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MissionML: A Mission Architecture Modeling Language based on Unified Architecture Framework

Yilong Yang¹ (Presenter), Wenxiao Song¹, Chuangye Chang², Xinghai Gao²

1. School of Software, Beihang University, Beijing, China

2. Institute of Unmanned Systems, School of Software, Beihang University, Beijing, China



Introduction

What is the mission?

- A **mission** is a **duty** assigned to an individual or unit^[1].

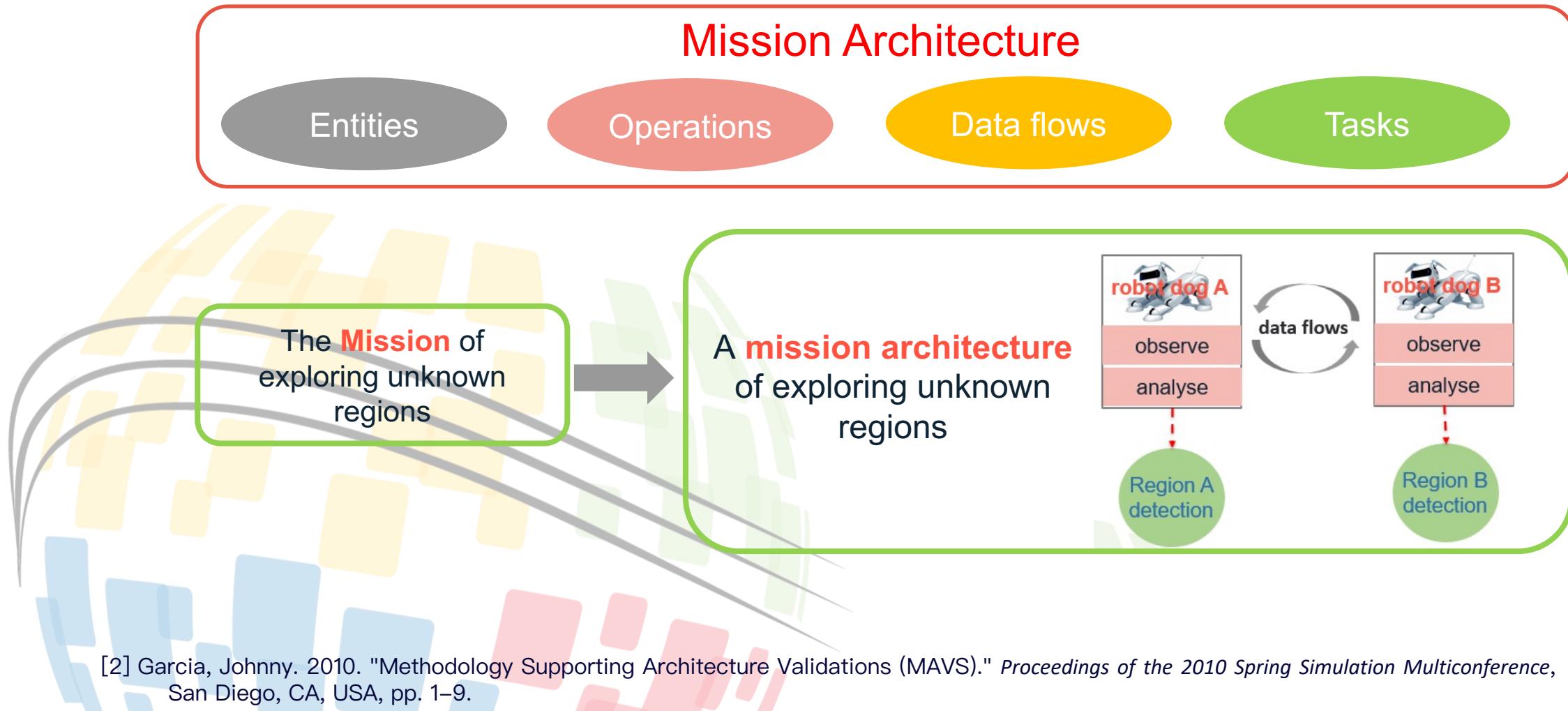


- **Robotic dogs:** to explore unknown regions
- **Robotic arms:** produce and process products

[1] Office of the Under Secretary of Defense for Research and Engineering. 2020. *Mission Engineering Guide*. Washington, D.C.

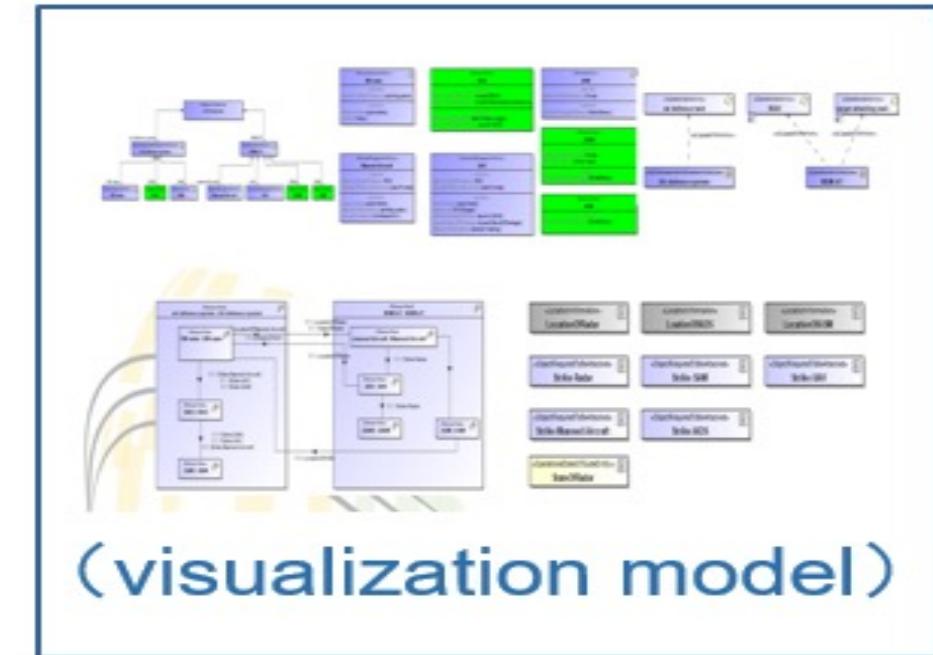
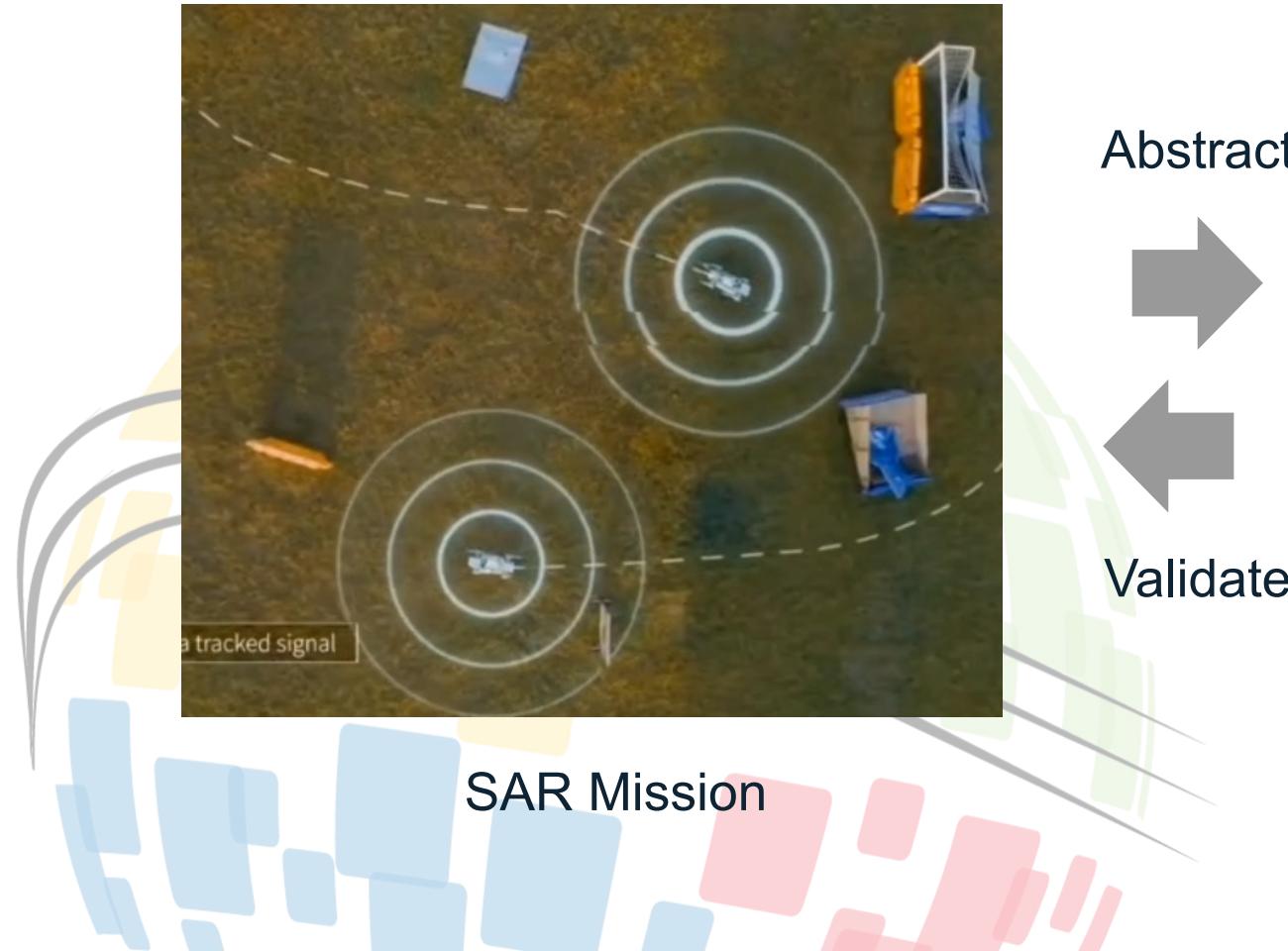
What is the mission architecture?

- “Mission architecture” refers to an organizational **structure** or **framework** design for achieving a mission^[2]



Why modeling mission architecture?

- **Modeling** helps **analyze and visualize the mission**.
- Recognize shortcomings and validate early on whether they meet the requirements.



SAR Mission Architecture Model

Motivation

System Engineers have knowledge of system modeling such as SysML and UAF but lack domain knowledge.

OMG Standards

UML

SysML

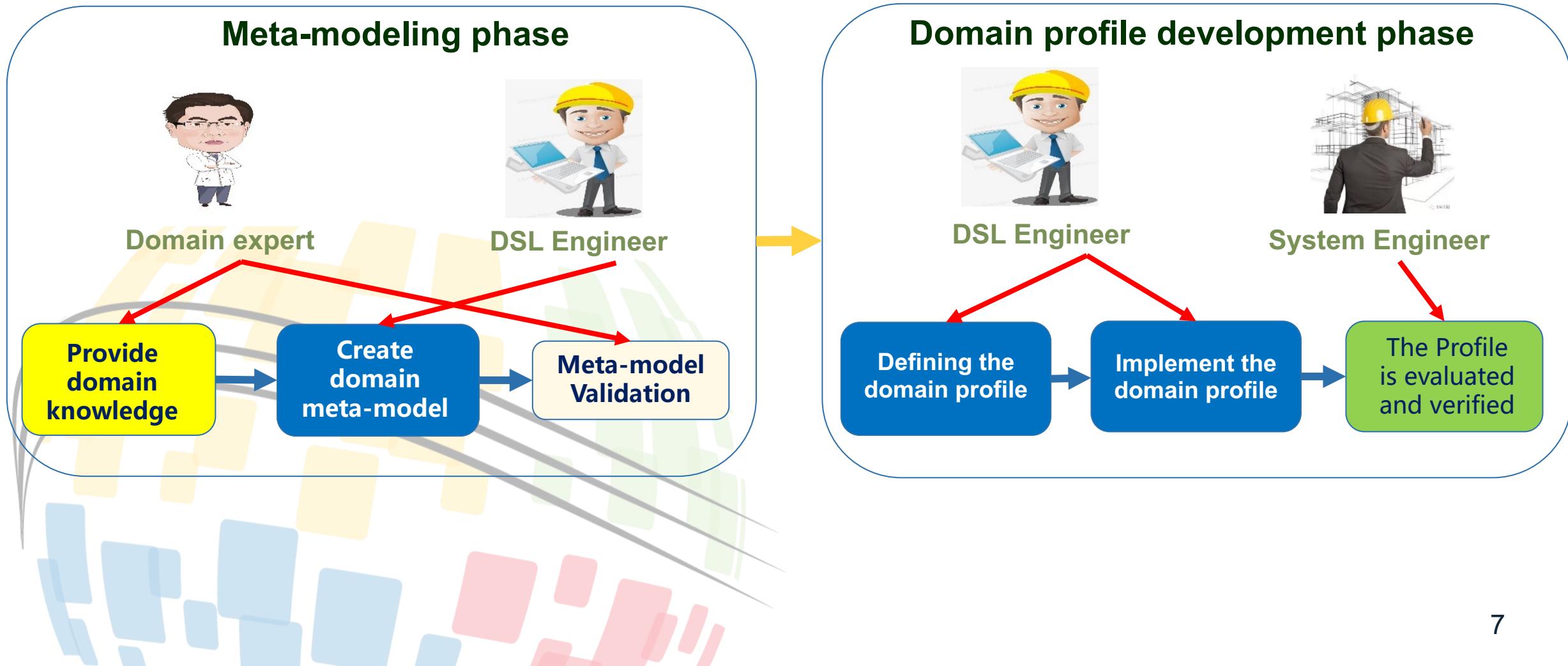
UAF

Existing problems

- Lack of domain knowledge
- hard to model the mission for the new engineers

Objective : Propose a mission architecture modeling language to **utilize the knowledge** of system modeling and incorporate **relevant domain knowledge** to enable system engineers to **model and analyze** the mission architecture **efficiently**

