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Towards an Automated UAF-based Trade Study Process for System of Systems Architecture

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Outlines

- Motivation
- MBSE approach and UAF
- Proposed Trade Study Process
- Conclusions

Motivation

- One of the core processes in the architecture development lifecycle is to perform architecture evaluation
- The main goal of this process is to select architecture for design and implementation
- In order to automate this complex process, it is necessary to develop a digital, unambiguous, and precise model-based environment
  - MBSE is a backbone for automated trade study process
- The worldwide systems engineering community has acknowledged and is currently using various trade study analysis processes
- The list narrows down significantly when we talk about MBSE and system of systems (SoS)
  - National Aeronautics and Space Administration (NASA) proposed trade study process
  - NATO Architecture Framework (NAF)

Purpose

- The goal of this paper is to take the best practices from existing trade-off processes and propose a new trade study analysis process, compatible with UAF modeling language and framework
- It is the starting point for in-depth study of the automated UAF-based trade study analysis process

MBSE approach

- UAF is the collection of best practices used in systems, systems of systems, and enterprise engineering for more than 30 years. Moreover, UAF is applicable to any domain. Additionally, it is still the best choice to build DoDAF, NAF, and MODAF architectures.
  - Common Vocabulary and graphical SysML-based notation
  - Analysis and Simulation
- UAF has been designed to support trade studies at different levels:
  - trade-off operational scenarios against capability requirements,
  - or trade-off solution architectures against operational needs
- The mechanism to capture required data is provided; however, the process of doing that is missing.

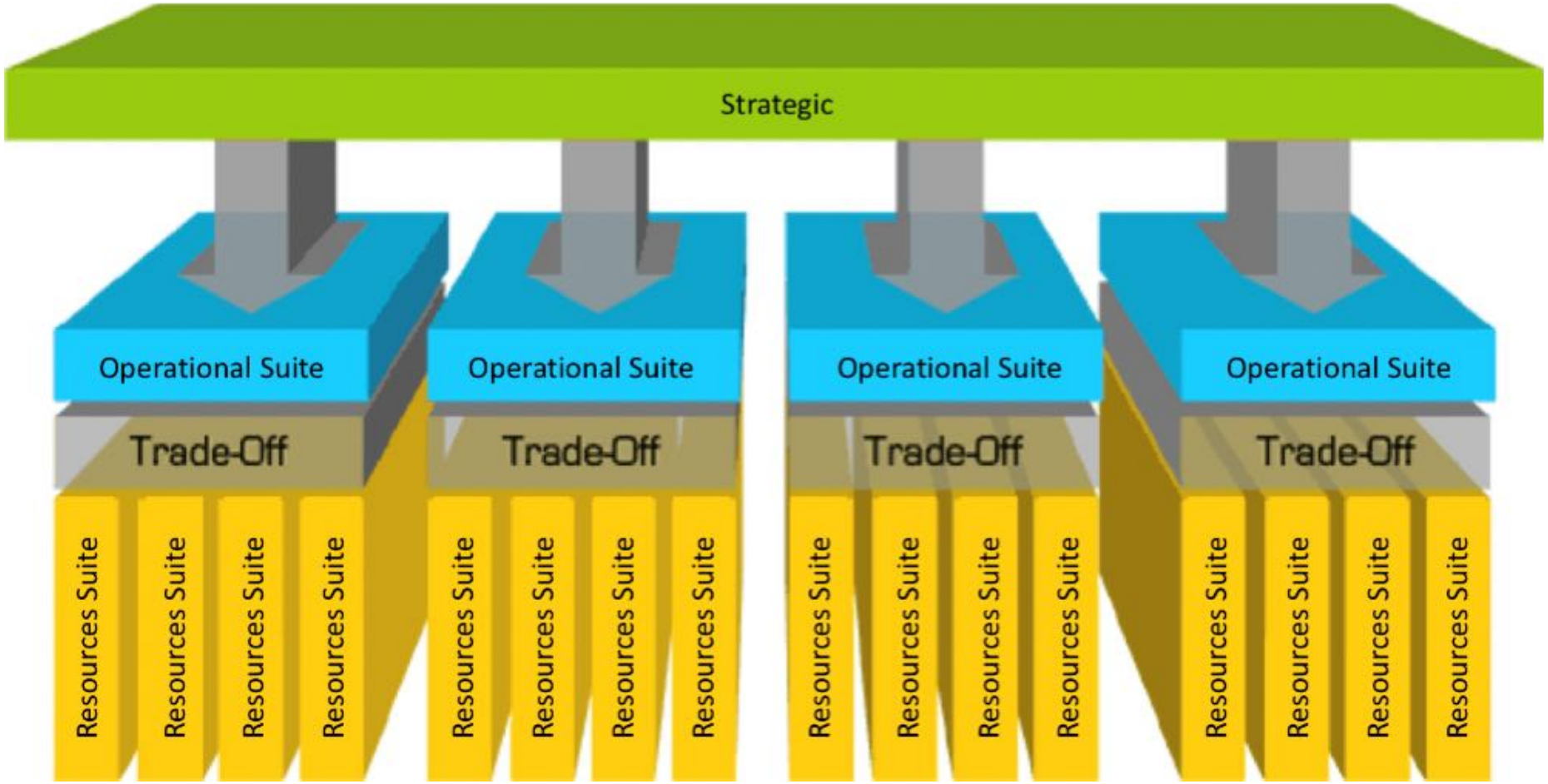
UAF	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Interaction Scenarios Is	Information If	Parameters Pm	Constraints Ct	Roadmap Rm	Traceability Tr
Metadata Md	Metadata Taxonomy Md-Tx	Architecture Viewpoints [a] Md-Sr	Metadata Connectivity Md-Cn	Metadata Processes [a] Md-Pr	-	-			Metadata Constraints [a] Md-Ct		Metadata Traceability Md-Tr
Strategic St	Strategic Taxonomy St-Tx	Strategic Structure St-Sr	Strategic Connectivity St-Cn	Strategic Processes St-Pr	Strategic States St-St	Strategic Interaction Scenarios St-Is			Strategic Constraints St-Ct	Strategic Deployment, Strategic Phasing St-Rm	Strategic Traceability St-Tr
Operational Op	Operational Taxonomy Op-Tx	Operational Structure Op-Sr	Operational Connectivity Op-Cn	Operational Processes Op-Pr	Operational States Op-St	Operational Interaction Scenarios Op-Is			Operational Constraints Op-Ct		Operational Traceability Op-Tr
Services Sv	Service Taxonomy Sv-Tx	Service Structure Sv-Sr	Service Connectivity Sv-Cn	Service Processes Sv-Pr	Service States Sv-St	Service Interaction Scenarios Sv-Is	Conceptual Data Model,	Environment Pm-En	Service Constraints Sv-Ct	Service Roadmap Sv-Rm	Service Traceability Sv-Tr
Personnel Pr	Personnel Taxonomy Pr-Tx	Personnel Structure Pr-Sr	Personnel Connectivity Pr-Cn	Personnel Processes Pr-Pr	Personnel States Pr-St	Personnel Interaction Scenarios Pr-Is	Logical Data Model,		Competence, Drivers, Performance Pr-Ct	Personnel Availability, Personnel Evolution, Personnel Forecast Pr-Rm	Personnel Traceability Pr-Tr
Resources Rs	Resource Taxonomy Rs-Tx	Resource Structure Rs-Sr	Resource Connectivity Rs-Cn	Resource Processes Rs-Pr	Resource States Rs-St	Resource Interaction Scenarios Rs-Is	Physical Data Model,	Measurements Pm-Me	Resource Constraints Rs-Ct	Resource evolution, Resource forecast Rs-Rm	Resource Traceability Rs-Tr
Security Sc	Security Taxonomy Sc-Tx	Security Structure Sc-Sr	Security Connectivity Sc-Cn	Security Processes Sc-Pr	-	-			Security Constraints Sc-Ct	-	Security Traceability Sc-Tr
Projects Pj	Project Taxonomy Pj-Tx	Project Structure Pj-Sr	Project Connectivity Pj-Cn	Project Processes Pj-Pr	-	-			-	Project Roadmap Pj-Rm	Project Traceability Pj-Tr
Standards Sd	Standard Taxonomy Sd-Tx	Standards Structure Sd-Sr	-	-	-	-			-	Standards Roadmap Sd-Rm	Standards Traceability Sd-Tr
Actuals Resources Ar		Actual Resources Structure, Ar-Sr	Actual Resources Connectivity, Ar-Cn	Simulation [b]					Parametric Execution/ Evaluation [b]	-	-
Dictionary * Dc											
Summary & Overview Sm-Ov											
Requirements Req											

Understand enterprise objectives, defining and deploying capabilities

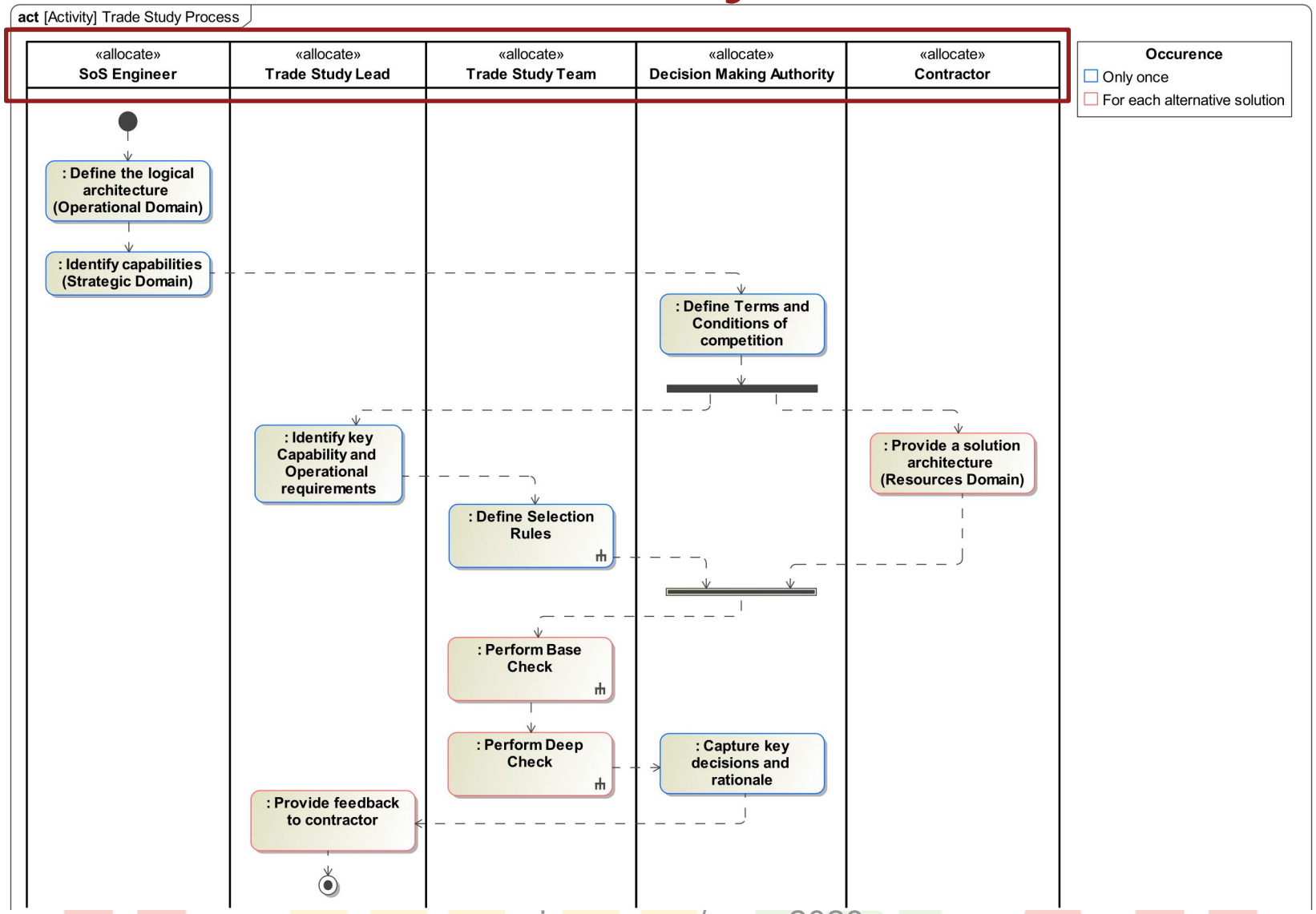
Understand the SoS from Operational/ Logical Perspective

