required Capabilities and the proposed Operational Performers. The Scout Forces and Air Transport Forces are not included in the Attack context.

- All required capabilities have been exhibited.

- This is the functional hierarchy of the Execute Planetary Invasion Mission Thread.

- It is broken into Mission Threads of Scout Planet, Weaken Planetary Defenses, Attack Primary Objective and Deploy Attack Force.

- Each of these are further decomposed into Mission Tasks.

- The Empire forces are those which will be deployed as part of their attack strategy. These are the abstract elements, from which Resources will be chosen to implement them.

- Each has a set of Operational Activities that they can perform.

- If MBSE is already established in an organization, these would be part of a library and reused.

- For a new installation, these would form the basis of the library to be populated as further missions are defined.

- These activities are referenced by the Mission Tasks.

Operational Processes [Empire Operational Processes]

«OperationalPerformer»
Empire Forces

«OperationalPerformer»
Empire Air Attack Forces

«OperationalActivity»
Escort Air Transports

«OperationalActivity»
Fire Weapons

«OperationalPerformer»
Empire Ground Attack Forces

«OperationalActivity»
Fire Weapons

«OperationalActivity»
Capture Enemy Leaders

«OperationalPerformer»
Empire Scout Forces

«OperationalActivity»
Identify Enemy Defensive Capabilities

«OperationalActivity»
Locate Enemy Base

«OperationalPerformer»
Empire Space Forces

«OperationalActivity»
Transport Ground and Air Units

«OperationalActivity»
Bombard Enemy Defenses

«OperationalPerformer»
Empire Command

«OperationalActivity»
Command Deployment

«OperationalActivity»
Command Attack

«OperationalPerformer»
Empire Air Transport Forces

«OperationalActivity»
Transport Troops and Equipment

- Traceability table showing the Actual Missions, Mission Threads, Mission Tasks and operational activities that exhibit the required capabilities.

- The scope has been focused on the Planetary Attack capability and its owned capabilities.

- This helps to validate the Mission thread against the required capabilities.

- Metrics could be added to determine the required and provided measures for trade-off analysis.

- Once again, these are the Rebel Force elements that have been discovered as well as their perceived functionality.

Operational Processes [Rebel Operational Processes]

«OperationalPerformer» **Rebel Forces**

«OperationalPerformer» **Rebel Ground Defense Forces**

«OperationalActivity» **Provide Cannon Fire**

«OperationalActivity» **Destroy Attacking Ground Forces**

«OperationalPerformer» **Rebel Shield**

«OperationalActivity» **Repel Heavy Artillery**

«OperationalActivity» **Provide Short Range Fires**

«OperationalPerformer» **Rebel Escape Transport**

«OperationalActivity» **Evacuate Troops and Equipment**

«OperationalPerformer» **Rebel Air Defense Forces**

«OperationalActivity» **Destroy Attacking Air Forces**

«OperationalActivity» **Destroy Attacking Ground Forces**

«OperationalPerformer» **Rebel Command**

«OperationalActivity» **Command Evacuation**

«OperationalActivity» **Command Fires**

«OperationalActivity» **Evaluate Battle Damage**

«OperationalActivity» **Command Ground Forces**

«OperationalActivity» **Command Air Forces**

«OperationalActivity» **Coordinate Forces**

- This is an abbreviated for of the Mission Thread. Details have been excluded to ensure that the diagram is legible

- Note the interactions between the rebel and Empire Forces.

- The Ground Attack Forces Fire Weapons and the Rebel Forces Incur Damage and Emit a Visual Signature. The Signature is detected and analyzed by the Assess Damage and Scan for Rebel Defense Forces activities.