Two-phase approach



Case Studies for Mission Architecture

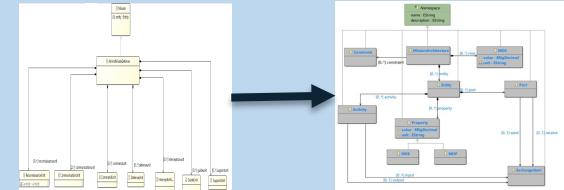
SN	Mission Name	References
1	Air-To-Ground (ATG) mission	Wang, Wei, Yang, Feng, Ma, Wei, Li, Xia, and Wu, Yu. 2015. "A Domain Ontology for Ballistic Missile Defense Conceptual Model." In <i>Proceedings of the 48th Annual Simulation Symposium (ANSS '15)</i> , pp. 181-187. San Diego, CA: Society for Computer Simulation International.
2	A Multi-robot object detection mission within a large marine area	Harbin, J., Gerasimou, S., Matragkas, N., Zolotas, A., & Calinescu, R. 2021. "Model driven simulation-based analysis for multi-robot systems." <i>Proceedings of the 24th ACM/IEEE International Conference on Model Driven Engineering Languages and Systems (MODELS)</i> , pp. 331-341.
3	Joint Air Defense and Anti-Missile Mission architecture	Cao, Guanping, Wang, Yueli, and Gao, Ming. 2020. "Research on the Method of Generating Capability Index Requirements for Joint Air Defense and Anti-Missile System Based on UAF." <i>Military Operations Research and Systems Engineering</i> , vol. 34, no. 02, pp. 13-19.
4	Air defense and Anti-Missile architecture	Zhang, Mengmeng, Chen, Honghui, Luo, Aimin, and Shu, Zhen. 2016. "Timeliness Analysis of Air Defense and Anti-Missile System Based on UPDM." <i>Systems Engineering and Electronics</i> , vol. 38, no. 05, pp. 1059-1066.
5	Maritime Search and Rescue (SAR)	The example is from the software "Magic Cyber Systems Engineer".

The development process of MissionML

Input document

1. SAR (Search and Rescue) Mission document;
2. Disaster Warning Mission document;
3. Multi-robot object detection mission document

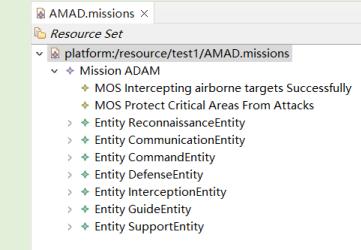
1、Mission Architecture Meta-modeling



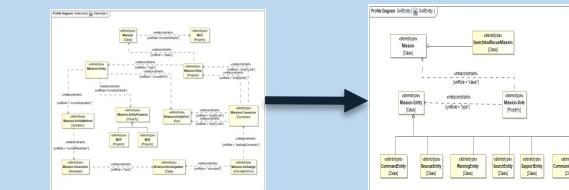
domain-specific mission metamodel

common mission metamodel

2. Validate mission meta-model



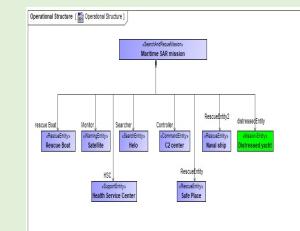
3、Defining MissionML



the core Elements of Language

the Misson Elements of Language

4. Validate MissionML

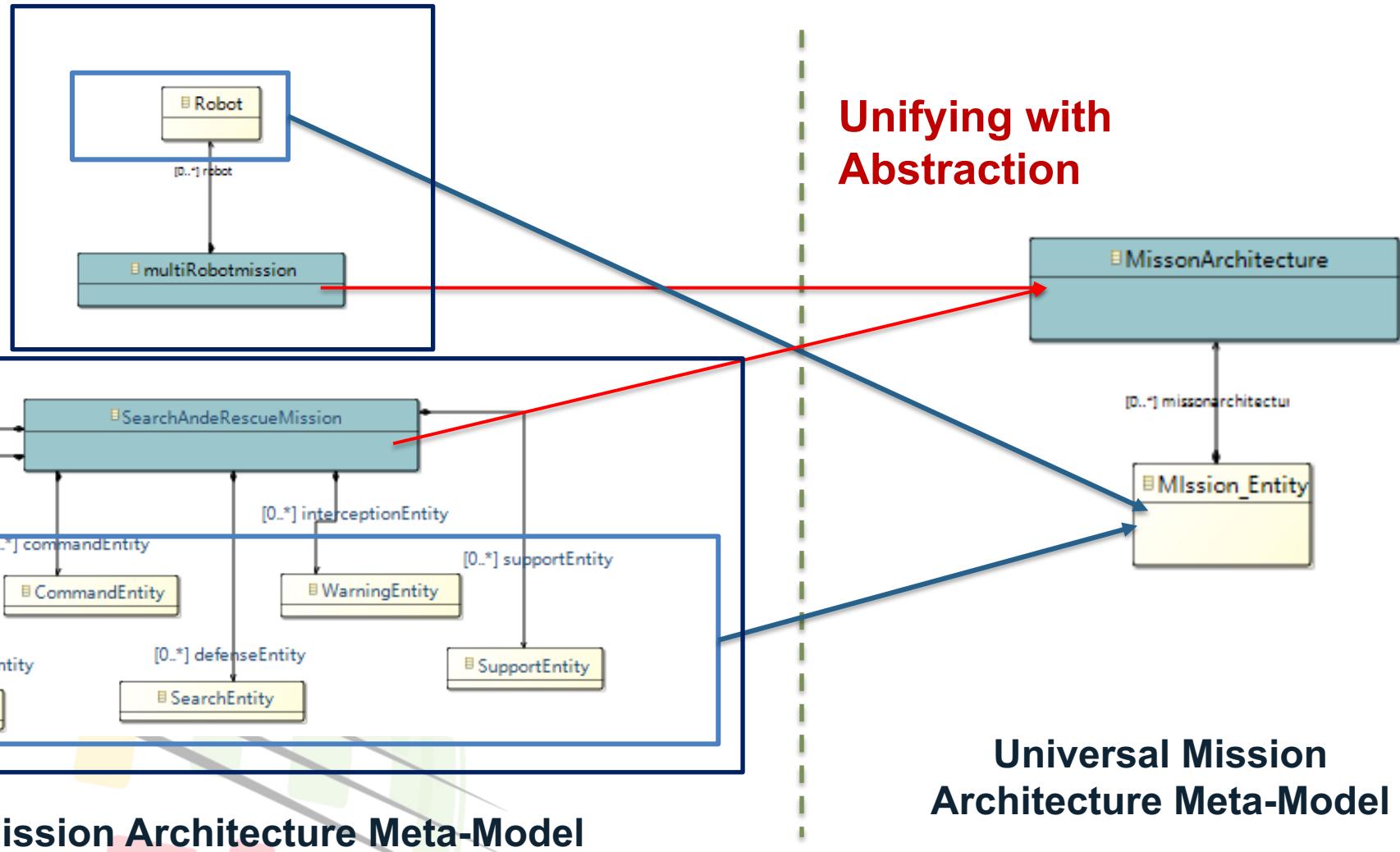


Documentation for validation

1. ADAM(Air Defense And Anti Missile) Mission document ;
2. STAS(Strike Target At Sea) Mission document

Step 1: Mission Architecture Meta-modeling

- Multi-robot object detection mission
- Mission SAR (Search and Rescue)



Domain-Specific Mission Architecture Meta-Model

Unifying with Abstraction

Universal Mission Architecture Meta-Model

Step 2: Validating Mission Meta-model with Eclipse EMF

AMAD.missions X

Resource Set

platform:/resource/test1/AMAD.missions

- Mission ADAM
 - MOS Intercepting airborne targets Successfully
 - MOS Protect Critical Areas From Attacks
- Entity ReconnaissanceEntity
- Entity CommunicationEntity
 - Entity CommandEntity
 - Entity DefenseEntity
 - Entity InterceptionEntity
 - Entity GuideEntity
 - Entity SupportEntity

1. Choose a Case Study

*AMAD.missions X

Resource Set

- Entity InterceptionEntity
- Entity GuideEntity
 - Activity Maneuver
 - Activity Track
 - Activity ReceiveSupport
 - Port pGuideEntity-CommandEntity
 - Port pGuideEntity-CommunicationEntity
 - Port pGuideEntity-SupportEntity
 - Port pGuideEntity-ReconnaissanceEntity
 - Port pGuideEntity-InterceptionEntity
 - MOE EffectivenessOf TrackingTarget
 - MOP RangeOfTrack
 - MOP RangeOfGuide
 - Property Survivability
 - Property Latitude
 - Property Longitude
 - Property Altitude
 - Property RangeOfMovement
 - Property RangeRemainedOfMovement
- Entity SupportEntity

platform:/resource/test1/LocationOfDestination.missions

platform:/resource/test1/ObjectRequiredToBeTracked.missions

Selection Parent List Tree Table Tree with Columns

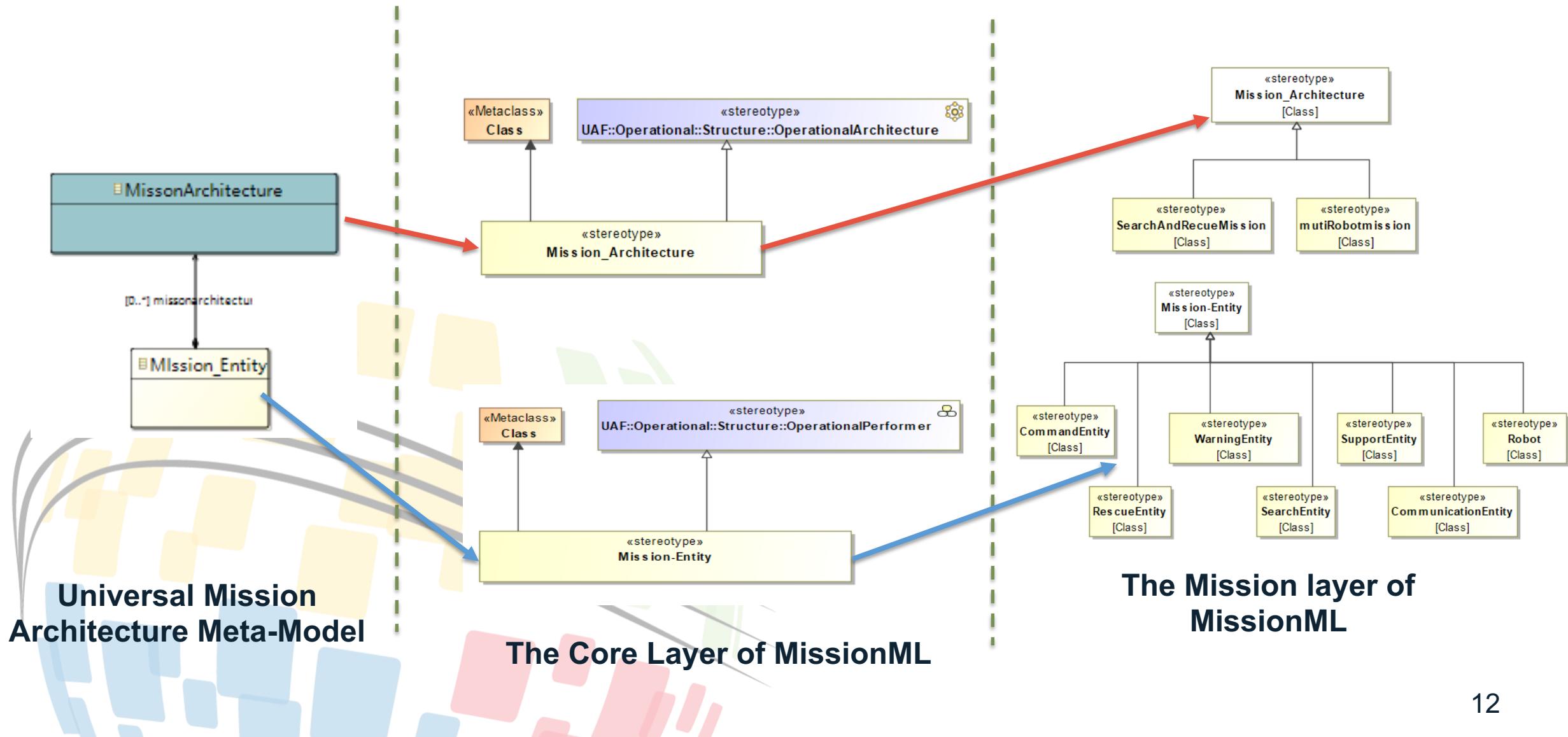
Properties X Problems

Property	Value
Connect1	Port pGuideEntity-CommandEntity
Connect2	Port pGuideEntity-CommandEntity
Description	
Name	pGuideEntity-CommandEntity
Receive	Command LocationOfDestination, Command
Send	Entity State OperationalStateOfGuideEntity