Understand constituent Systems of Systems and relationships to personnel/organizations

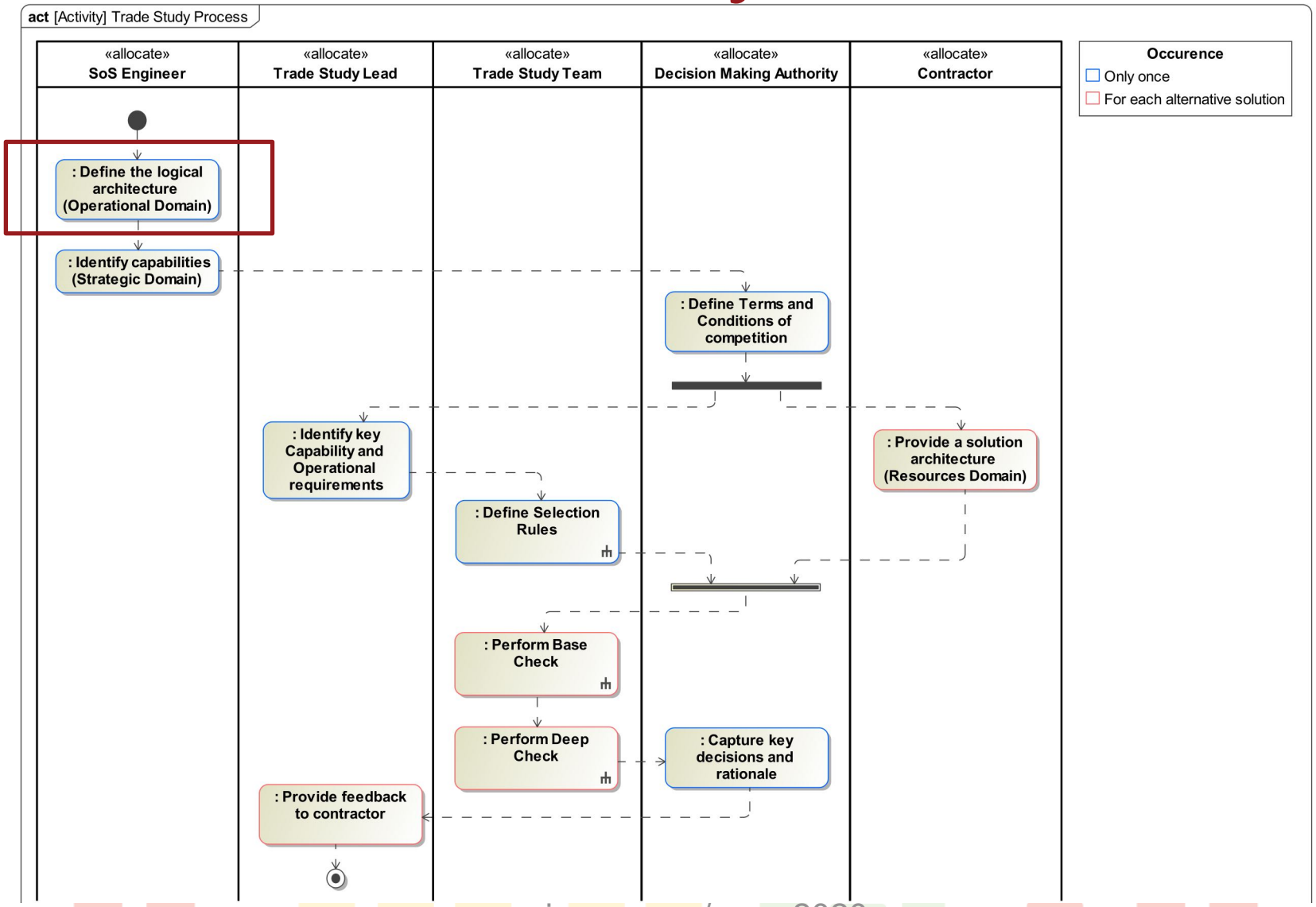
Trade Studies in UAF



UAF-based Trade Study Process

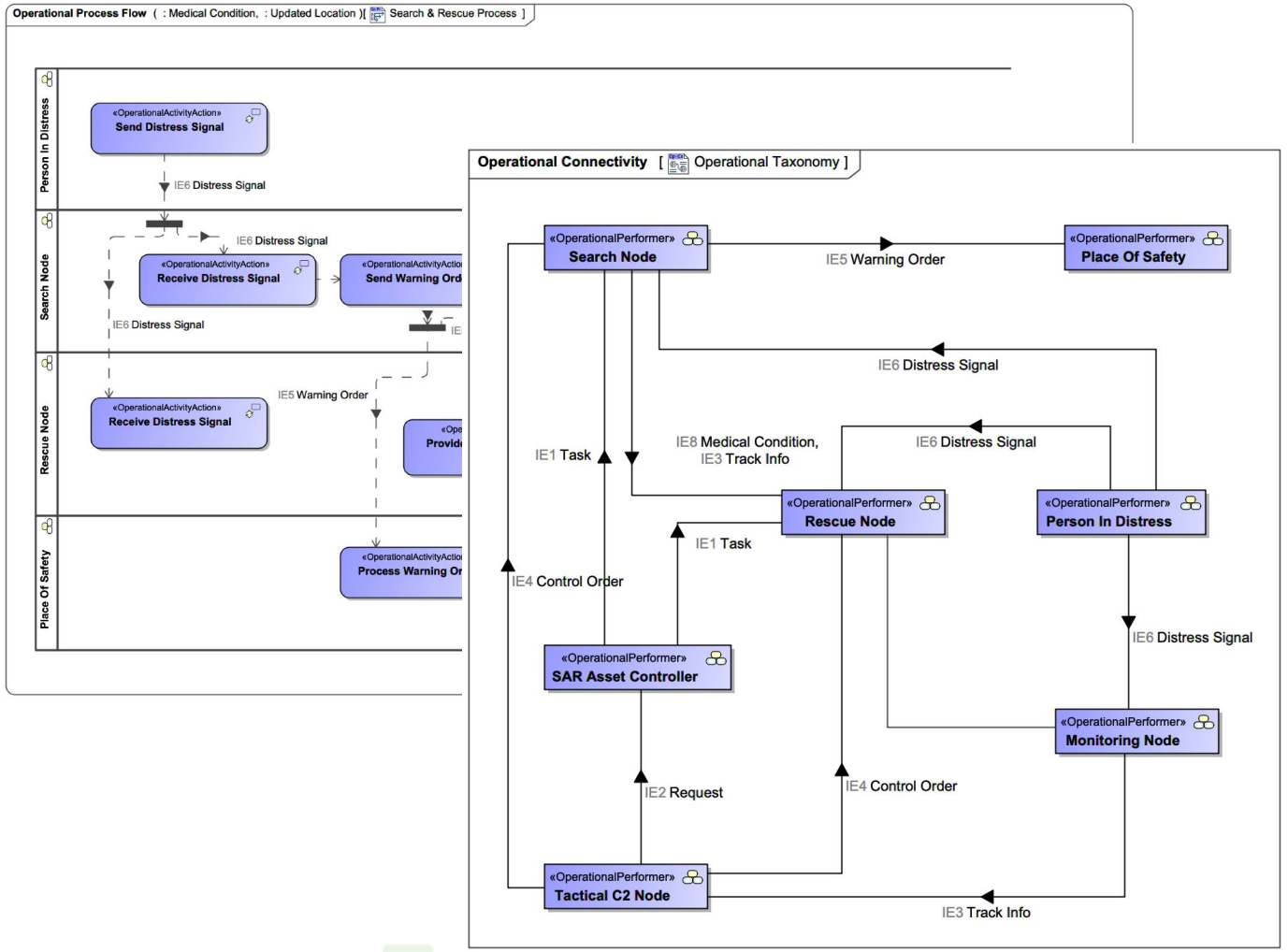


UAF-based Trade Study Process

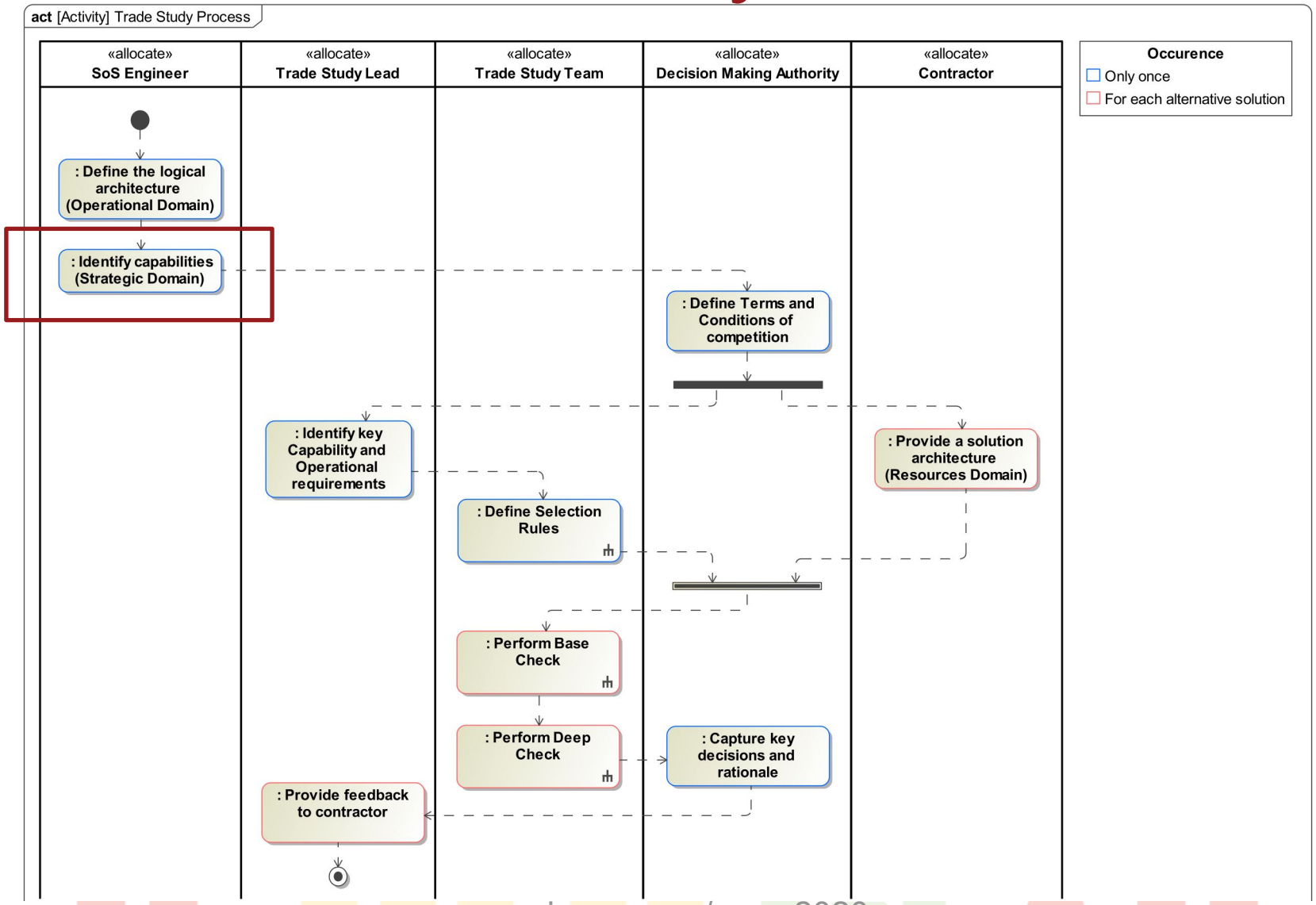


Define the logical architecture

- Operational Domain (Op) views of UAF are used to define the logical architecture.
- Detailed functional requirements are specified to meet stakeholder expectations.