- Counter attacks as well as other Rebel offensive activities should also be defined.
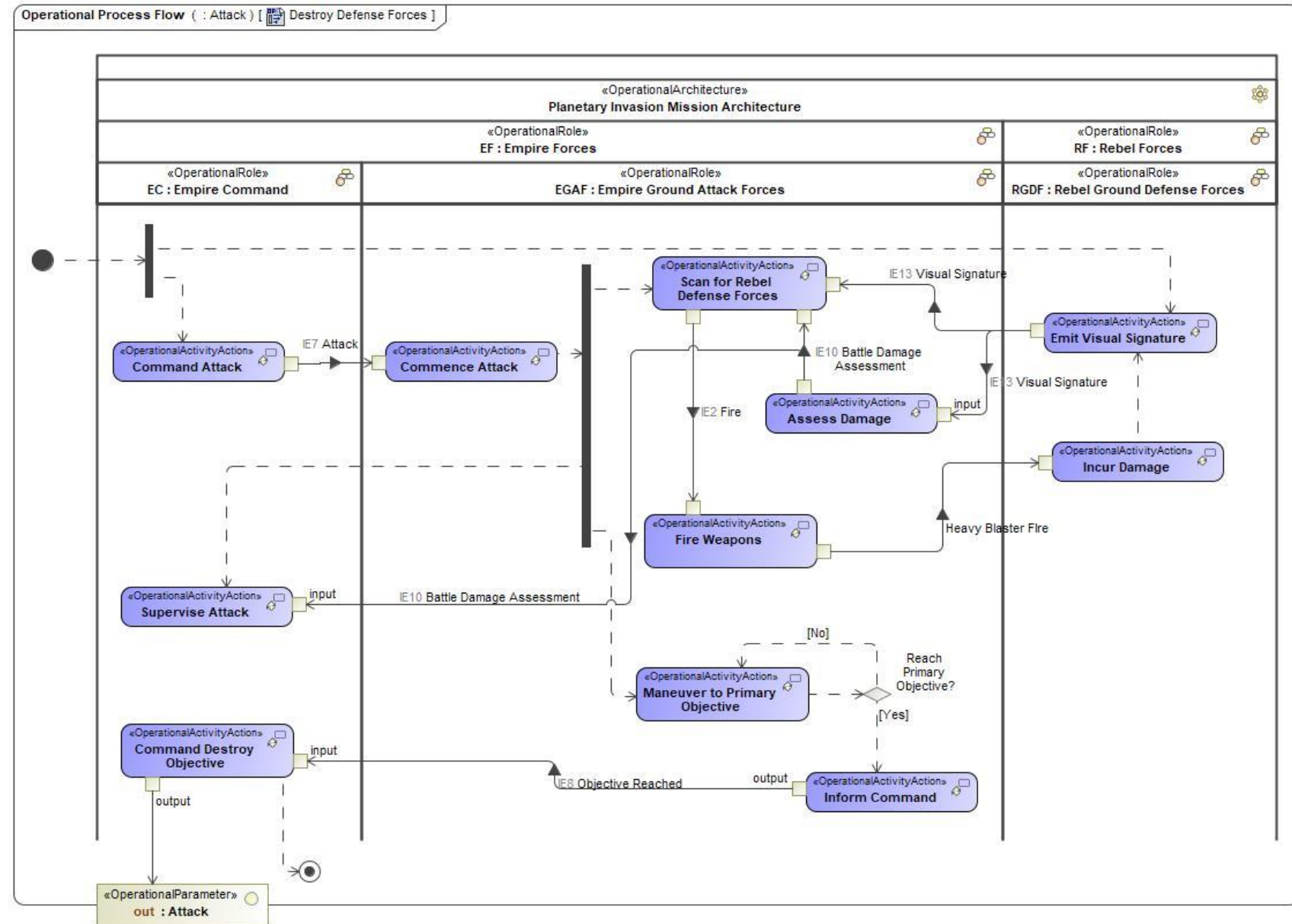
- Summary table showing the Information Elements and their relationships.

- They do not all appear on activity diagrams, indicating that the behavioral model is not yet complete.

| #	△ Name	Participates In Activity	Info Exchange	Exchange Source	Exchange Target
1	Attack	Command Attack / Commence Attack / Destroy Defense Forces	OE21 Operational Exchange:flow for Attack[/ OE22 Operational Exchange:flow for Attack[/ OE9 Operational Exchange:flow for Attack[O	Empire Command	Empire Air Attack Force / Empire Space Forces / Empire Ground Attack F
2	Battle Damage Ass	Assess Damage / Scan for Rebel Defense Forces / Supervise Attack	OE34 Operational Exchange:flow for Battle Da / OE35 Operational Exchange:flow for Battle Da / OE36 Operational Exchange:flow for Battle Da / OE43 Operational Exchange:flow for Battle Da	Empire Ground Attack F / Empire Space Forces / Empire Air Attack Force	Empire Command / Empire Ground Attack F
3	Damage Report		OE27 Operational Exchange:flow for Damage / OE28 Operational Exchange:flow for Damage / OE29 Operational Exchange:flow for Damage / OE30 Operational Exchange:flow for Damage / OE11 Operational Exchange:flow for Damage	Rebel Shield / Rebel Ground Defense F / Rebel Escape Transport / Rebel Air Defense Force / Empire Ground Attack F	Rebel Command / Empire Ground Attack F
4	Evacuate		OE8 Operational Exchange:flow for Evacuate[/ OE24 Operational Exchange:flow for Evacuate / OE25 Operational Exchange:flow for Evacuate	Rebel Command	Rebel Escape Transport / Rebel Ground Defense F / Rebel Air Defense Force
5	Fire	Fire Weapons / Scan for Rebel Defense Forces	OE6 Operational Exchange:flow for Fire[Oper / OE26 Operational Exchange:flow for Fire[Ope / OE10 Operational Exchange:flow for Fire[Ope	Rebel Command / Empire Ground Attack F	Rebel Ground Defense F / Rebel Air Defense Force / Empire Ground Attack F
6	Movement		OE7 Operational Exchange:flow for Movemer	Rebel Command	Rebel Air Defense Force
7	Objective Reached	Inform Command / Command Destroy Objective	OE12 Operational Exchange:flow for Objectiv	Empire Ground Attack F	Empire Command
8	OPORD		OE17 Operational Exchange:flow for OPORD[/ OE18 Operational Exchange:flow for OPORD[/ OE19 Operational Exchange:flow for OPORD[/ OE20 Operational Exchange:flow for OPORD[/ OE23 Operational Exchange:flow for OPORD[/ OE3 Operational Exchange:flow for OPORD[O / OE4 Operational Exchange:flow for OPORD[O	Empire Command / Rebel Command	Empire Space Forces / Empire Scout Forces / Empire Air Transport Fo / Empire Air Attack Force / Empire Ground Attack F / Rebel Air Defense Force / Rebel Escape Transport
9	Scan Data		OE39 Operational Exchange:flow for Scan Dat / OE40 Operational Exchange:flow for Scan Dat	Rebel Ground Defense F / Rebel Shield	Empire Scout Forces
10	Scout Report		OE33 Operational Exchange:flow for Scout Re	Empire Scout Forces	Empire Command
11	Sector Scan		OE37 Operational Exchange:flow for Sector S / OE38 Operational Exchange:flow for Sector S	Empire Scout Forces	Rebel Ground Defense F / Rebel Shield
12	Status				
13	Visual Signature	Emit Visual Signature / Scan for Rebel Defense Forces / Assess Damage	OE41 Operational Exchange:flow for Visual Si / OE42 Operational Exchange:flow for Visual Si	Rebel Ground Defense F	Empire Ground Attack F

- Details the command hierarchy of the main organizations and posts.