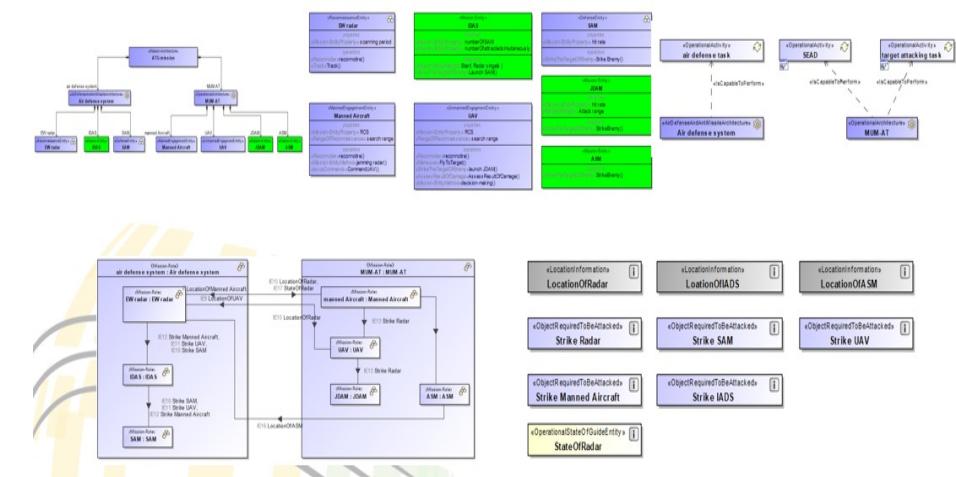
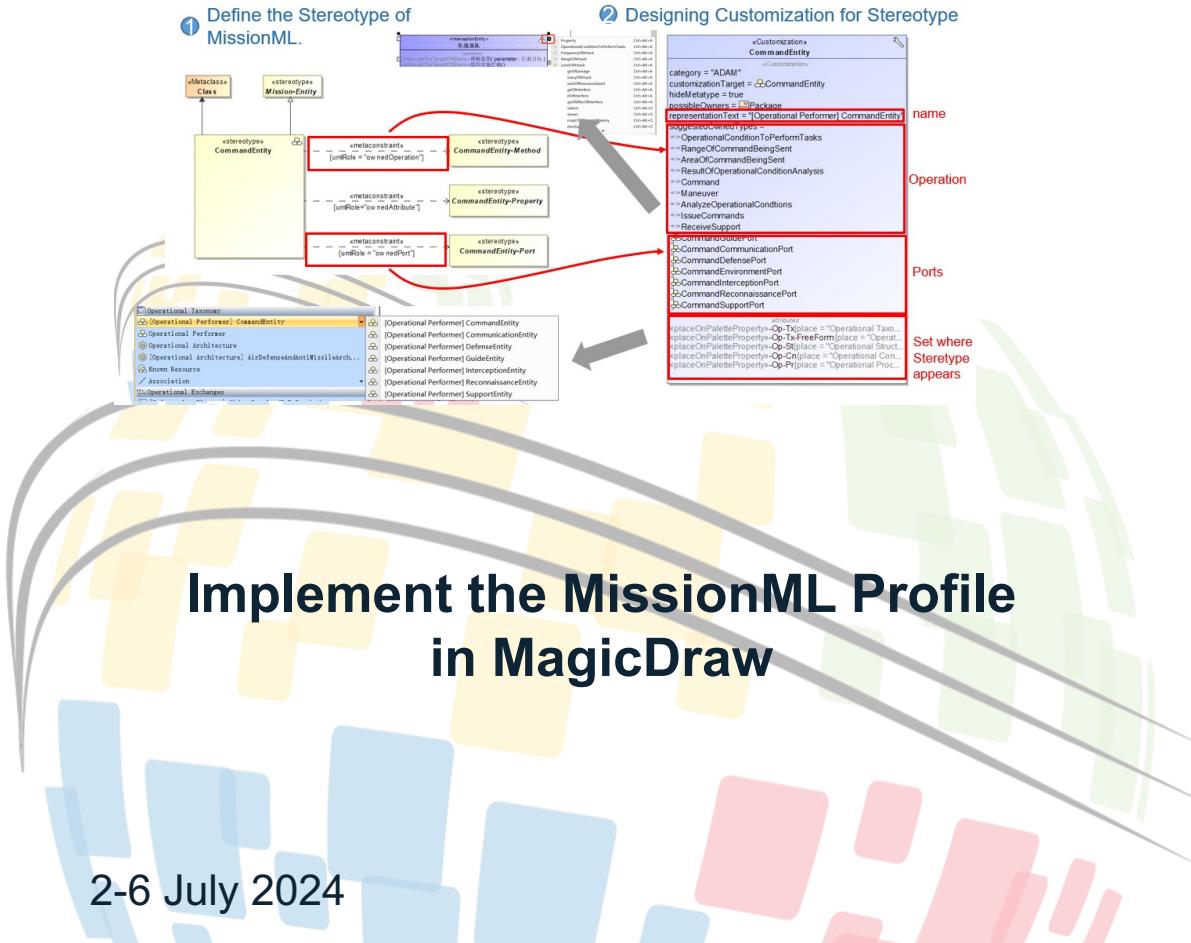
2. Specifying Mission Entity

3. Specifying Entity Interaction

Step 3: Building MissionML Profile (UAF-based)



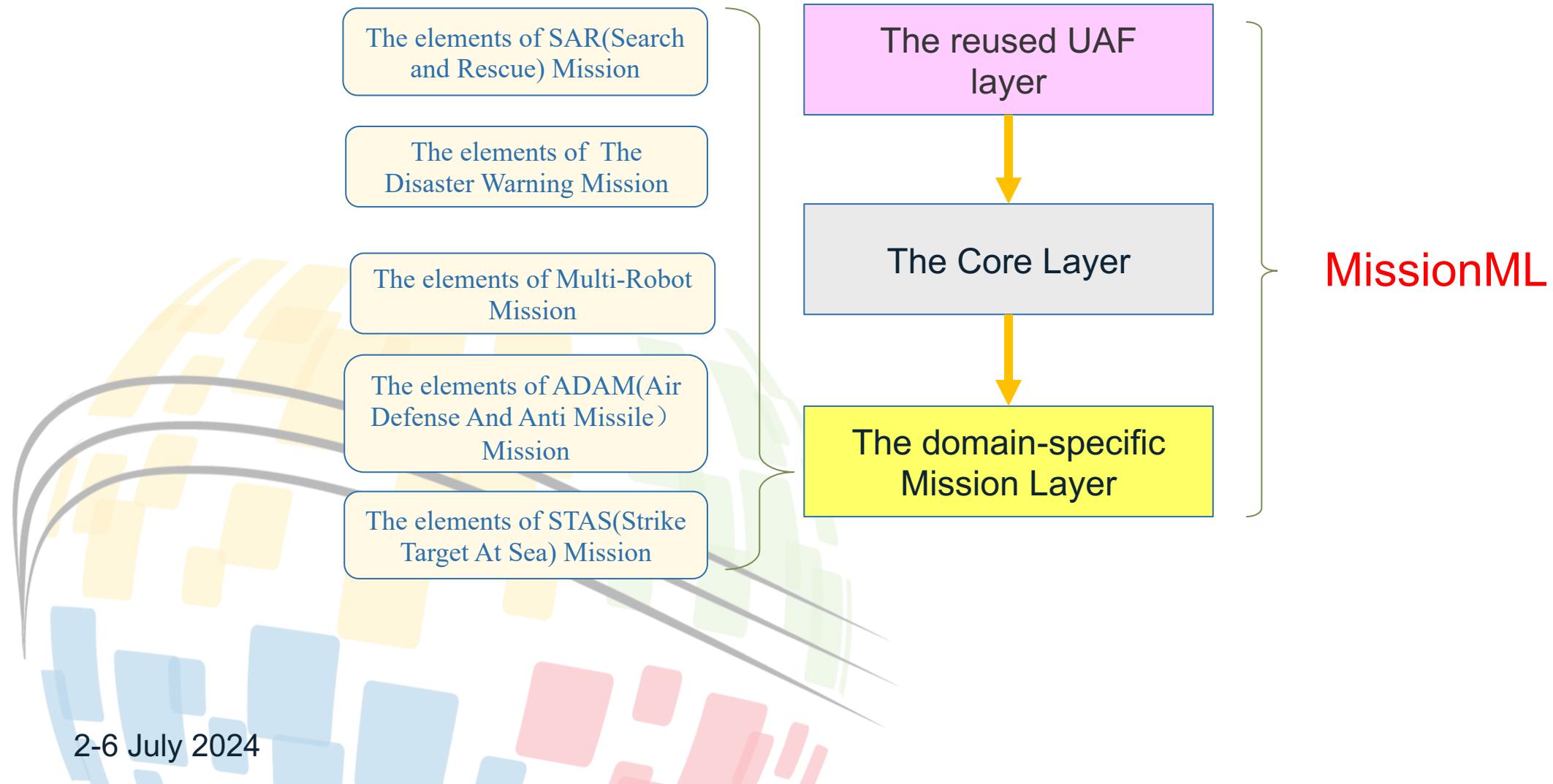
Step 4: Implementing and Validating MissionML Profile



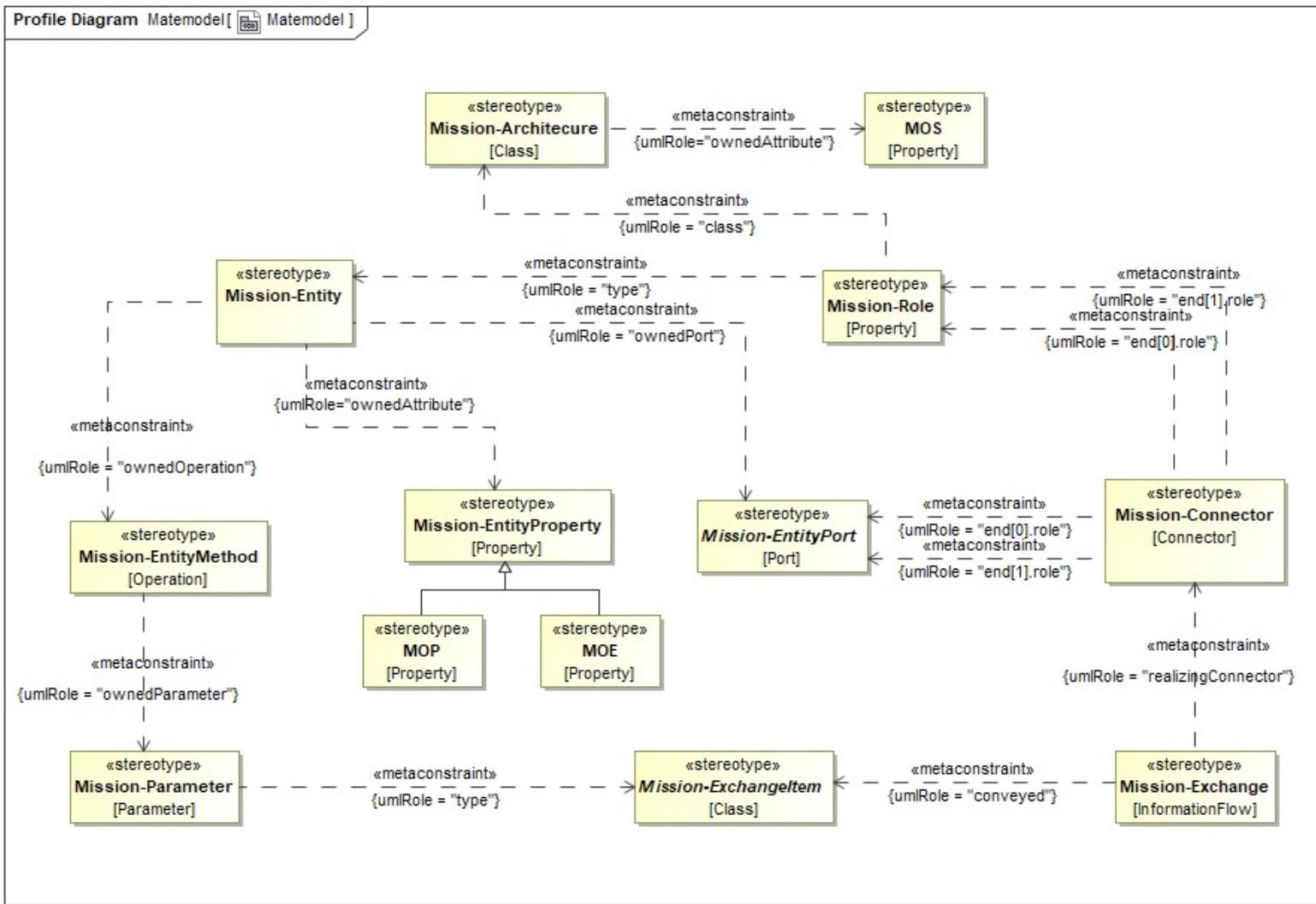


MissionML

Introduction of MissionML



The Core Layer of MissionML



The Core Layer of MissionML

	Motivation Mv	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Sequences Sq	Information If	Parameters Pm	Constraints Ct	Roadmap Rm	Traceability 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)	Envmt, Msmts, Risks (En-Pm, Me-Pm, Rk-Pm)	Operational Constraints Op-Ct	-	Operational Traceability Op-Tr