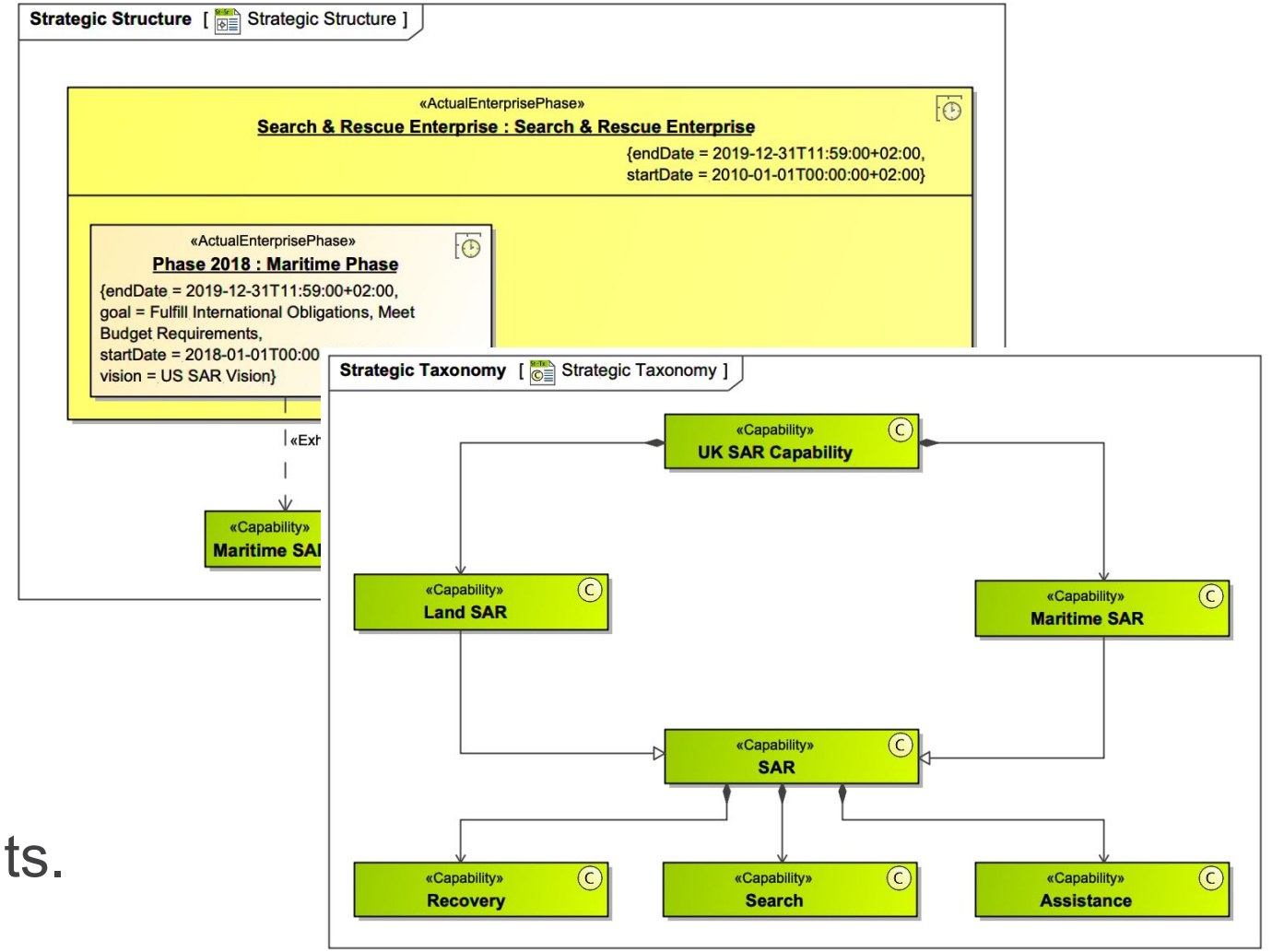


UAF-based Trade Study Process

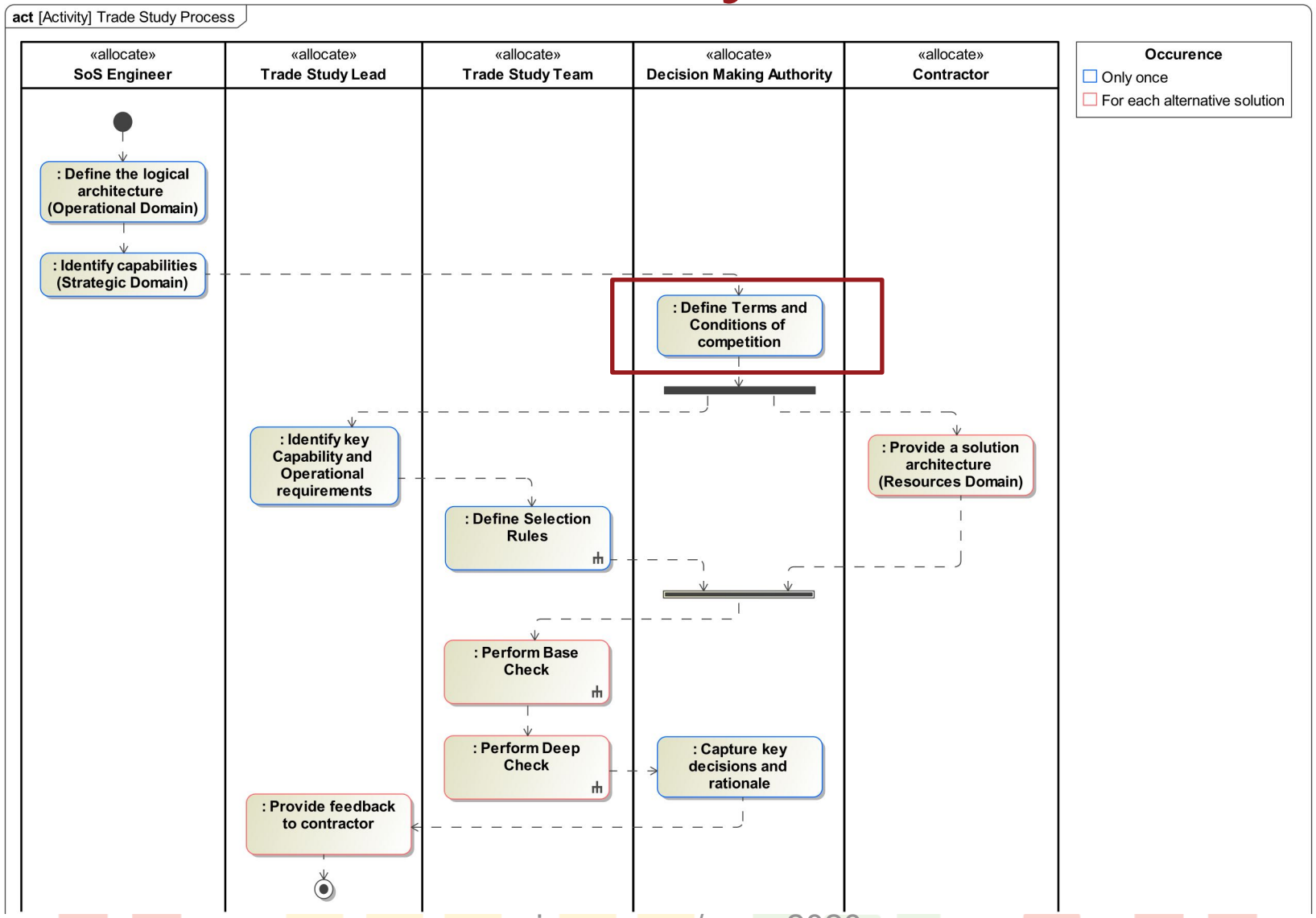


Identify capabilities

- Strategic Domain (St) views of UAF are used to identify capabilities.
- Capabilities represent certain functionality and implementation into resources.
- Capabilities and capability requirements specify what characteristics they possess to satisfy stakeholders' requirements.