- These posts and organizations are reused in subsequent diagrams/slides showing different configurations.

- Instead of showing composition a commands relationship is shown. This keeps its elements loosely coupled.

- These can then be inherited from and reused in other structures without overly constraining them.

- Competencies, equipment, and executed functions can also be shown.
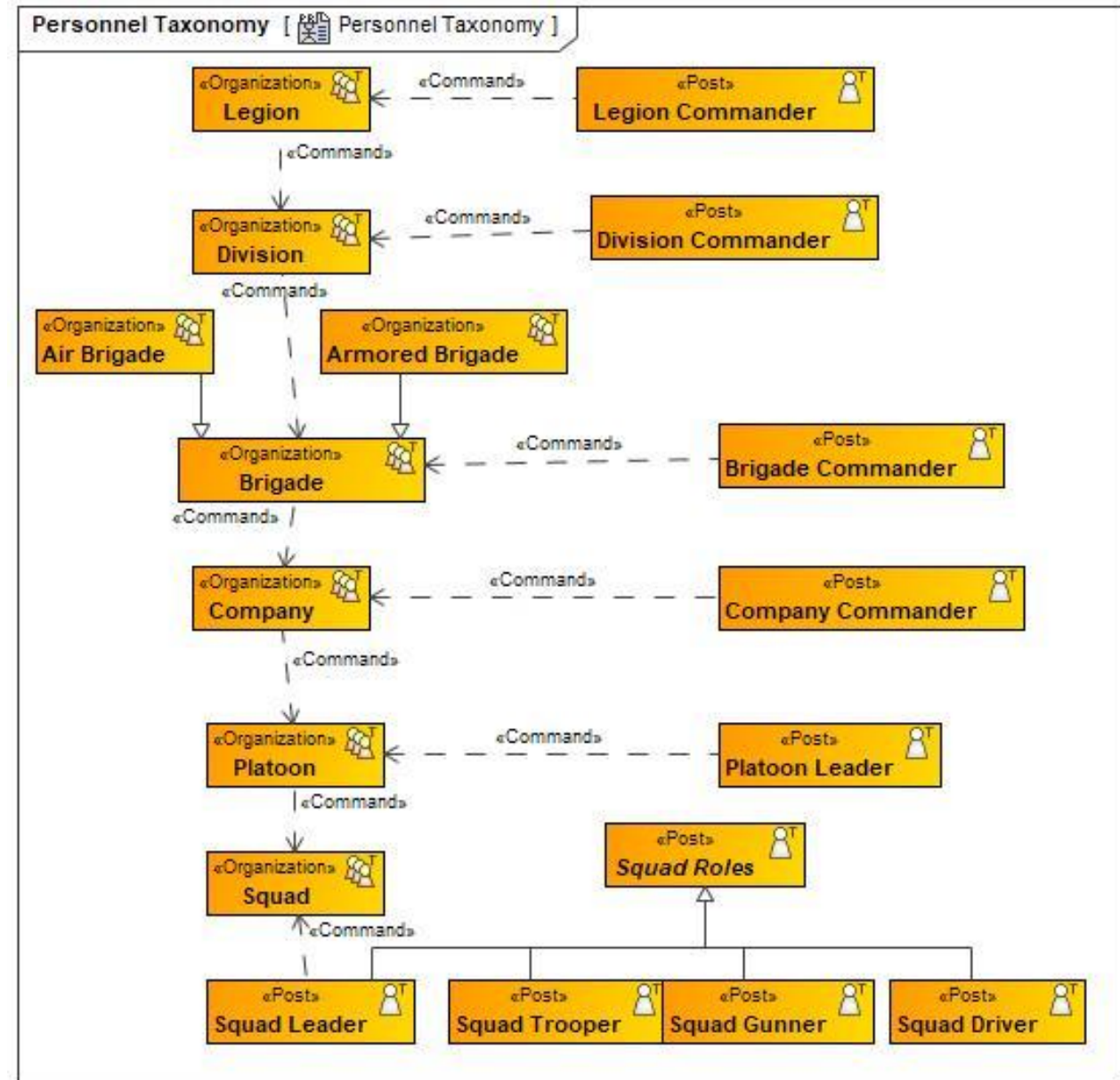
- Similar structure to the previous slide for the AT-AT platoon reusing the previously defined structure.

- Posts are inherited as are organizations.

- Elements are inherited to take advantage of equipment and competencies, etc. and ensure uniformity to Empire structures.