Elements of MissionML	Elements of UAF	Definition of Concept
Mission-Architecture	Operational::Structure::OperationalArchitecture	<p>UAF: An element used to denote a model of the Architecture, described from the Operational perspective.</p> <p>MissionML: Mission-architecture is a general model Architecture for describing Mission</p>
Mission-Role	Operational::Structure::OperationalRole	<p>UAF: Usage of a OperationalPerformer or OperationalArchitecture in the context of another OperationalPerformer or OperationalArchitecture. Creates a whole-part relationship.</p> <p>MissionML: Mission-Role represents that «Mission-Architecture» is the context of «Mission-Entity», a part of relationship</p>
Mission-Entity	Operational::Structure::OperationalPerformer	<p>UAF: A logical entity that IsCapableToPerform OperationalActivities which produce, consume and process Resources.</p> <p>MissionML: The mission-entity is the Entity in the Mission.</p>

The Core Layer of MissionML

	Motivation Mv	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Sequences Sq	Information If	Parameters Pm	Constraints Ct	Roadmap Rm	Traceability 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)	Envmt, Msmts, Risks (En-Pm, Me-Pm, Rk-Pm)	Operational Constraints Op-Ct	-	Operational Traceability Op-Tr

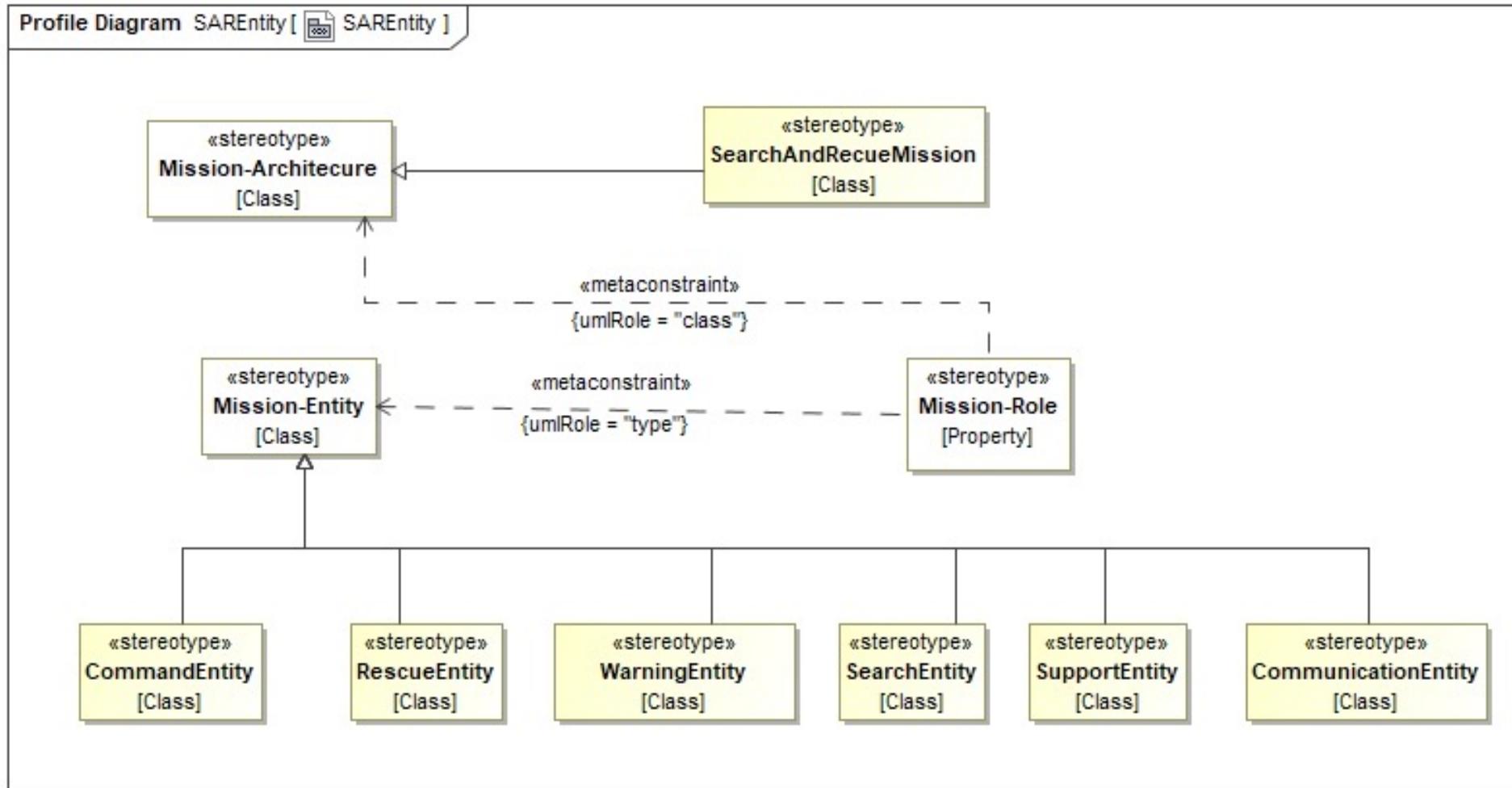
Elements of MissionML	Elements of UAF	Definition of Concept
Mission-EntityMethod	Operational::Structure:: OperationalMethod	<p>UAF: A behavioral feature of an OperationalAgent whose behavior is specified in an OperationalActivity.</p> <p>MissionML: Mission-EntityMethod is a method that an entity within a Mission can possess or employ..</p>
Mission-EntityProperty	Property	<p>MissionML: "Mission-EntityProperty" represents a property that an entity within a mission can possess or include.</p>
Mission-EntityPort	Operational::Structure:: OperationalPort	<p>UAF: An interaction point for an OperationalAgent through which it can interact with the outside environment and which is defined by an OperationalInterface.</p> <p>MissionML: Mission-EntityPort" represents a port that an entity within a mission can possess or include.</p>
Mission-Parameter	Operational::Structure:: OperationalParameter	<p>UAF: An element that represents inputs and outputs of an OperationalActivity. It is typed by an OperationalExchangeItem.</p> <p>MissionML: "Mission-EntityMethod" can have parameters of in, out, and inout types.</p>

The Core Layer of MissionML

	Motivation Mv	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Sequences Sq	Information If	Parameters Pm	Constraints Ct	Roadmap Rm	Traceability 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)	Envmt, Msmts, Risks (En-Pm, Me-Pm, Rk-Pm)	Operational Constraints Op-Ct	-	Operational Traceability Op-Tr

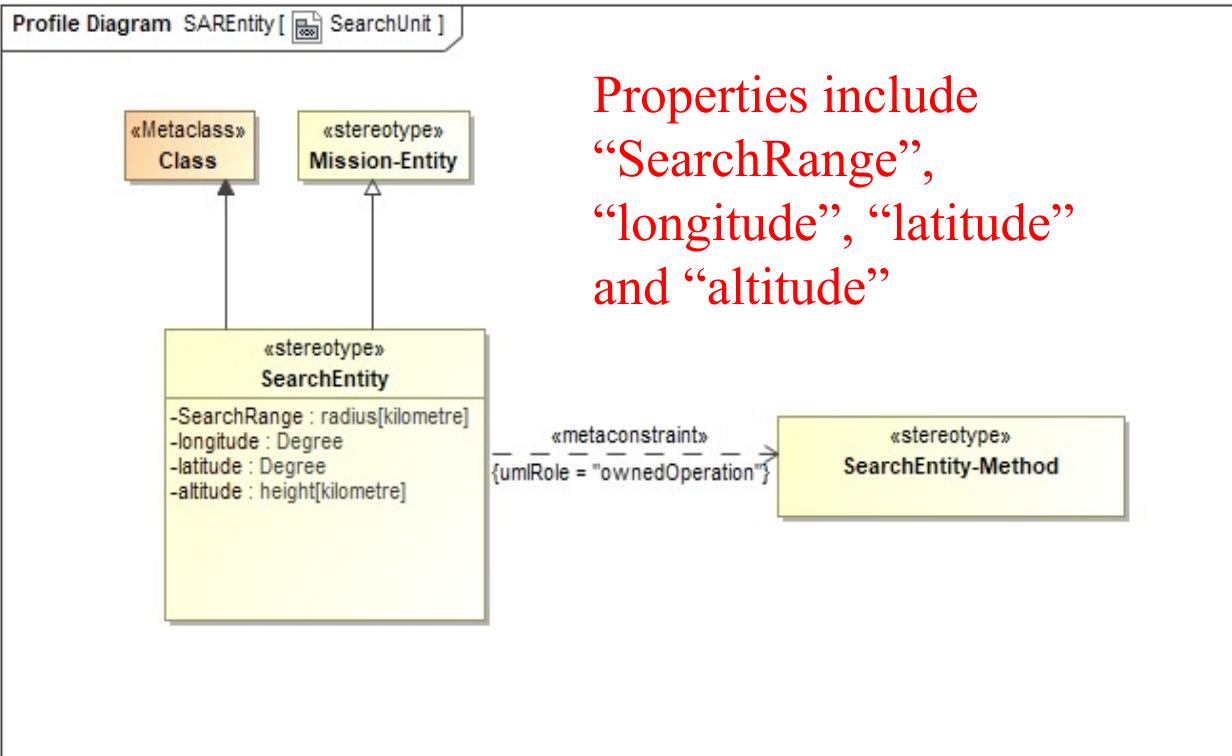
Elements of MissionML	Elements of UAF	Definition of Concept
Mission-Interface	Operational::Connectivity:: OperationalInterface	<p>UAF: A declaration that specifies a contract between the OperationalPerformer it is related to, and any other OperationalPerformers it can interact with.</p> <p>MissionML: In a mission architure, an interaction contract between one entity and other entities.</p>
Mission-Connector	Operational::Connectivity:: OperationalConnector	<p>UAF: A Connector that goes between OperationalRoles representing a need to exchange Resources. It can carry a number of OperationalExchanges.</p> <p>MissionML: A connection between "Mission-Role" indicating that there is a need for interaction between them, which can contain some "Mission-Exchange"</p>
Mission-Exchange	Operational::Connectivity:: OperationalExchange	<p>UAF: Asserts that a flow can exist between OperationalPerformers (i.e., flows of information, people, materiel, or energy).</p> <p>MissionML: Represents the flows that can exist between entities (information flow, command flow, etc.).</p>