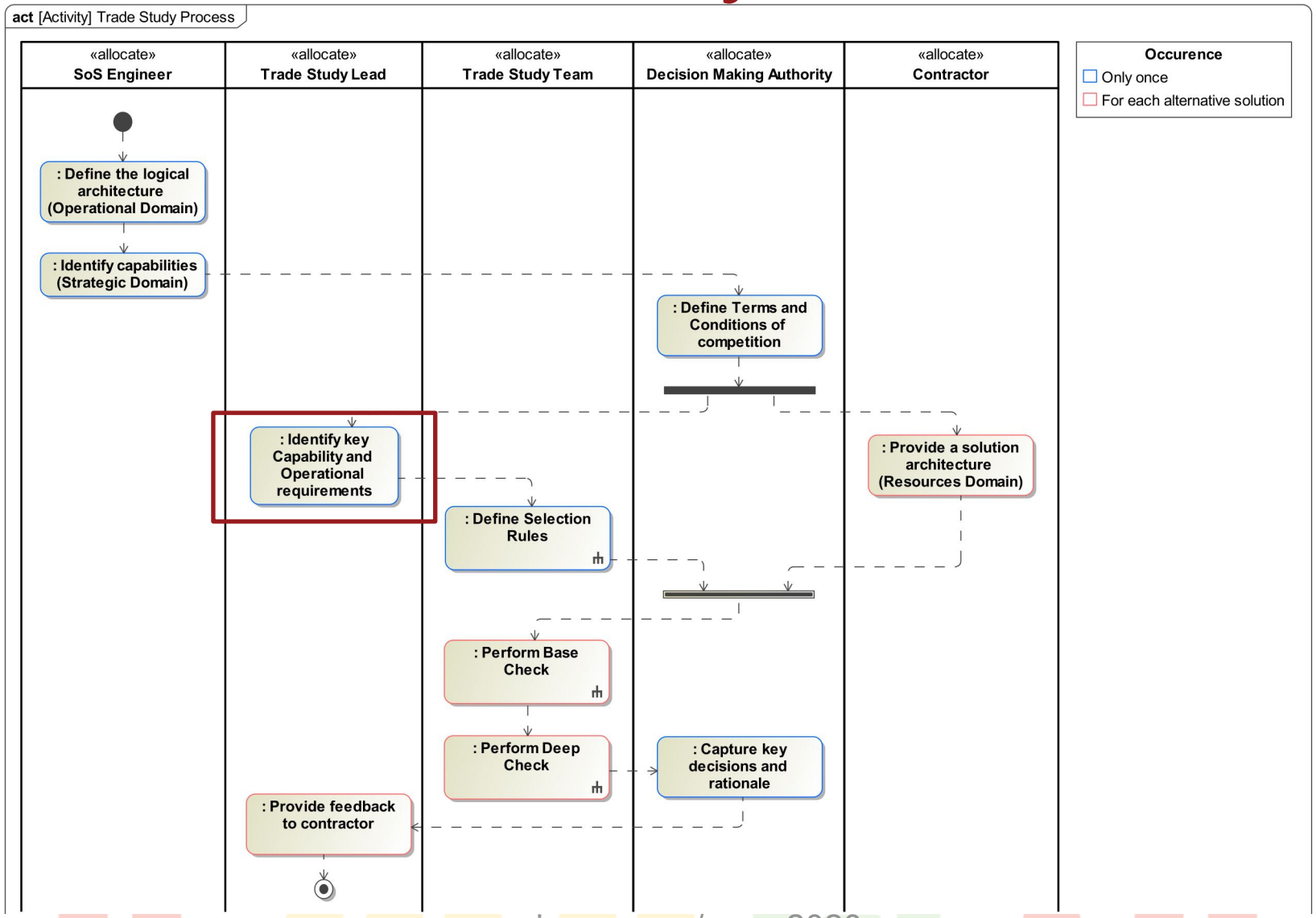
UAF-based Trade Study Process



Define Terms and Conditions of competition

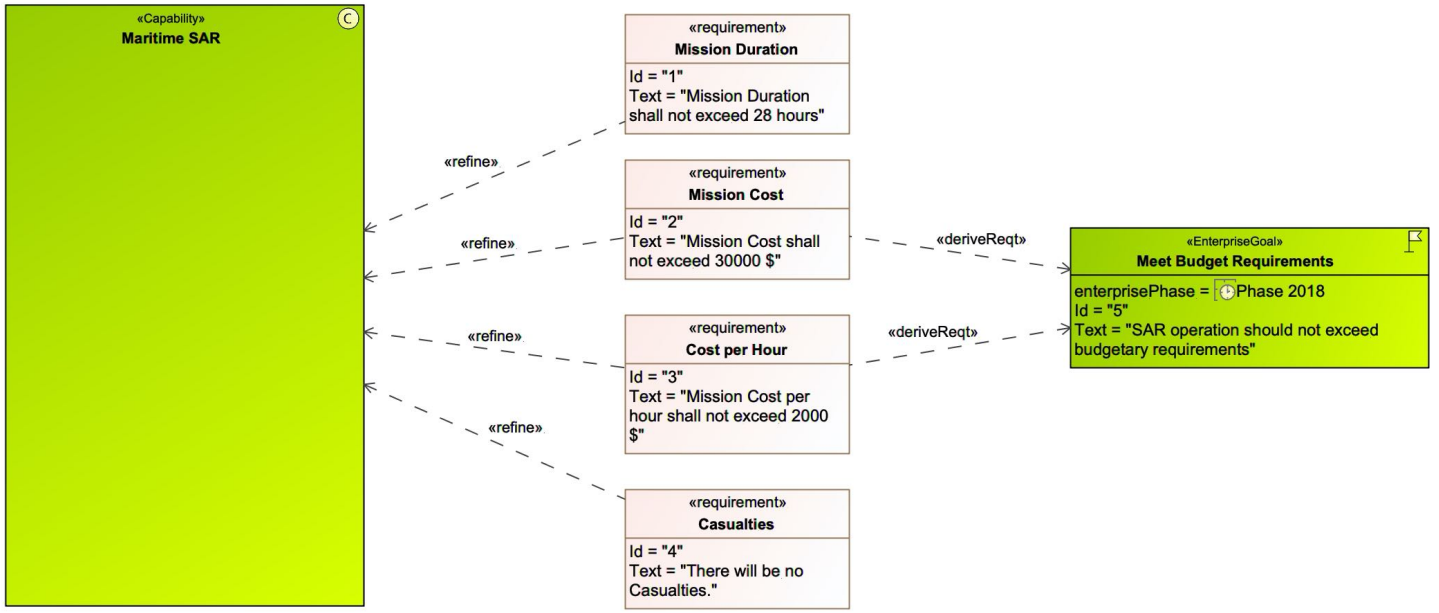
- Terms and conditions that comply with applicable Government regulations are defined:
  - how the competition is conducted
  - who can participate and what requirements they need to meet
  - how entries can be submitted

UAF-based Trade Study Process

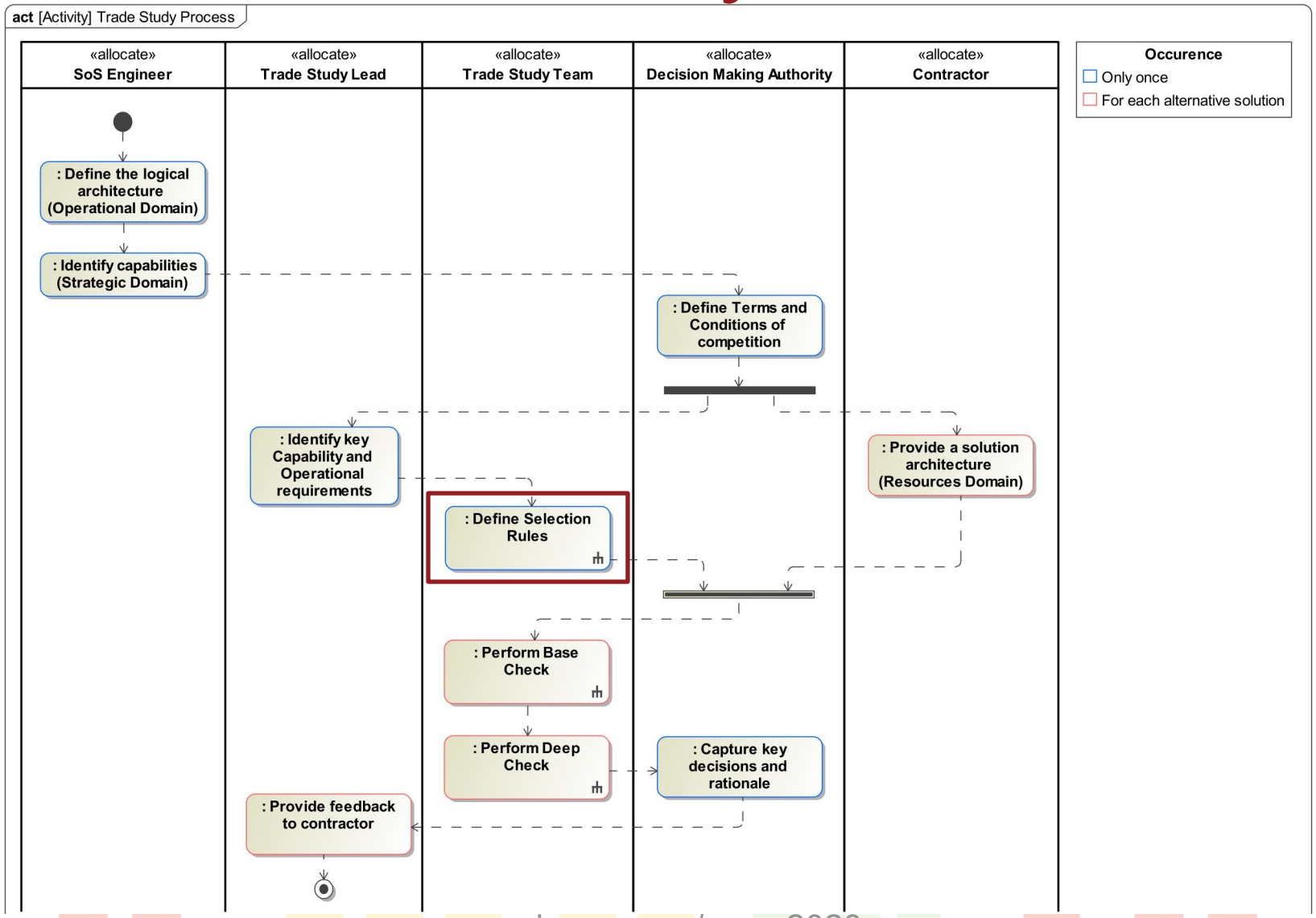


Identify key Capability and Operational requirements

- Key Capabilities and Operational requirements indicate the most essential functionality of preferred solution.
- Key requirements can be prioritized.