- These will be combined with equipment to form capability configurations.
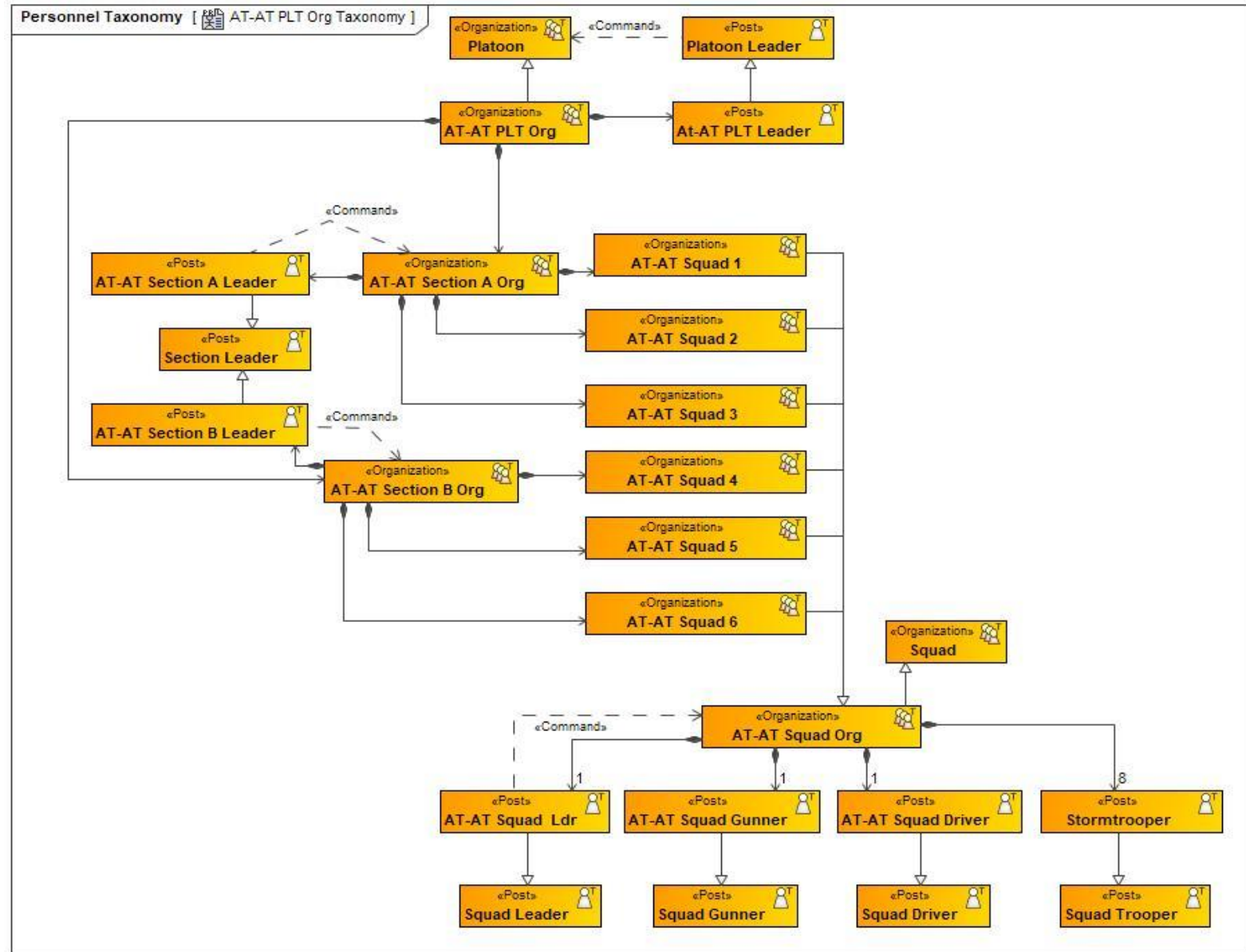
- Heavy Mechanized Platoon Structure combines the systems on the left with the organizations on the right.

- These can be deployed into battle and the functionality of the capability configurations as well as the organizations can be combined and documented.
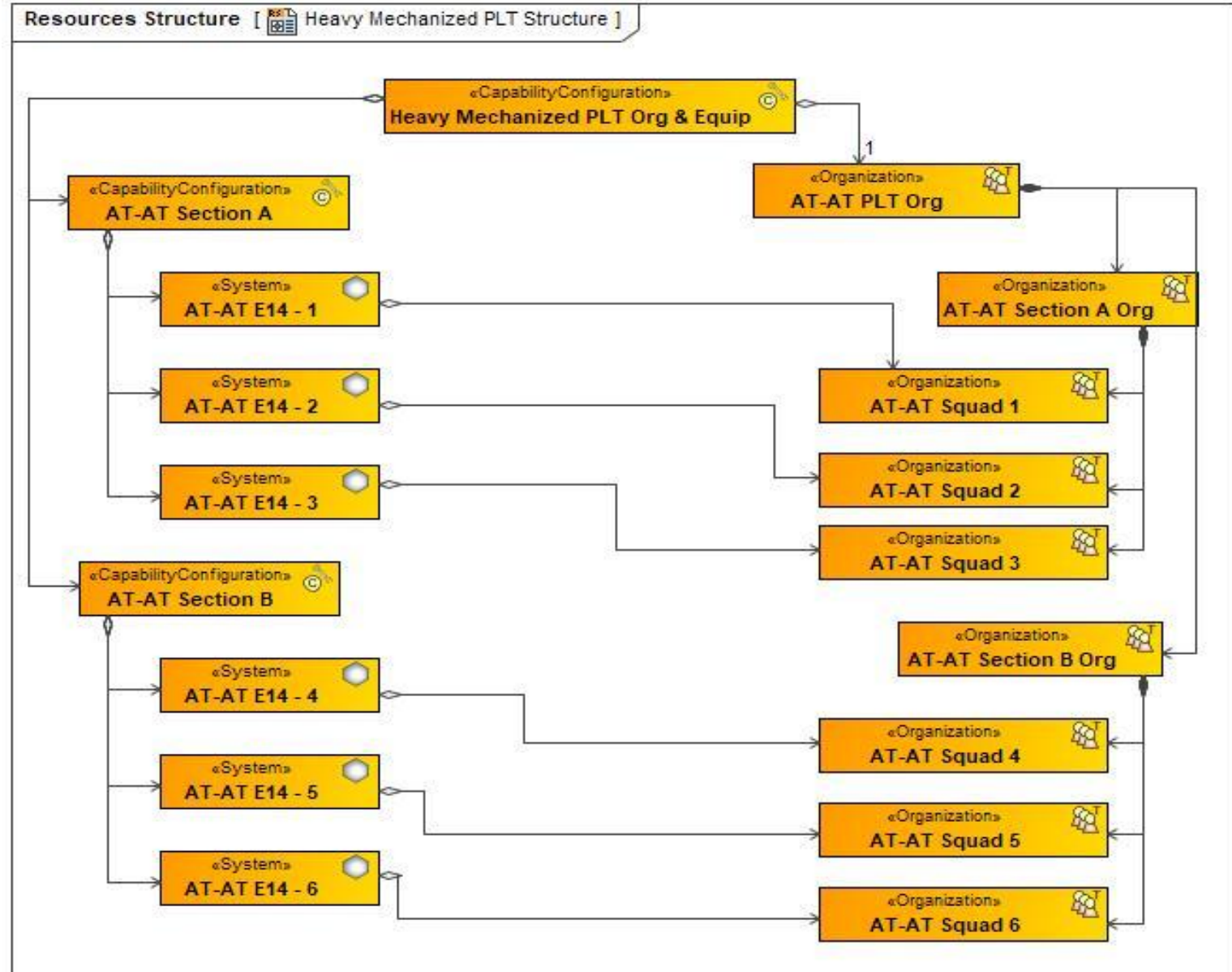
- The Mission Engineering Thread detailing the various steps of Execute Hoth Planetary Invasion.