The Mission layer: SAR Entity

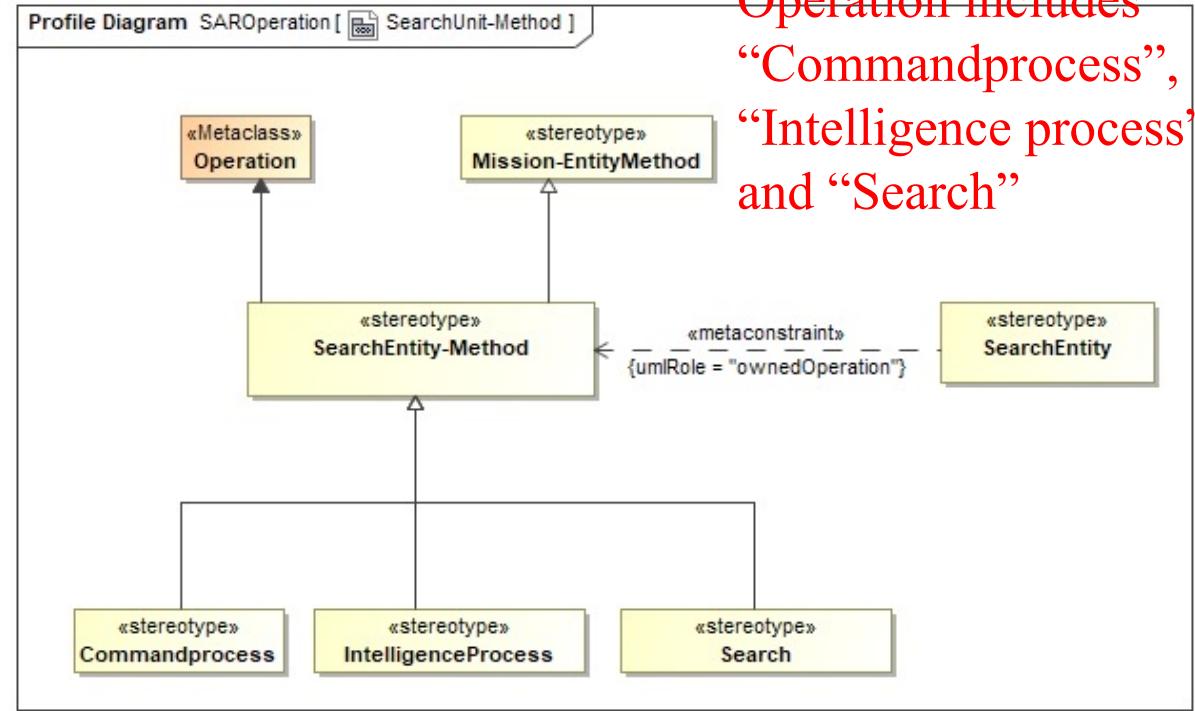


Entities in the SAR (Search and Rescue) Mission

The Mission layer: The Property and Operation of Entity



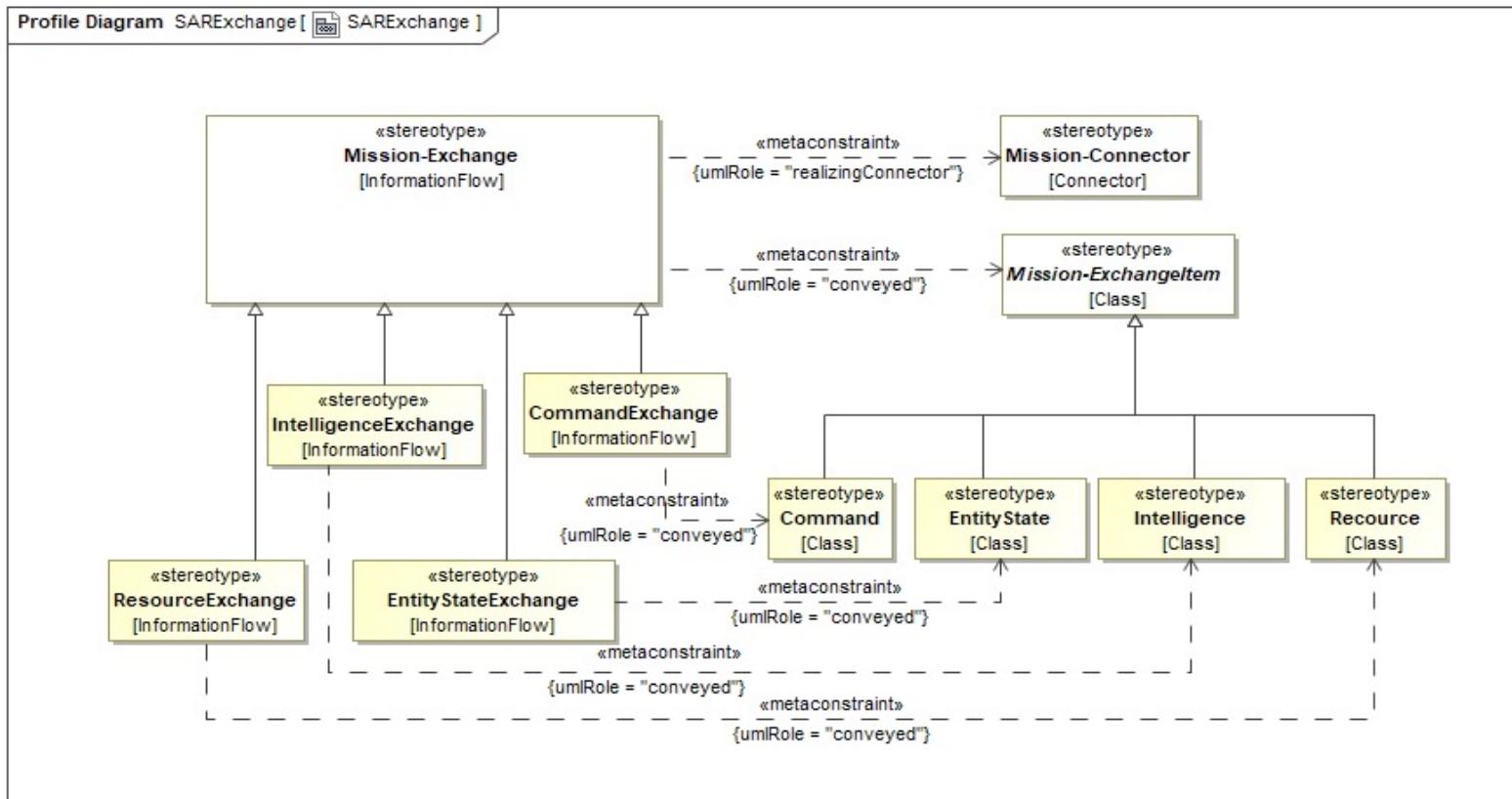
Properties include
“SearchRange”,
“longitude”, “latitude”
and “altitude”



Operation includes
“Commandprocess”,
“Intelligence process”
and “Search”

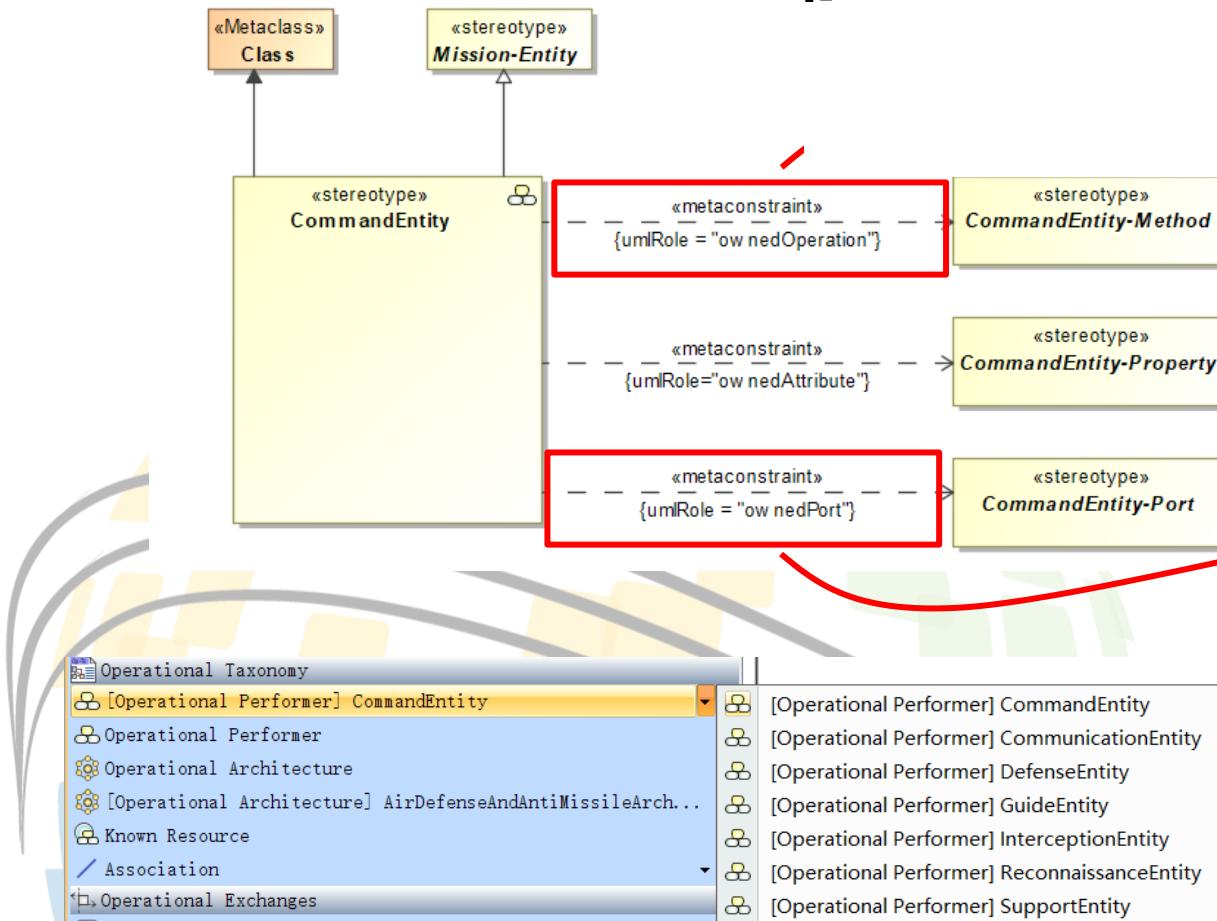
The Mission layer: SAR Entity Interactions

In the SAR mission, some individual information-related stereotypes have been expanded. we extend the stereotype “Command”, “Intelligence”, “Resource” and “EntityState” from “Mission-ExchangeItem”. In addition, separate transport channels are defined for each of these distinct types of interactions.

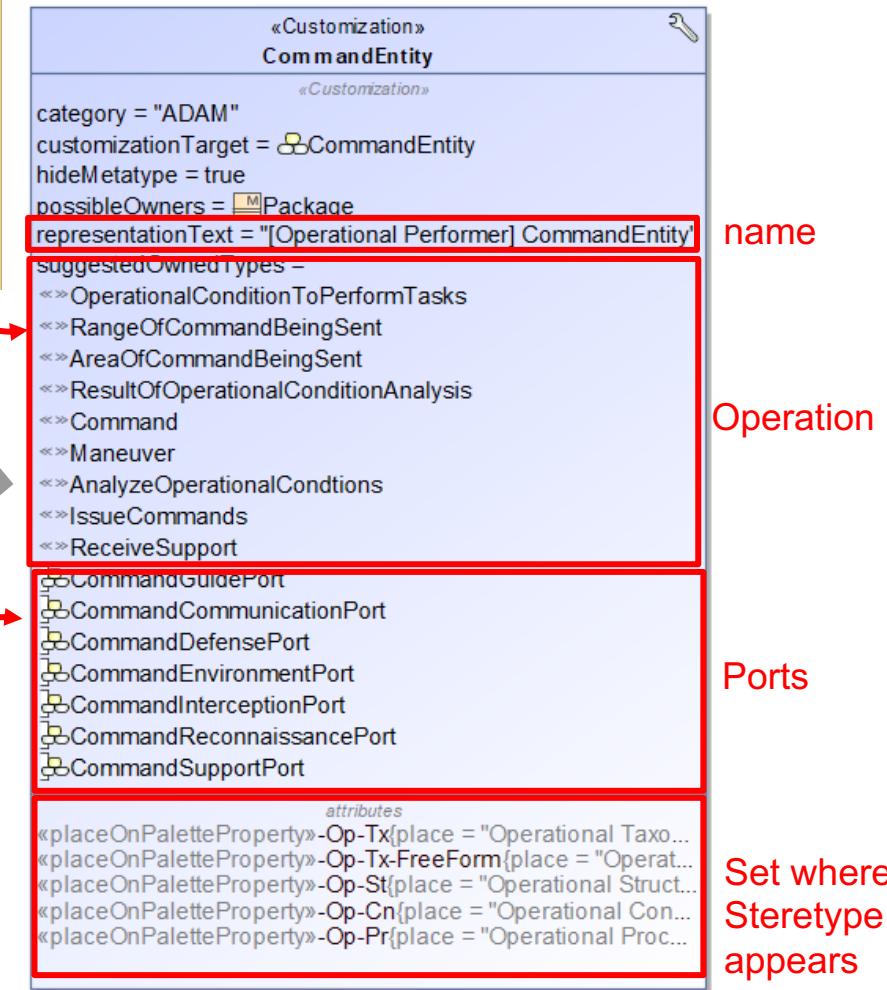


Implement MissionML Profile in MagicDraw

① Define the Stereotype of MissionML.