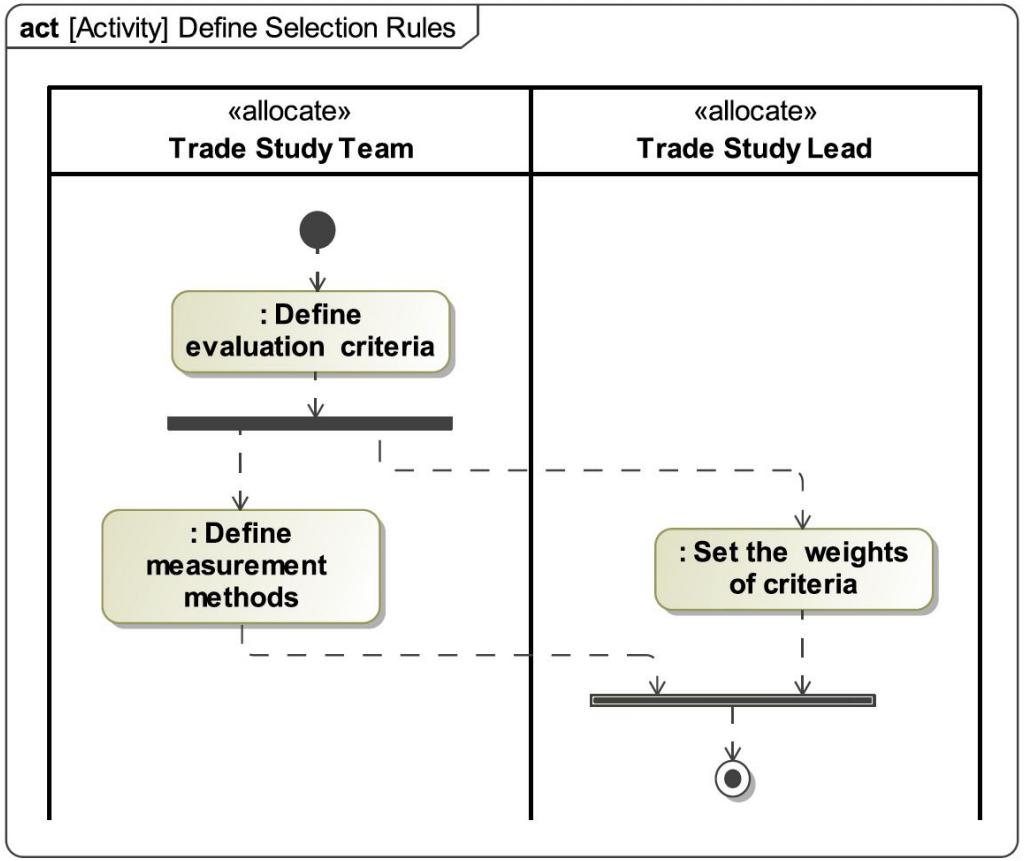


UAF-based Trade Study Process



Define Selection Rules

- Selection rules determine how the outcome variables are used to make a selection of the preferred alternative.
- Evaluation criteria indicates the level of importance.
- Assigned weights reflect rules criticality.



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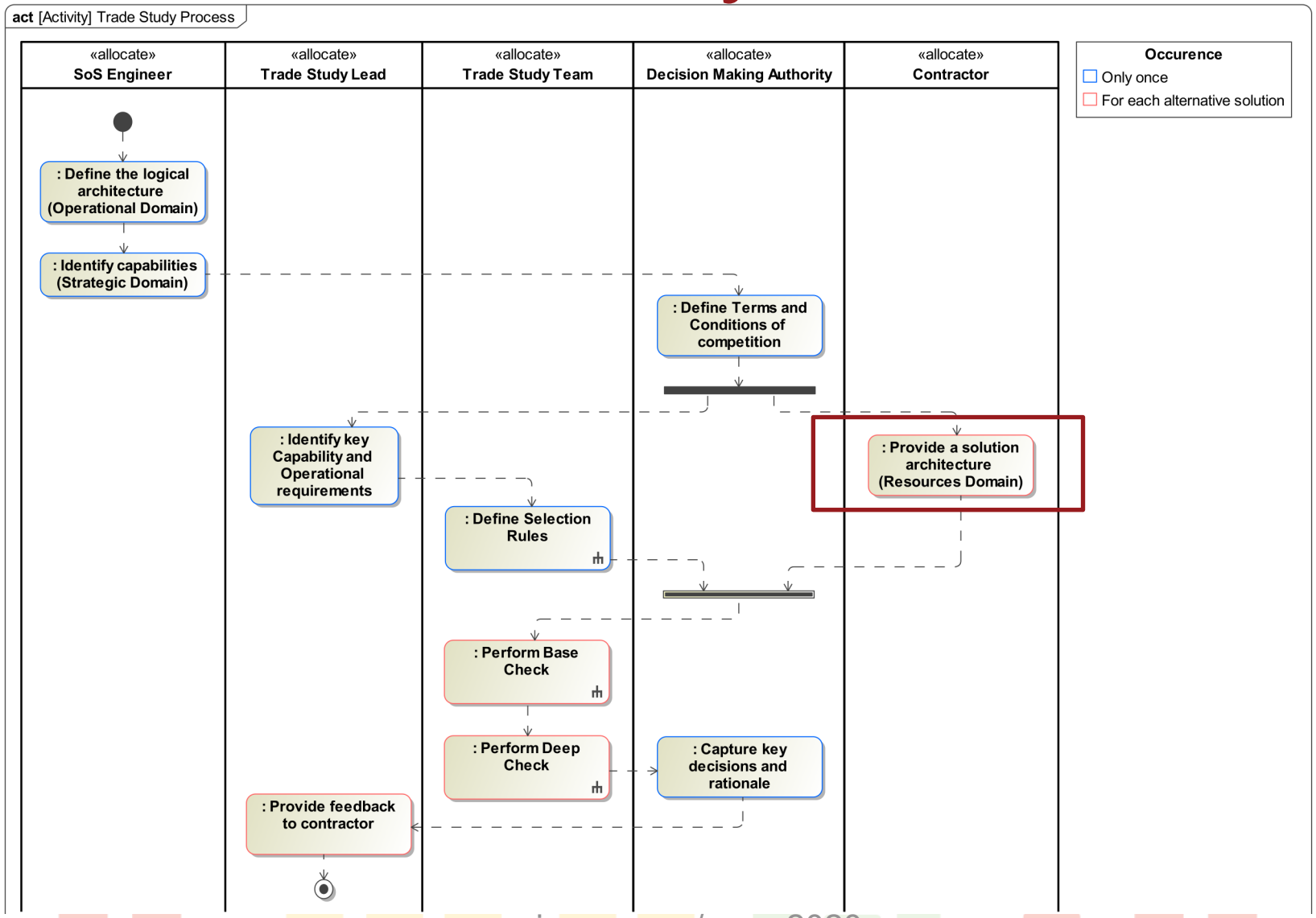
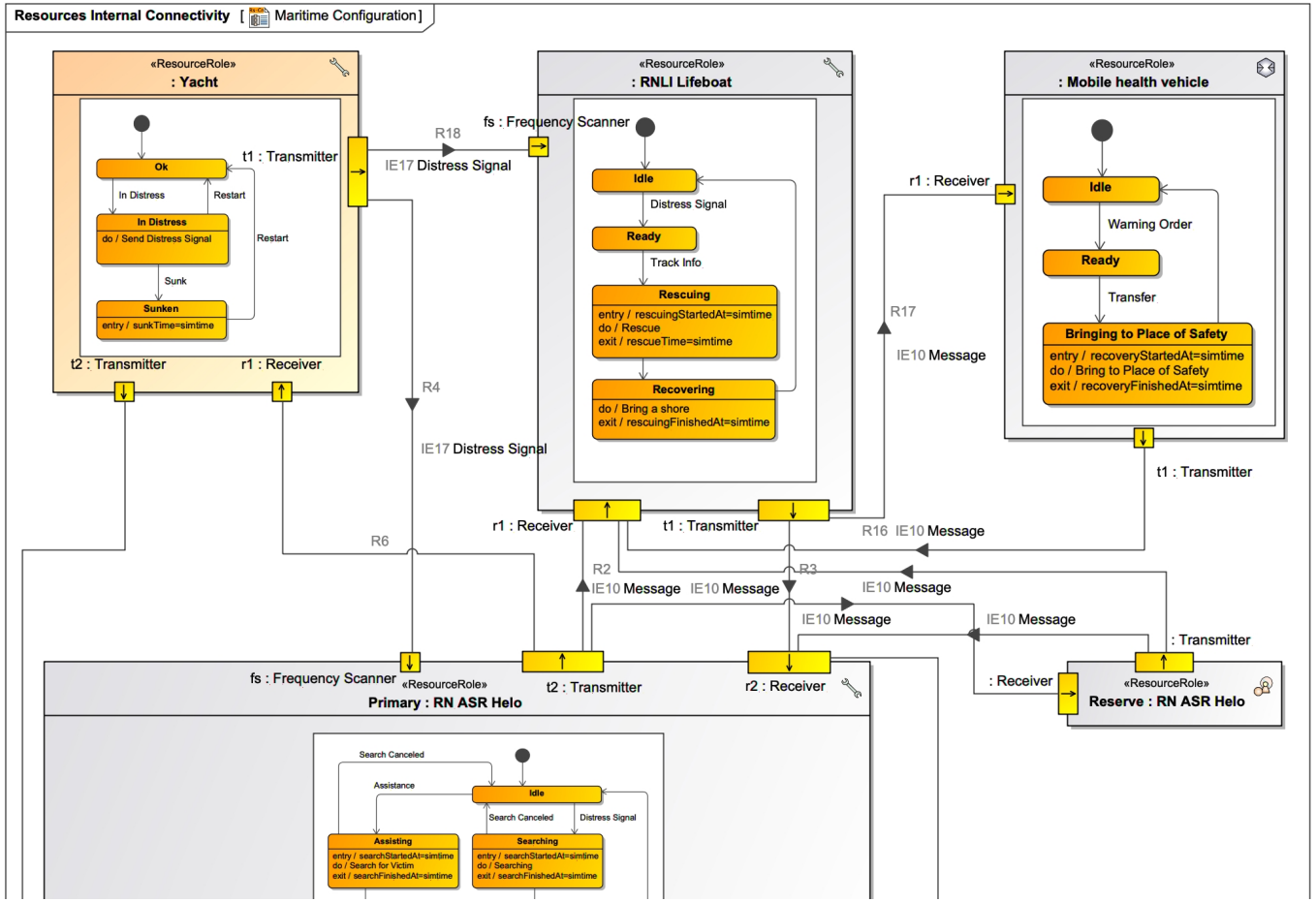
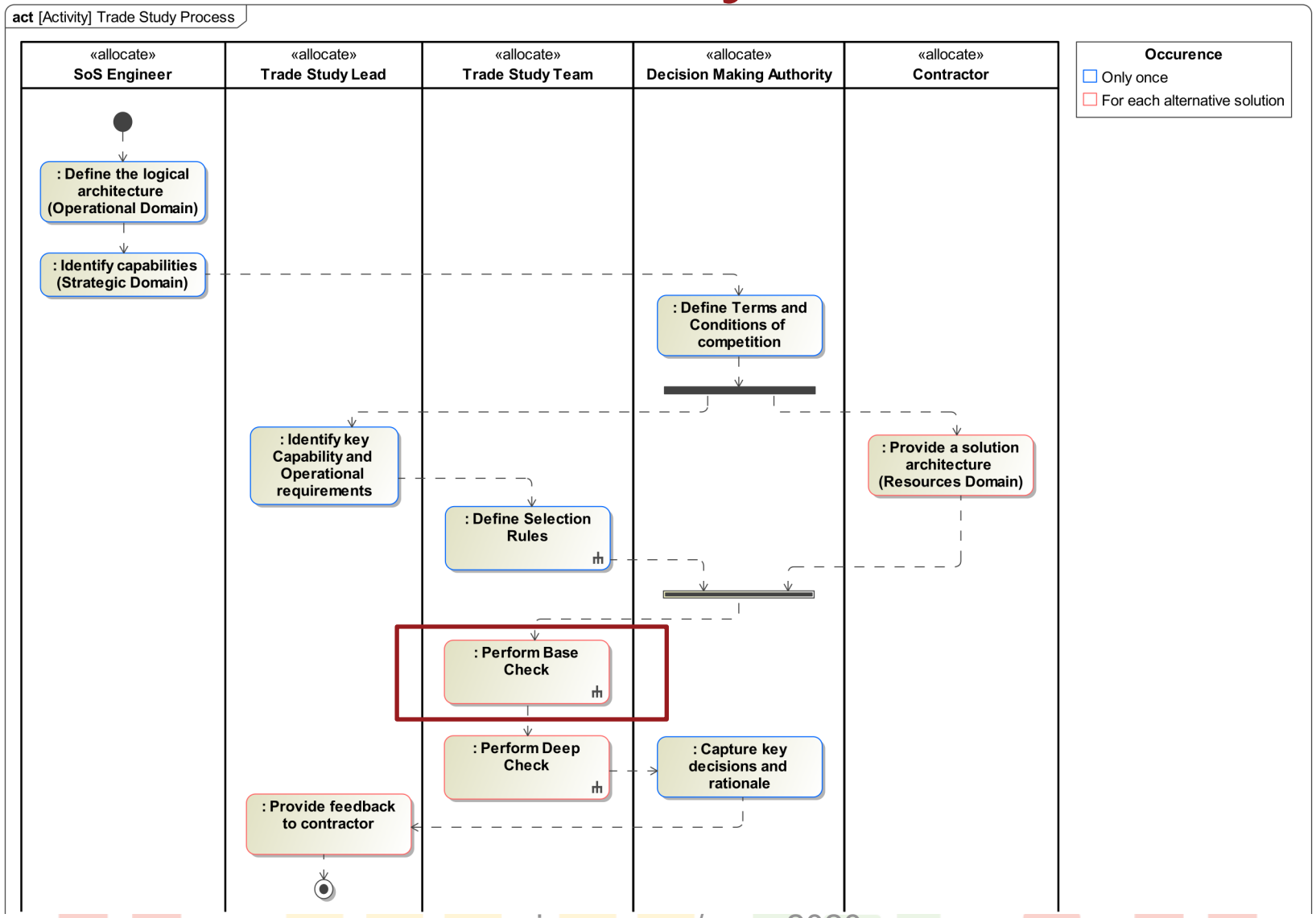