- The functions could either be part of the Mission Engineering Thread, or be functions performed by the resources, now that we have identified some of these.

Resources Processes [Resources Processes]

«MissionEngineeringThread»
Execute Hoth Planetary Invasion

«MissionEngineeringThread»
Scout Hoth Surface

«Function»
Deploy Scout Droids

«Function»
Explore Hoth Surface

«Function»
Identify Rebel Structures/Forces

«Function»
Report Findings

«MissionEngineeringThread»
Deploy Attack Force

«Function»
Load Equipment on Transports

«Function»
Load Personnel on Transports

«Function»
Launch Transports

«Function»
Maneuver to Landing Zone

«Function»
Disembark Troops

«Function»
Unload Equipment

«MissionEngineeringThread»
Assault Rebel Hoth Defenses

«Function»
Coordinate Air, Ground, Space Forces

«Function»
Maneuver to Shield Generators

«Function»
Protect Empire Ground Forces

«Function»
Attack Rebel Defense Positions

«Function»
Destroy Shield Generators

«Function»
Bombard Rebel Base

«Function»
Invade Rebel Base

«Function»
Capture Rebel Leaders

- Diagrammatic mapping between the Operational and Resource behaviors of all types.

- These include the Mission Threads, Mission Tasks and Operational Activities as well as the Mission Engineering Threads and Functions.

- Weaken Planetary Defenses does NOT have an implementation, which is why the rebels were able to shoot the Spacecraft out of the sky.

- This mapping is essential to ensure a fully implemented battle plan.