② Designing Customization for Stereotype





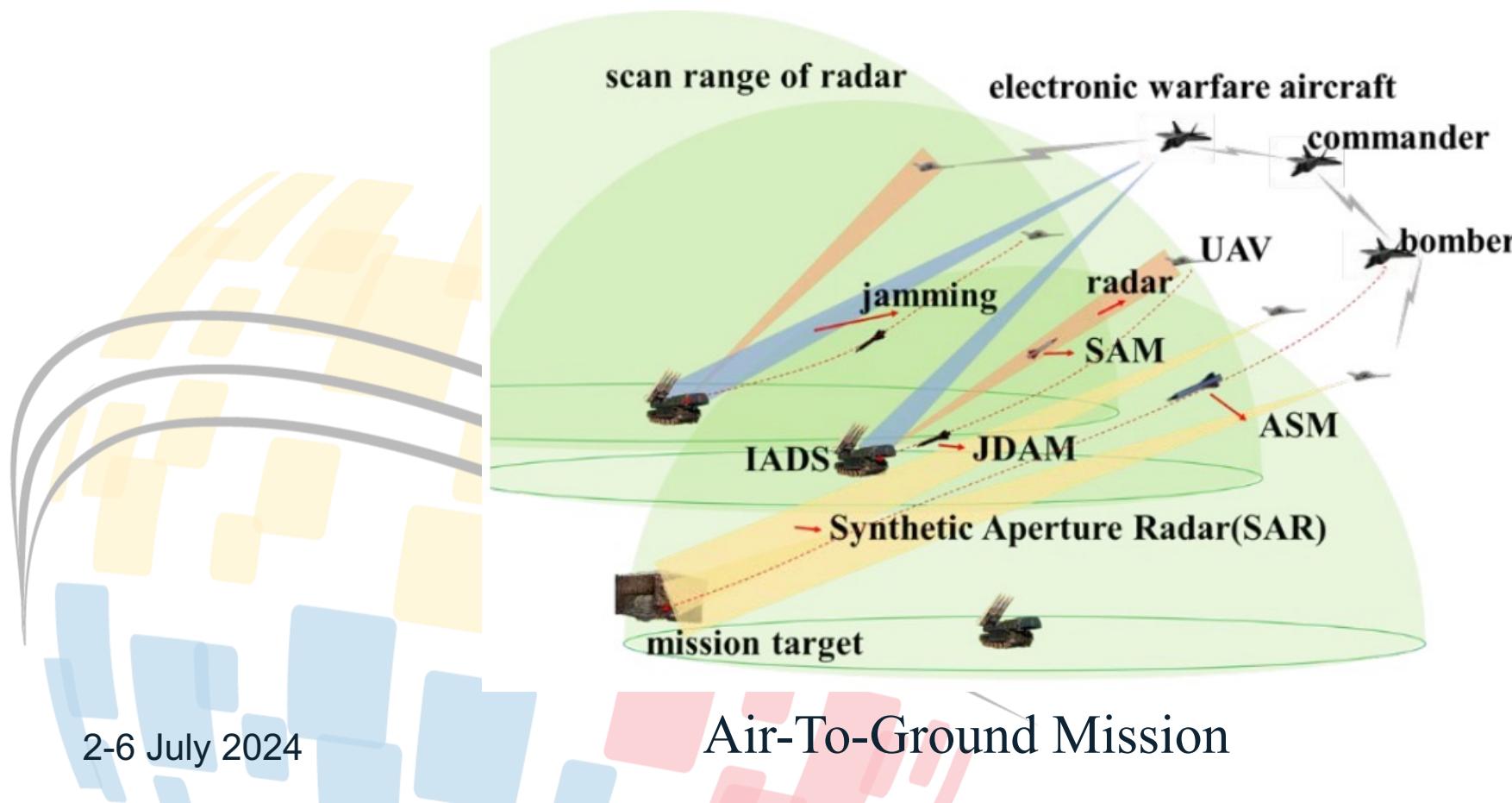
MissionML Case studies

Mission Case Studies

SN	Mission Name	Source of Cases
1	Air-To-Ground(ATG) mission scenario	Wang, Wei, Yang, Feng, Ma, Wei, Li, Xia, and Wu, Yu. 2015. "A Domain Ontology for Ballistic Missile Defense Conceptual Model." In <i>Proceedings of the 48th Annual Simulation Symposium (ANSS '15)</i> , pp. 181-187. San Diego, CA: Society for Computer Simulation International.
2	Maritime search and rescue (SAR) mission	The example is from the software "Magic Cyber Systems Engineer".

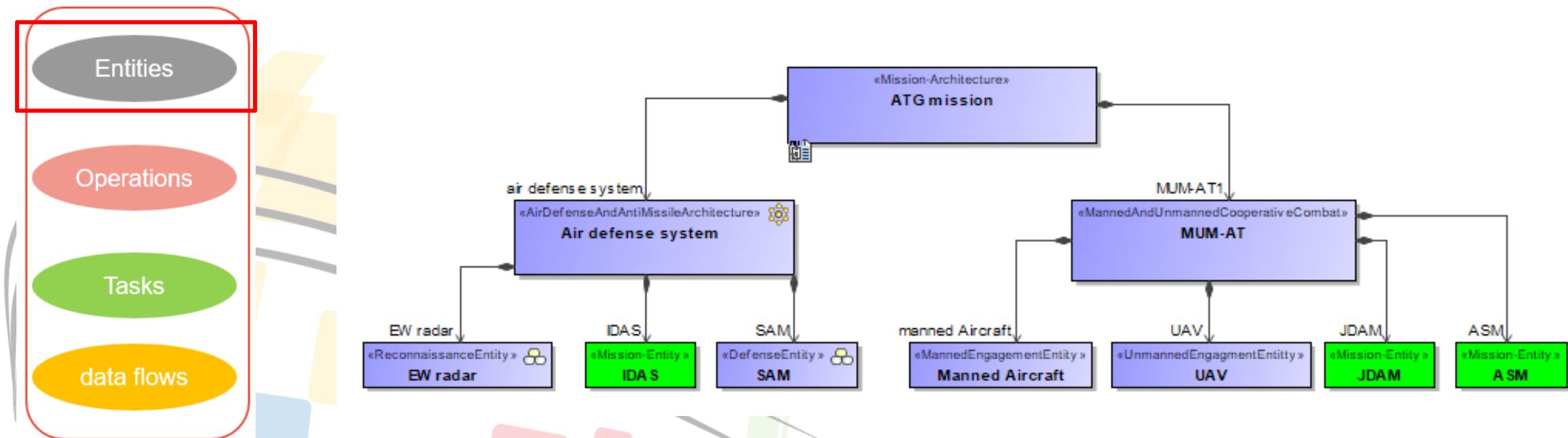
Air-To-Ground Mission

The first case is an Air-To-Ground (ATG) mission scenario in which a Manned/Unmanned Aerial Team (MUM-AT) strikes a group target with Air Defense Systems (IADS).



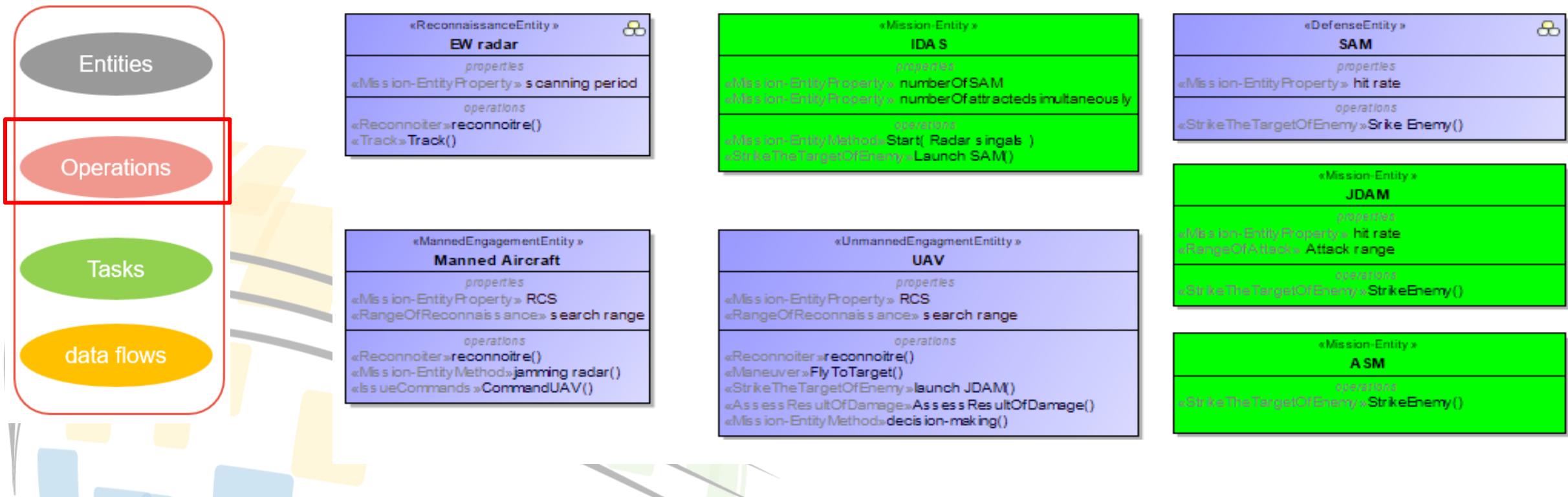
ATG Entities

This figure shows the **static structure of the ATG mission**, which comprises two competing systems: the Air Defense System and MUM-AT. The Air Defense System consists of three entities: Early Warning (EW) radar, Integrated Air Defense Systems (IADS), and Surface-to-Air Missile (SAM). The Manned/Unmanned Aerial Team (MUM-AT) includes several entities such as Manned Aircraft, Unmanned Aerial Vehicles (UAVs), Joint Direct Attack Munition (JDAM), and Air-to-Surface Missile (ASM) .



ATG Operations

This figure illustrates the attributes and methods of the entities in the ATG mission.