Provide a solution architecture

- Resources Domain (Rs) views are used to provide solution.
- Solution is modeled in accordance with Strategic and Operational domain models.

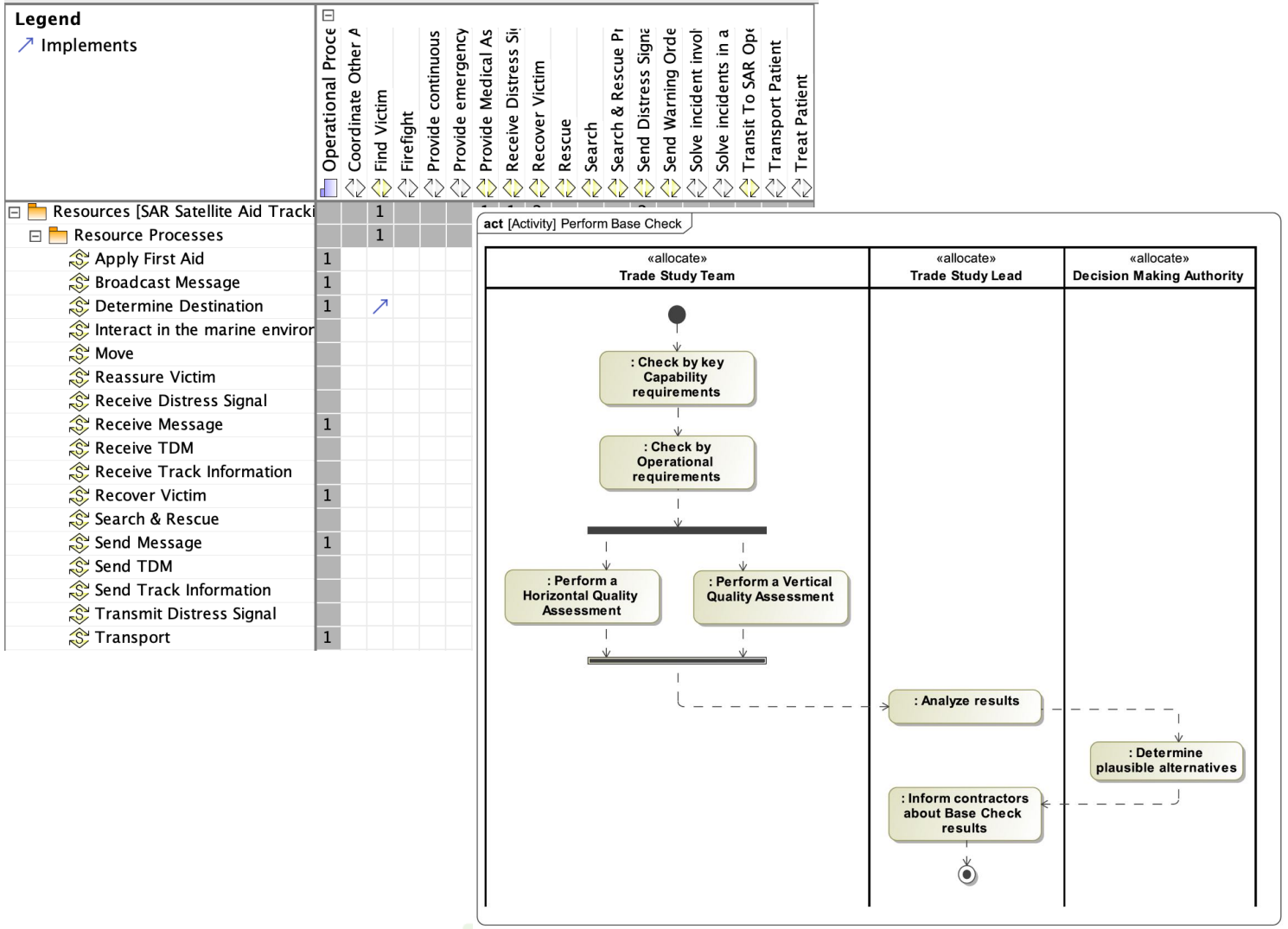


UAF-based Trade Study Process

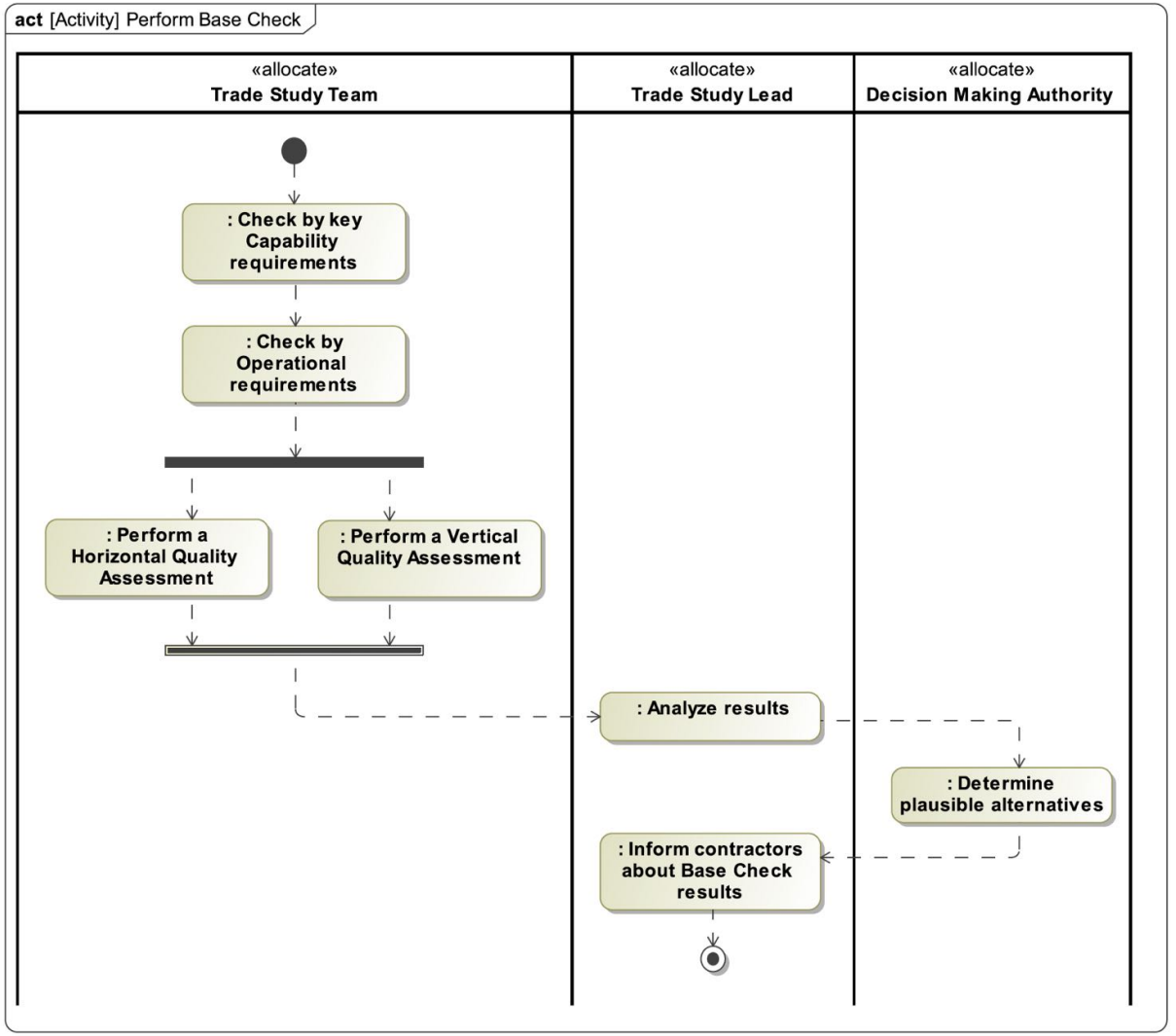


Perform the Base Check

- The satisfaction of key capabilities and operational requirements is checked.
- The quality of the solutions is determined.
- The set of submitted solutions is narrowed by selection of plausible solutions.