- Other relationships could also be helpful within each domain. For example:
  - Offensive Actions and Defensive responses from both sides
  - Offensive and defensive systems
  - Etc.
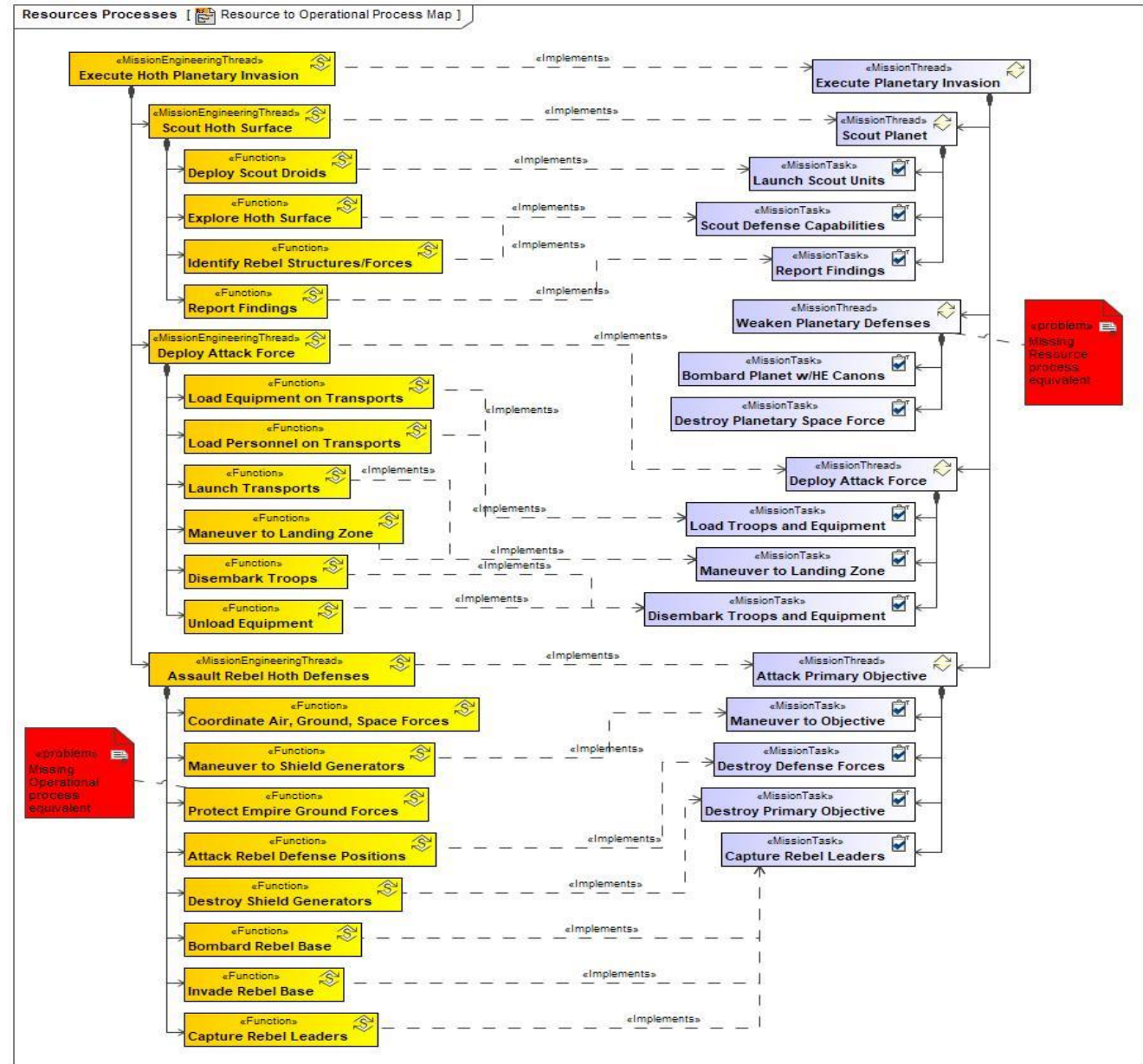
- Traceability table generated to map the Operational behaviors to the resource behaviors.

- Structural tables can also be generated.

- This matrix could be used to spot holes in the defensive or offensive capabilities.

- Finally, the Structure of the Resource Architecture using the previously defined Organizations and Capability Configurations is created.

- The Intelligence Info element defines the source, confidence and provenance of the data surrounding actual rebel forces.

- Given the multiplicity of the resources (8 Fighter Squadrons, 8 Light Mechanized Platoons, etc.) as well as all the posts and equipment in each one, this represents a massive scale.

- This is shown on the following slide.
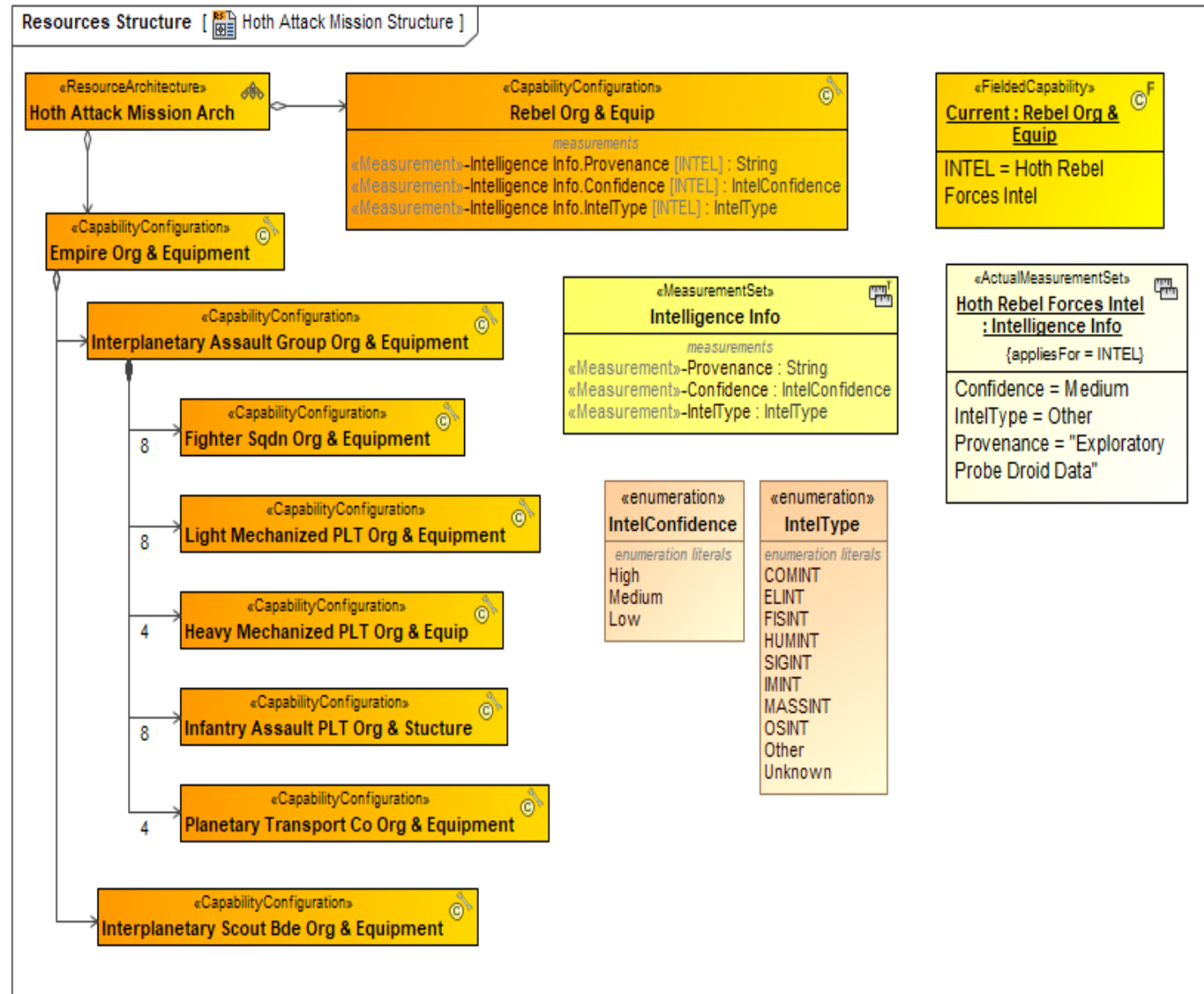
- This diagram illustrates the complexity of the structures defined so far.