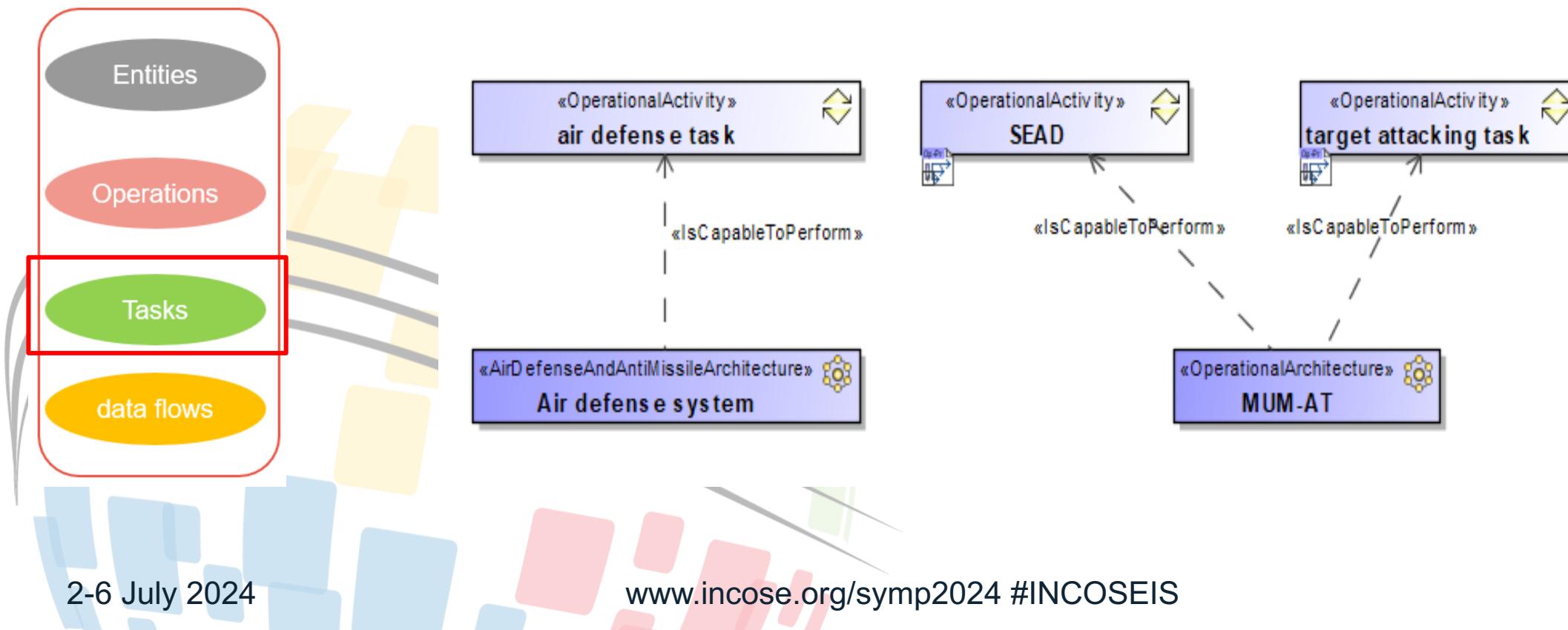


ATG Tasks

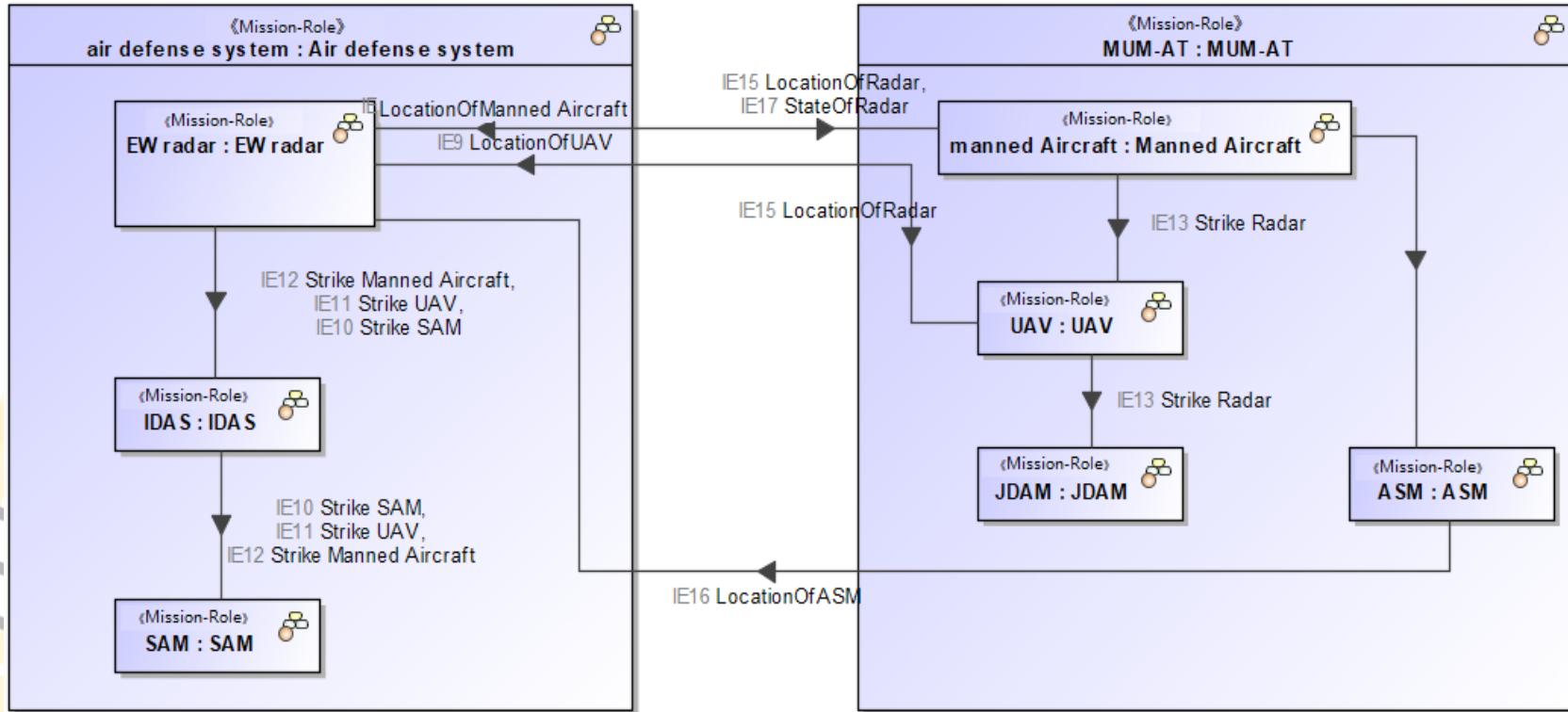
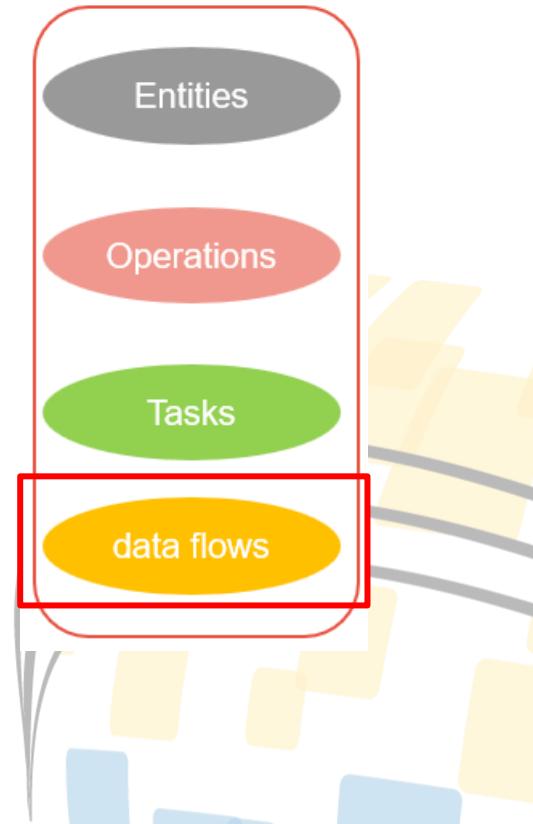
Figure shows the tasks that the Air defense system and MUM-AT need to perform. where the concept of "task" is represented by the UAFML's OperationalActivity concept, and its execution is represented by the UAFML's "IsCapableToPerform" concept.

MUM-AT: SEAD(Suppression of Enemy Air Defense) and target attacking task

Air defense system : Air defense task

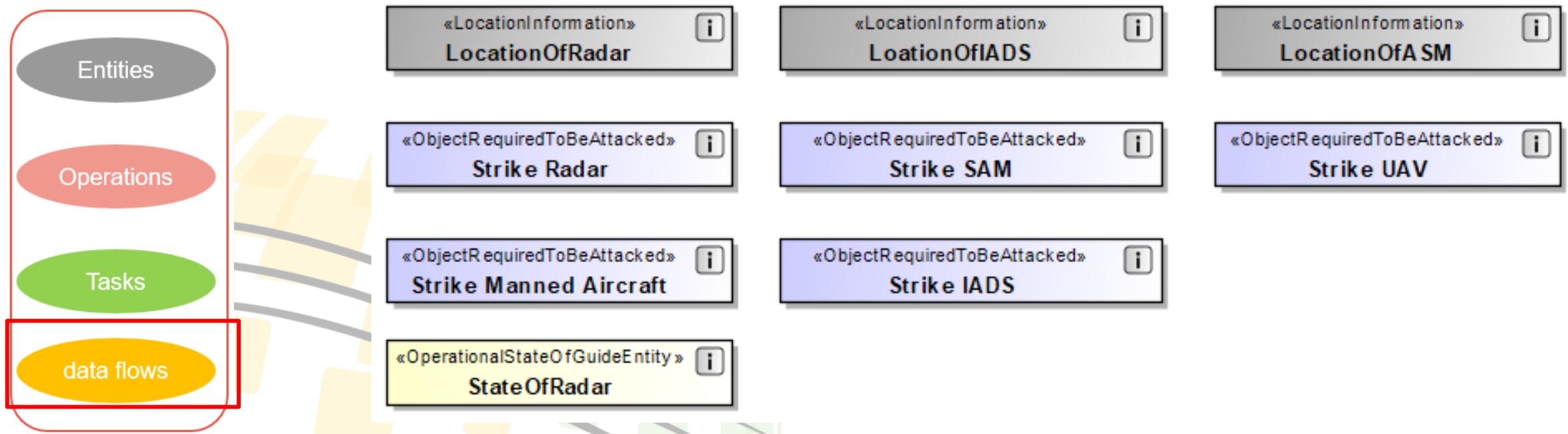


ATG Dataflows



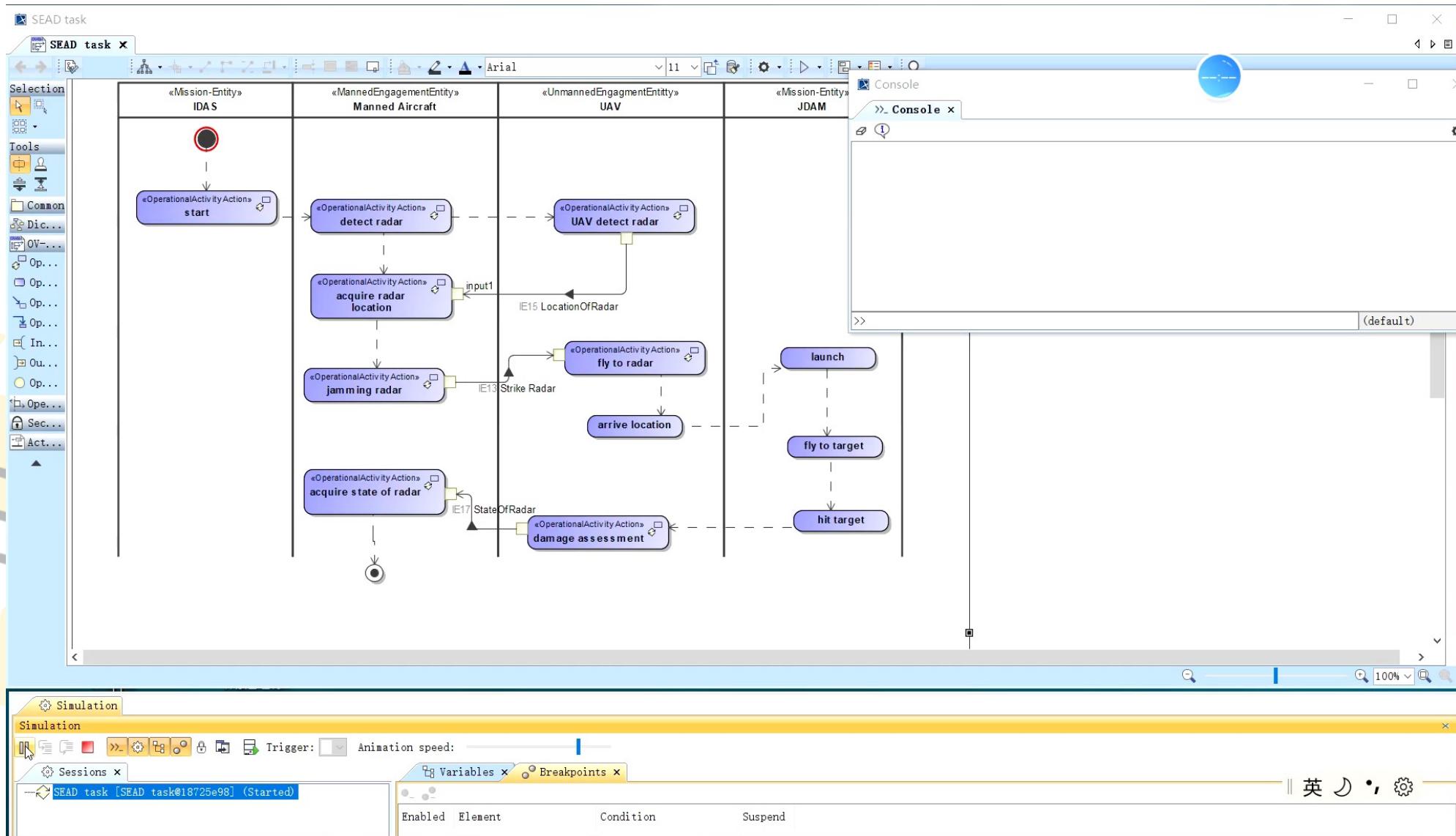
ATG Flow Information

Figure lists the types and names of these information.