Perform the Base Check



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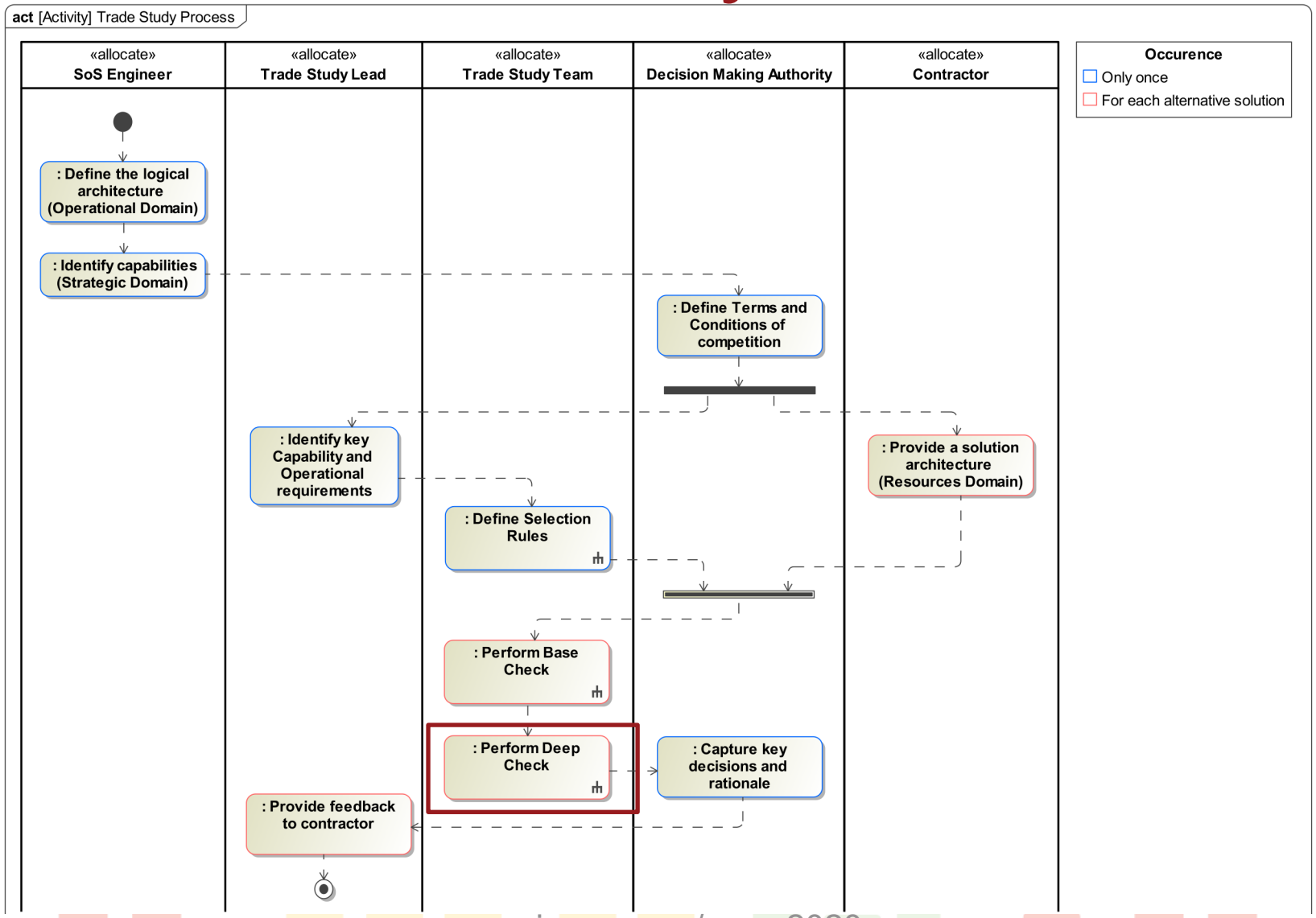
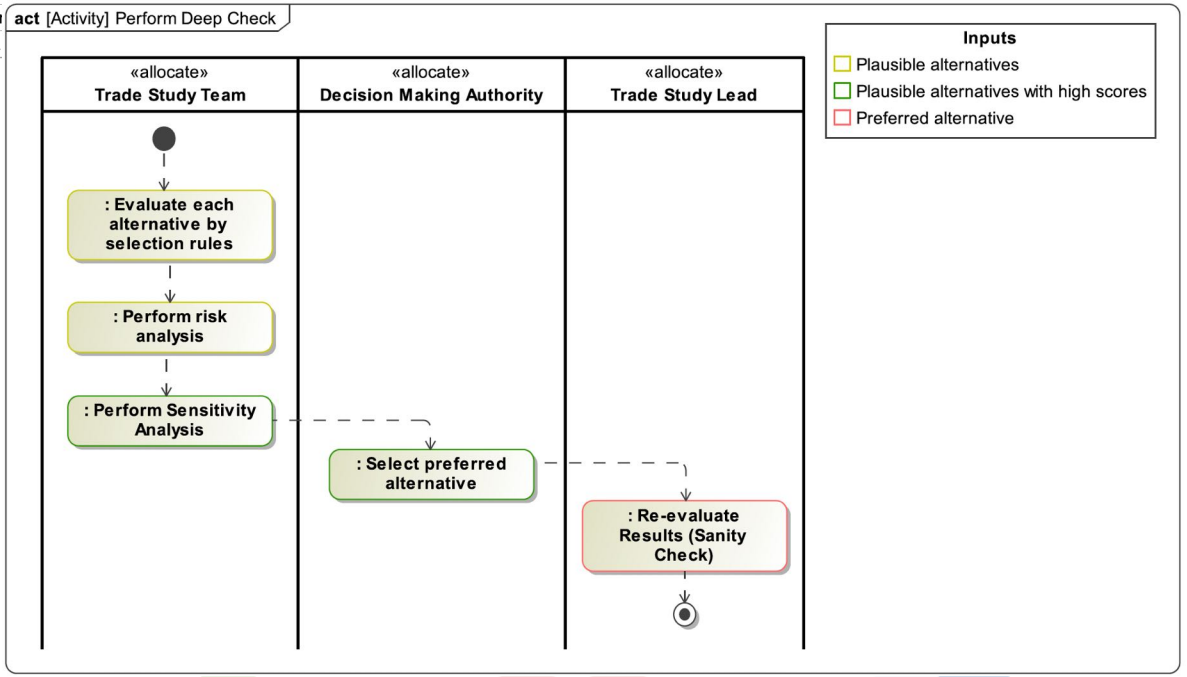


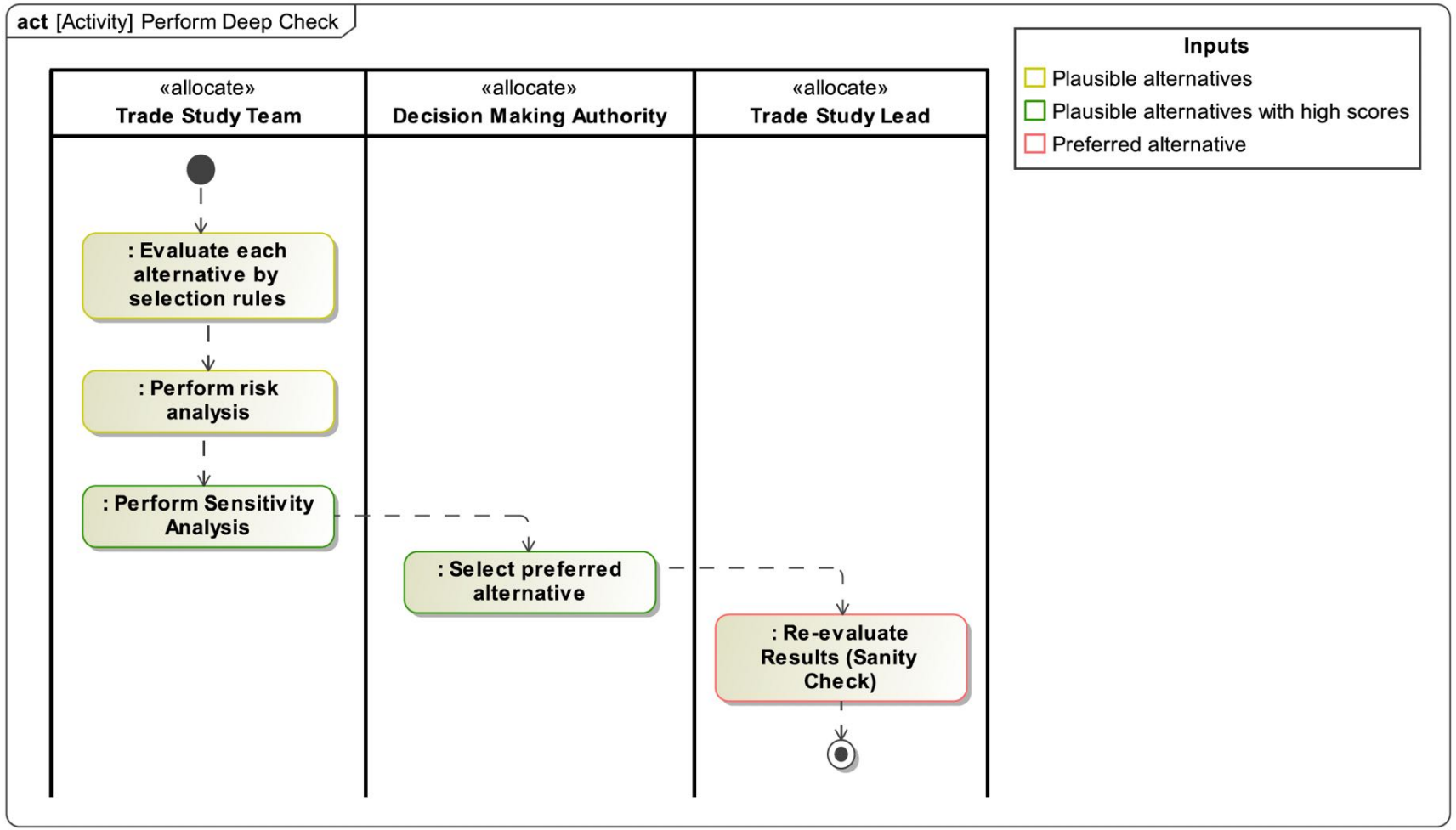
Perform Deep Check

- Detailed analysis for each solution is carried out.
- Sensitivity analysis is performed to facilitate the selection of the preferred alternative.
- The most preferred alternative that meets the key requirements and characteristics is identified.
- Re-valuation is performed to make sure that the right decision is made.