- Showing the detailed interactions would quickly lead to quite complex diagrams.

- It would also be difficult to show interactions between lower-level elements as they are within deep structures.

- Strategies will need to be devised on the best way to model this.

- This may involve defining the lower levels together to form the mission engineering threads.
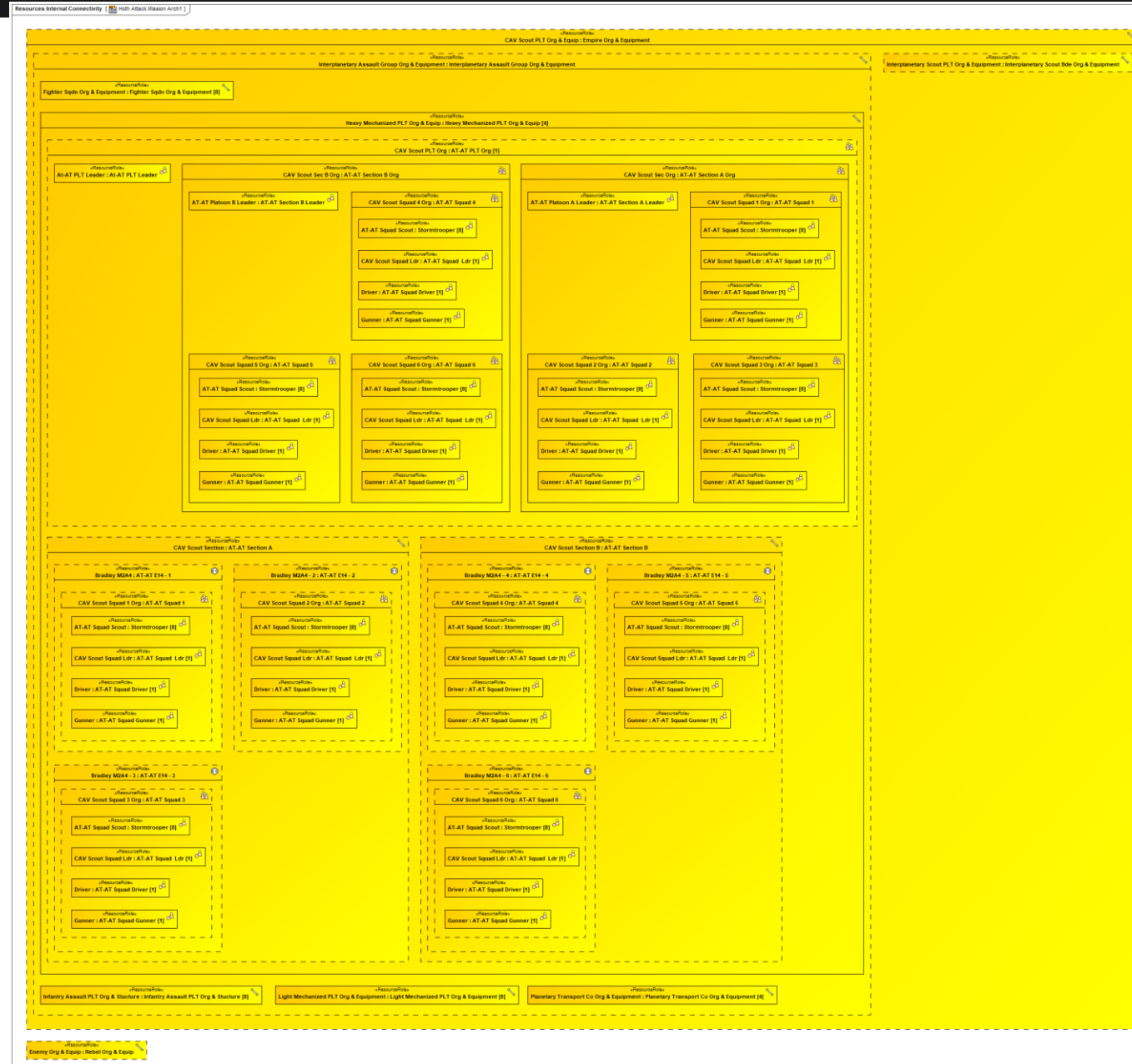
- Simple example showing the implementation of the Empire Persons, Organizations, and Posts.

- The Actual Persons represent identifiable people who fill specific posts.