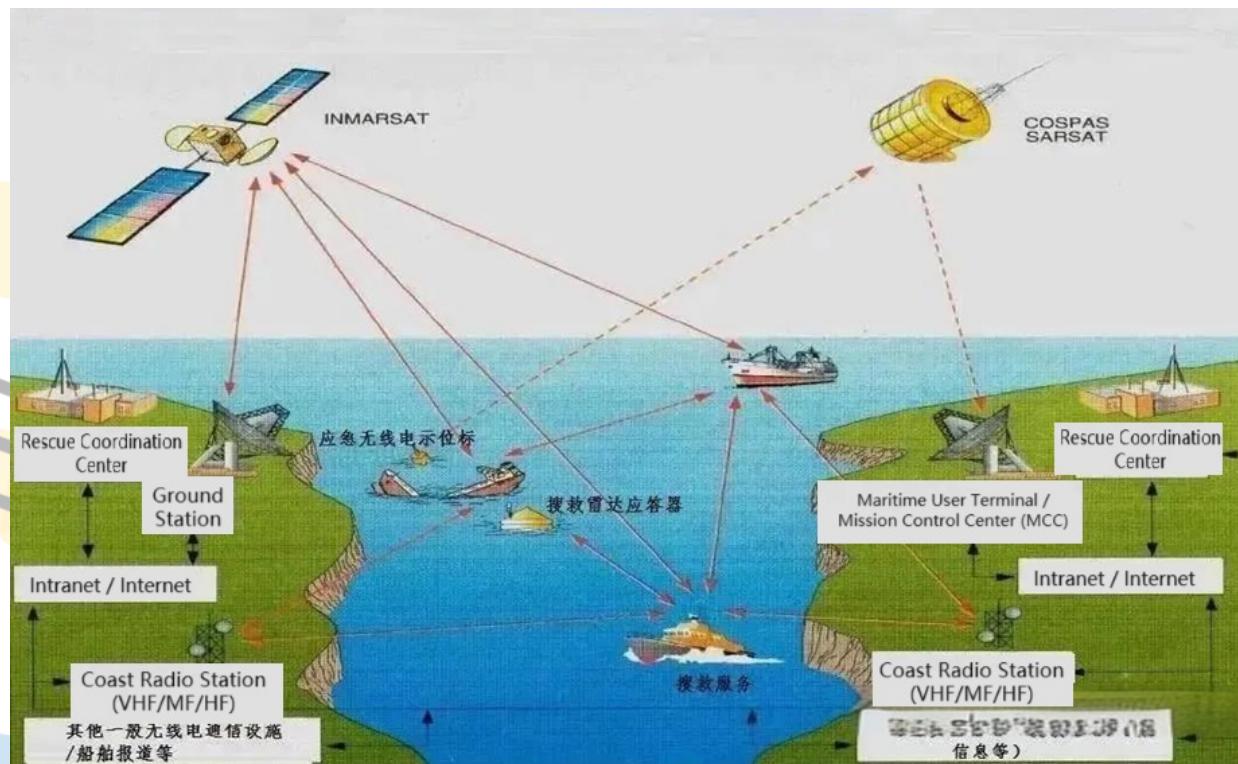
ATG Simulation

Simulation of
SEAD task



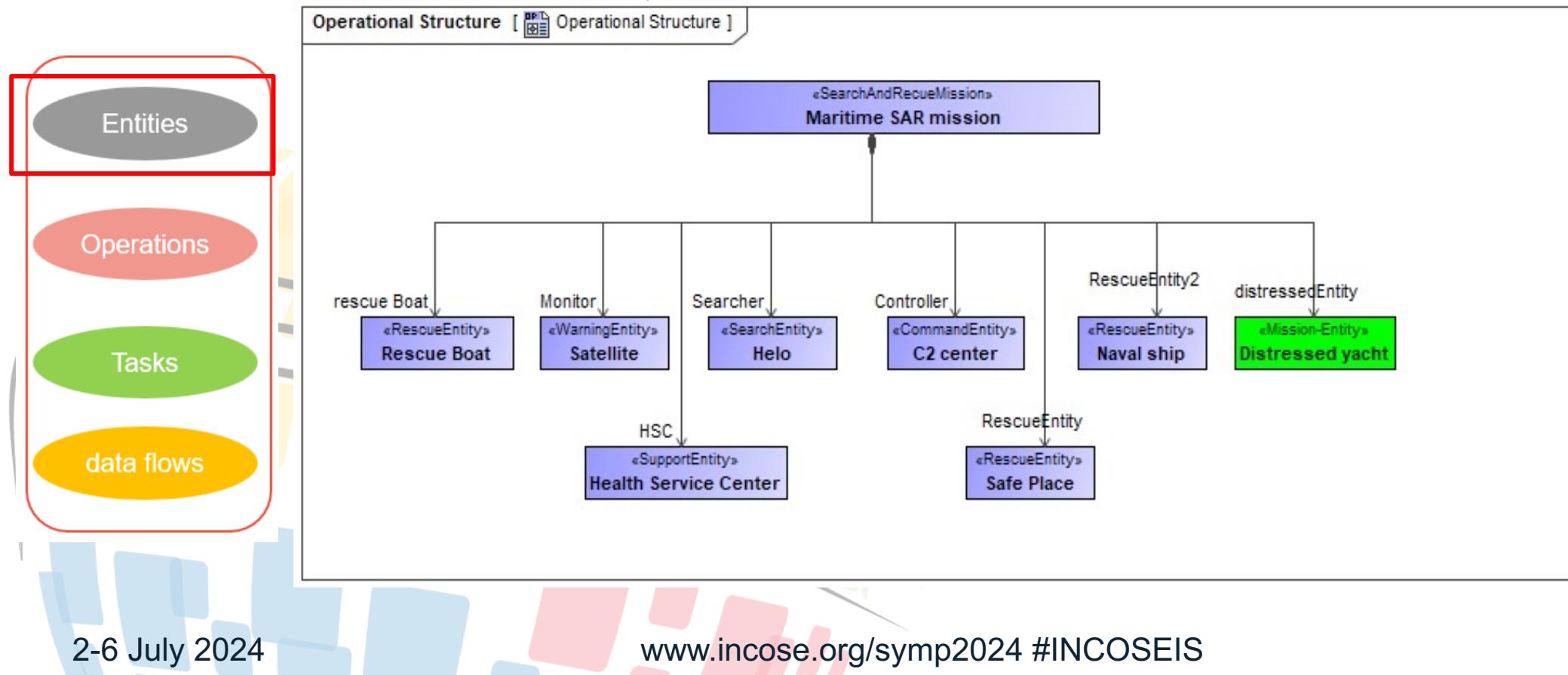
Maritime Search And Rescue (SAR) Mission

This case is a **maritime search and rescue (SAR) mission** scenario involving a distressed yacht. A monitoring unit picks up the distress signal from the yacht and passes it on to the Command and Control (C2) Center. The C2 Center coordinates the search and rescue operation among helicopters, a naval ship, and a civilian voluntary sea rescue organization.



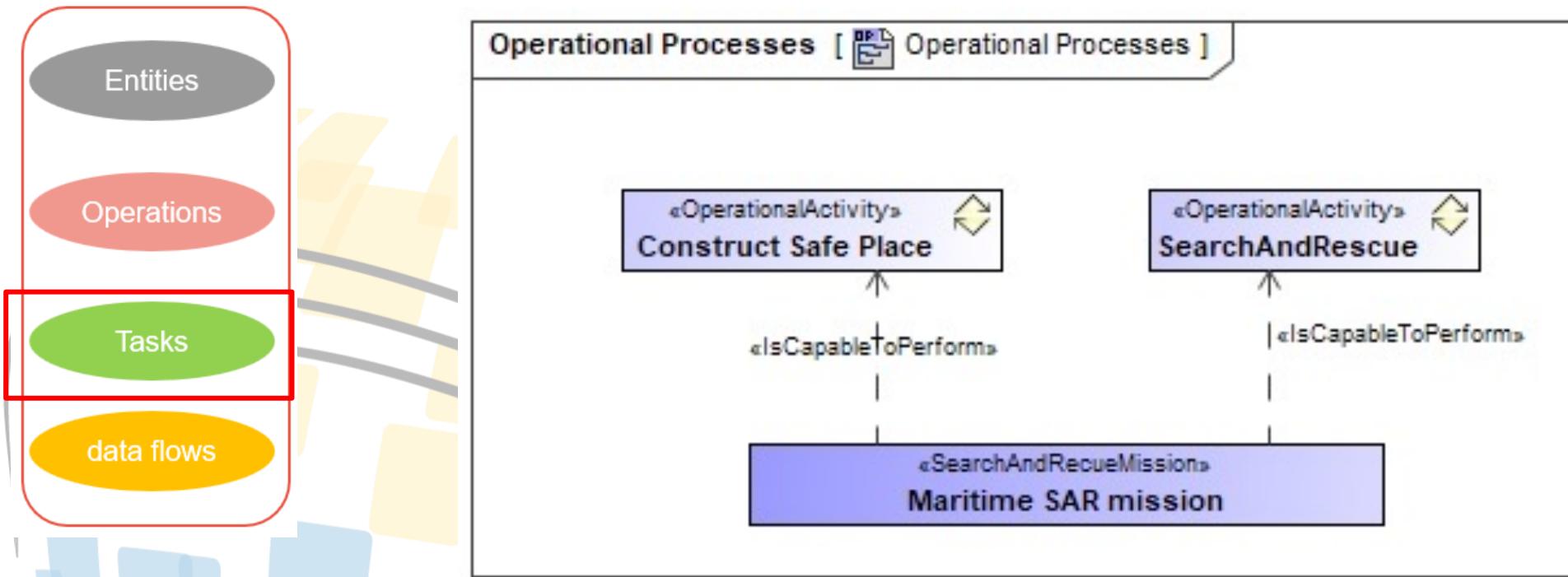
Maritime Search And Rescue (SAR) Mission

This figure shows the **static structure of the SAR Mission**, which comprises six entities: Rescue boat, Satellite, Helo, C2(Command and Control) center, Naval ship, Health Service Center, and Distressed yacht.



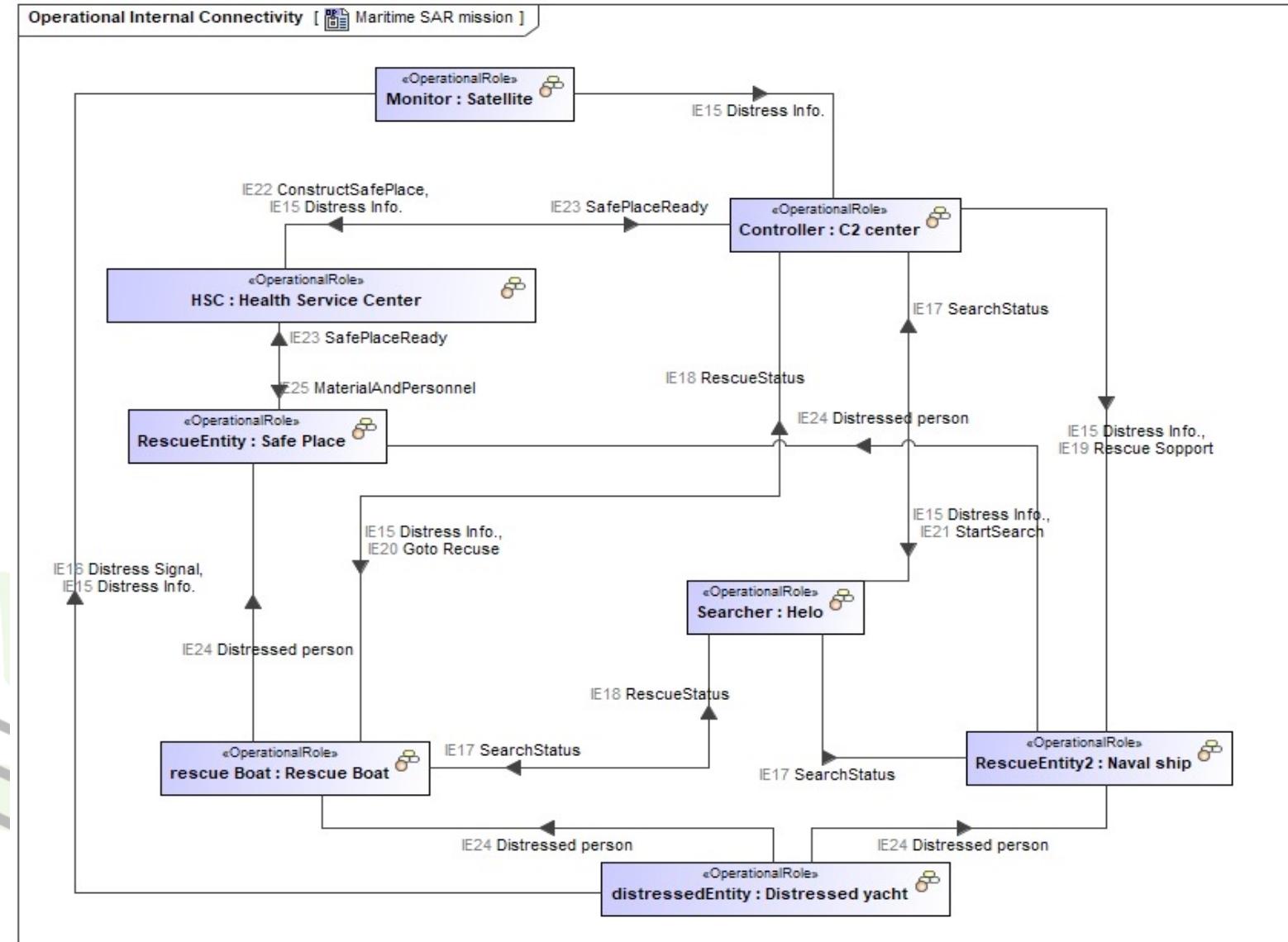
Maritime Search And Rescue (SAR) Mission

The figure illustrates the tasks that need to be performed in the Maritime SAR mission, including tasks such as ‘Construct Safe Place’ and ‘Search and Rescue’. The UAFML’s “OperationalActivity” concept represents the concept of “task,” while its “execution” is represented by the UAFML's "IsCapableToPerform" concept.



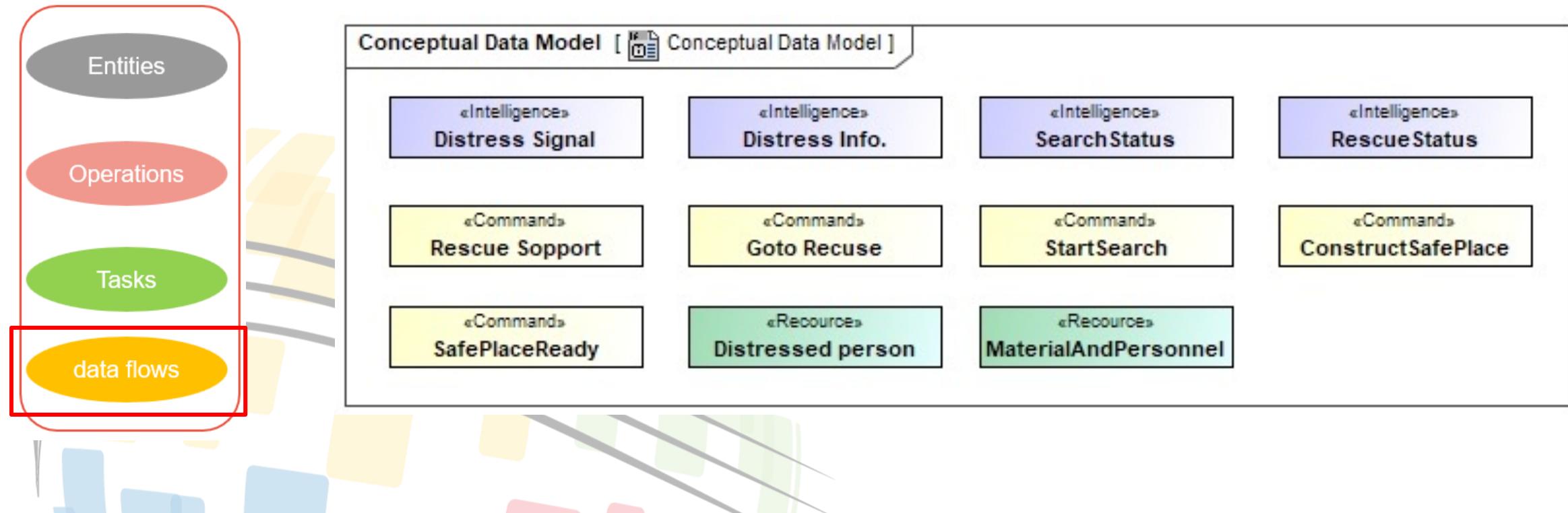
Maritime Search And Rescue (SAR) Mission

This figure shows the information that needs to be exchanged between entities in the SAR Mission.



Maritime Search And Rescue (SAR) Mission

This figure lists the types and names of these information. It is primarily defined by three elements of MissionML: intelligence, Command, and Resource.



Conclusion and Future Work

Conclusion:

- A mission architecture modeling language, **MissionML**, is proposed.
- **MissionML** can be used in other domains without too much cost for extending.

Future work:

- Automated generation of meta-models as well as profile by LLMs
- Automatic Evaluation of DSL by LLMs



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Thank you!
Email: yilongyang@buaa.edu.cn