- This could be used to ensure full staffing levels or simply to identify the main organizations and personnel.
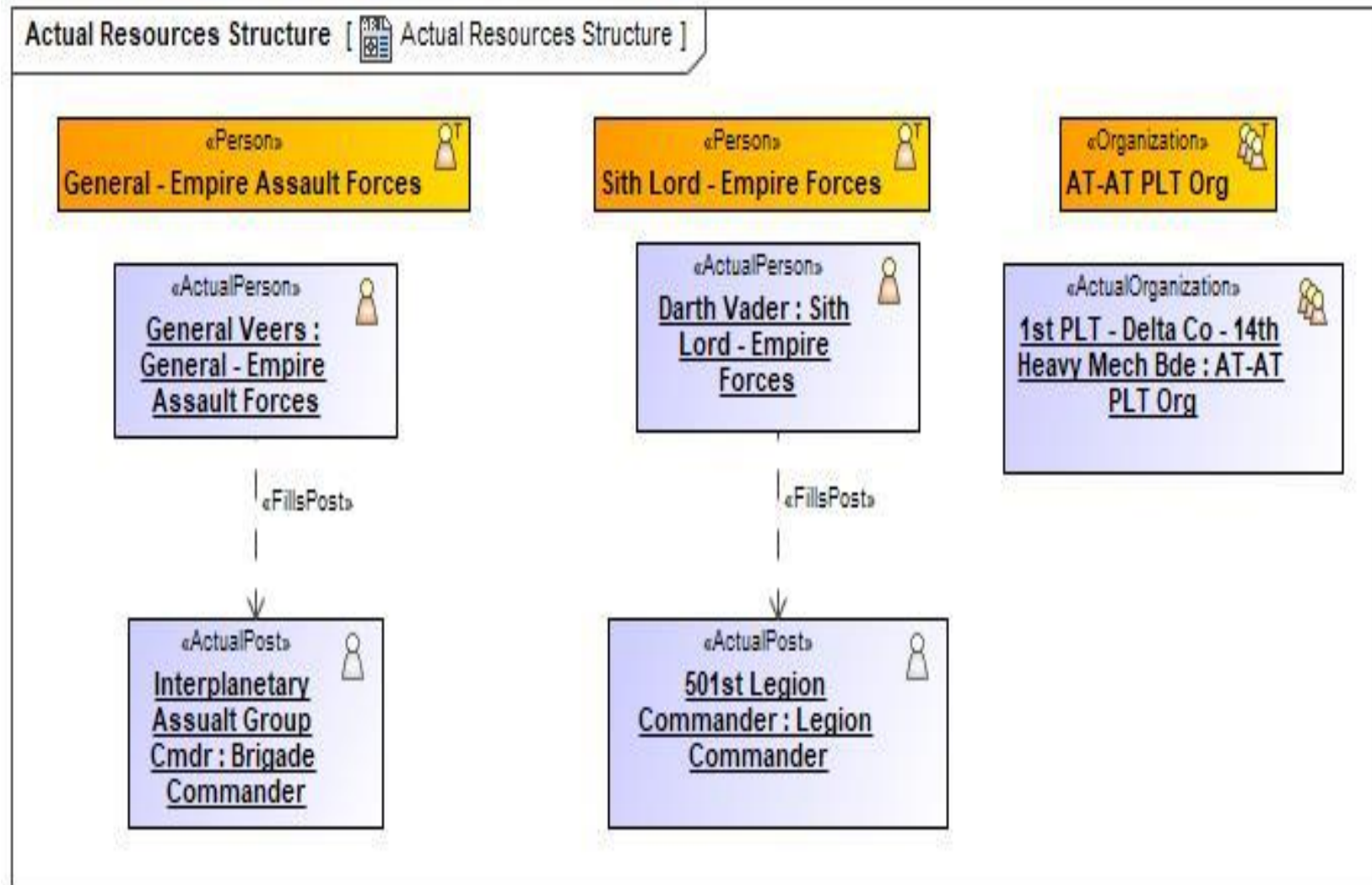
- Automatically generated table showing the actual posts and the actual persons who fill them

- This model was built as a proof of concept for UAF support for Mission Engineering.

- The current UAF metamodel and future extensions (UAF 1.3/2.0) will address most Mission Engineering concepts.

- Standardization of MBSE concepts in a profile is beneficial
  - Reduces learning curve, miscommunication, confusion, etc.

- Examples of model-based standardizations
  - UML was created to standardize SW engineering
  - SysML to extend UML for systems engineering
  - UPDM/UAF to extend SysML/UML for DoDAF/MODAF/NAF
  - RAAML for safety and security in SysML model evaluation

- SysML provides many Mission Engineering concepts but needs extensions

- The approach taken in this presentation provides these extensions

- We will continue to build the model and examine the issues of resource architecture complexity, scale, and detail.
- We need to build behavioral models at both the detailed and high levels.
  - Reuse will be an essential part of this effort – libraries, patterns, GRAs, etc.
- Additional model elements to be added to the model
  - Effects and Outcomes
  - MOS, MOE, MOP, MOX, etc.
  - Other existing elements such as Drivers, Opportunities, Challenges, and Risks.
- Add state machines and sequence diagrams.
- We are socializing the model so that people can build on this to ensure that the UAF Mission Engineering extensions are fit for purpose.
- We will create an unofficial version of these profile extensions to bridge the gap until the next release.
- Finally, we encourage any and all comments to help us achieve our goals.

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Questions?