#	Name	duration : hour	costPerHour : Dollar/hour	cost : Dollar	: NoCasualties
1	maritime Configuration	31	1934.129	59958	fail
6	maritime Configuration1	41	1535.2683	62946	pass
11	maritime Configuration2	28	915.7931	26558	pass
16	maritime Configuration3	31	1026.8125	32858	pass
21	maritime Configuration4	30	955.3871	29617	pass
26	maritime Configuration5	26	1004.5556	27123	pass
31	maritime Configuration6	28	1024.1034	29699	pass
36	maritime Configuration7	30	959.9355	29758	pass
41	maritime Configuration8	40	1567.625	62705	fail
46	maritime Configuration9	25	998.8	24970	pass
47	maritime Configuration9.mobile health vehicle	7	100	700	
48	maritime Configuration9.rn asr helo	8	1600	12800	
49	maritime Configuration9.rn asr helo1	0	NaN	0	
50					
51	ma				



Perform Deep Check



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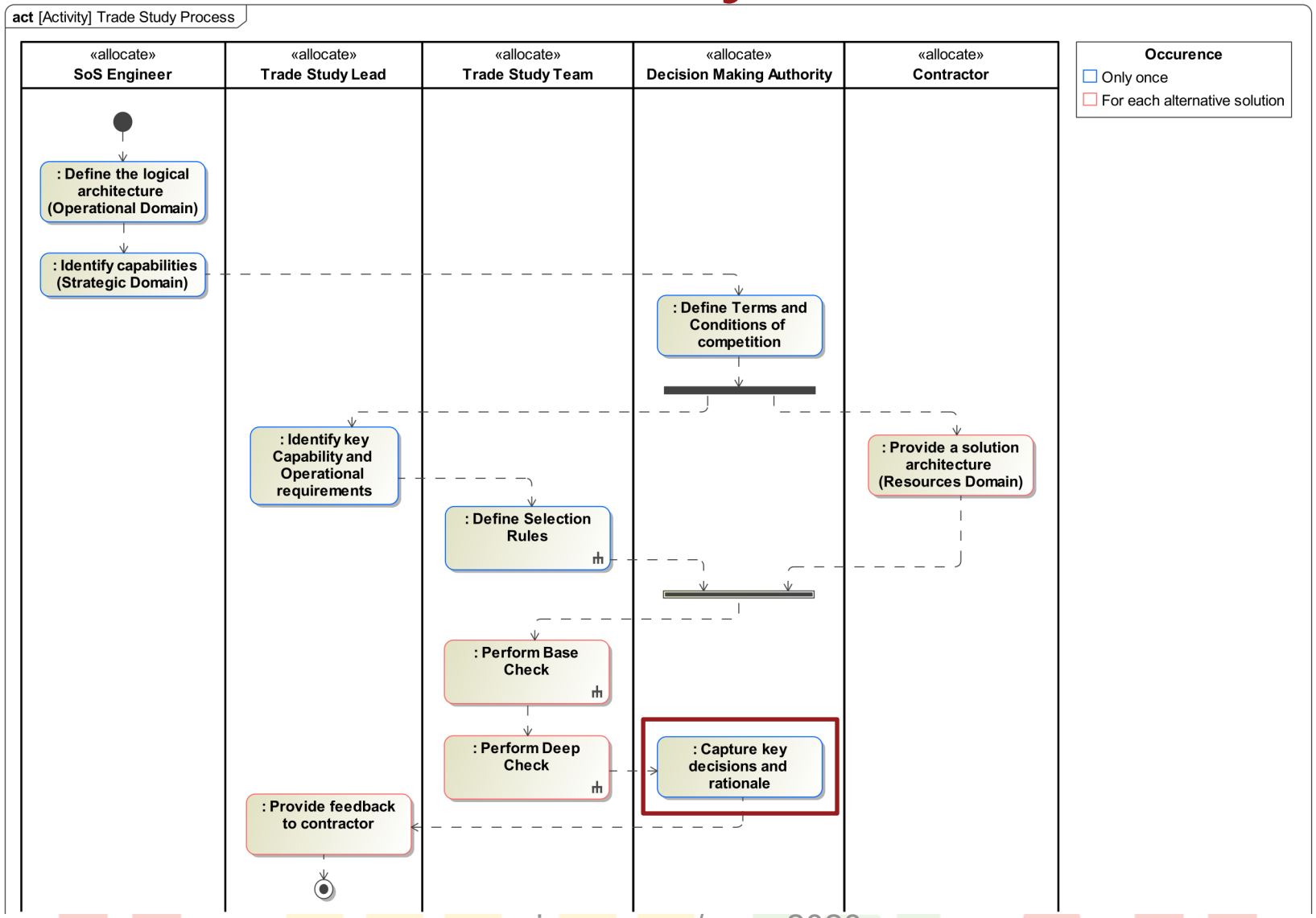
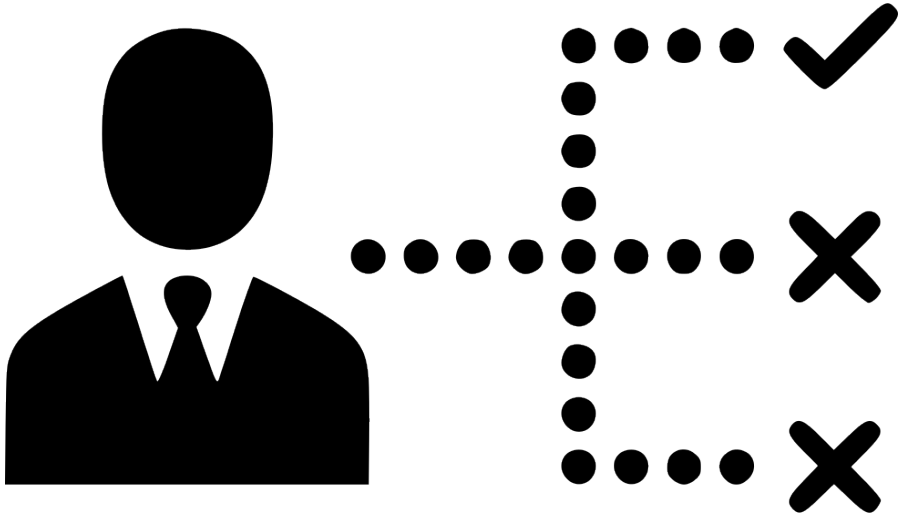


Capture key decision and rationale

- All results of the trade study are obtained and reviewed.
- This step may lead to a decision to extend the competition if none of the alternatives sufficiently meet the requirements and expectations of the preferred solution.



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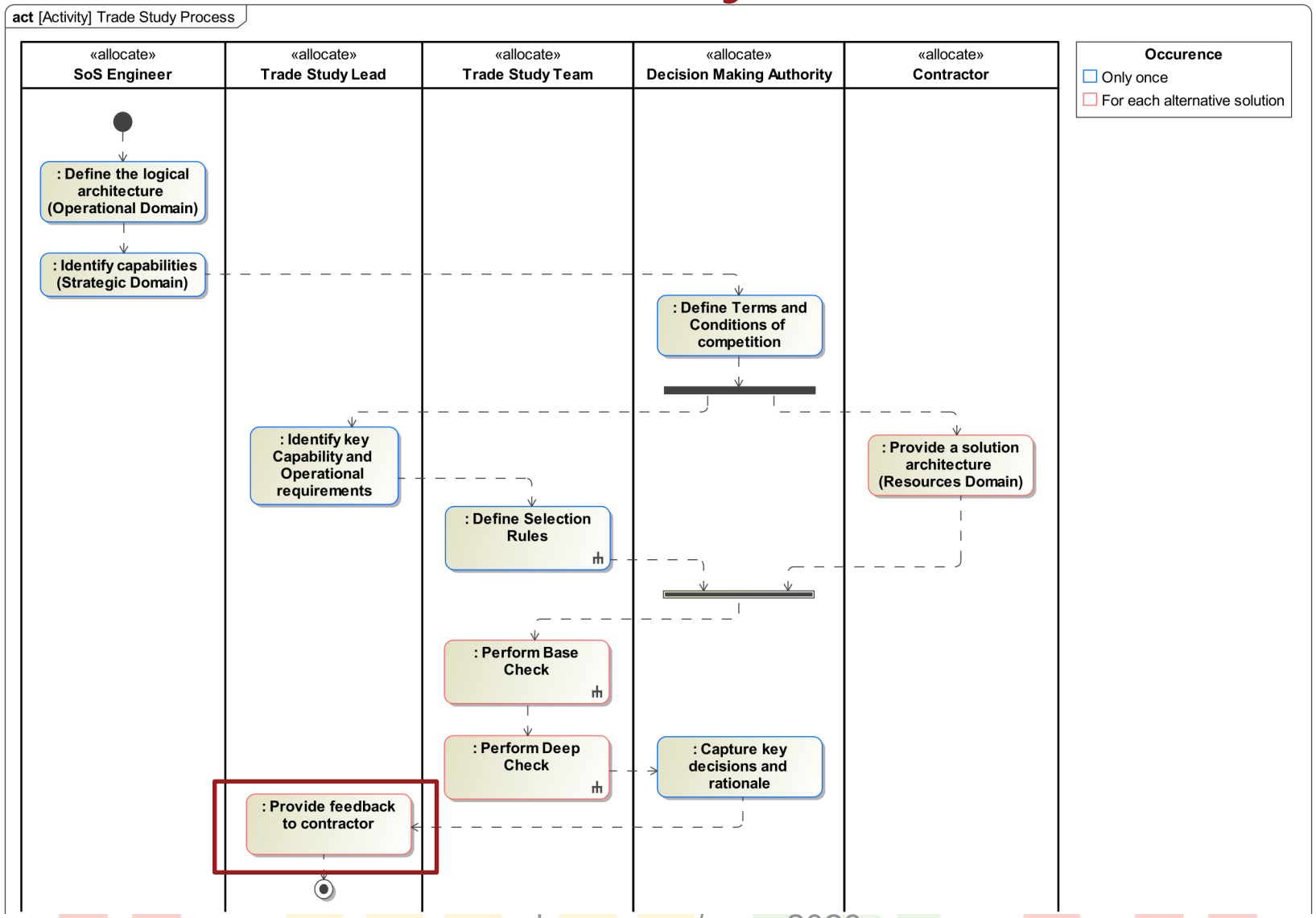
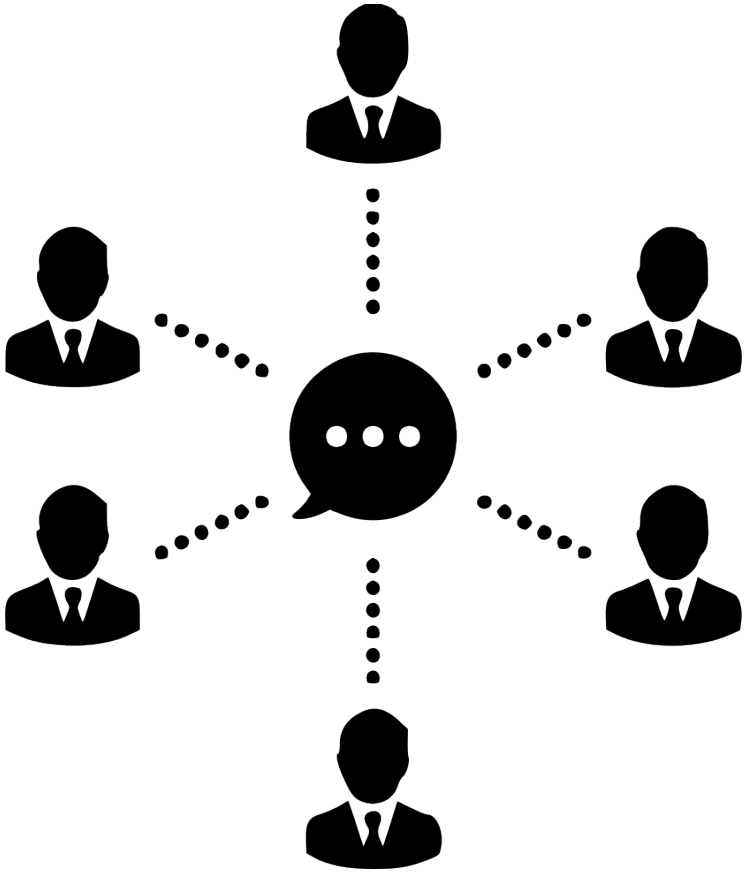
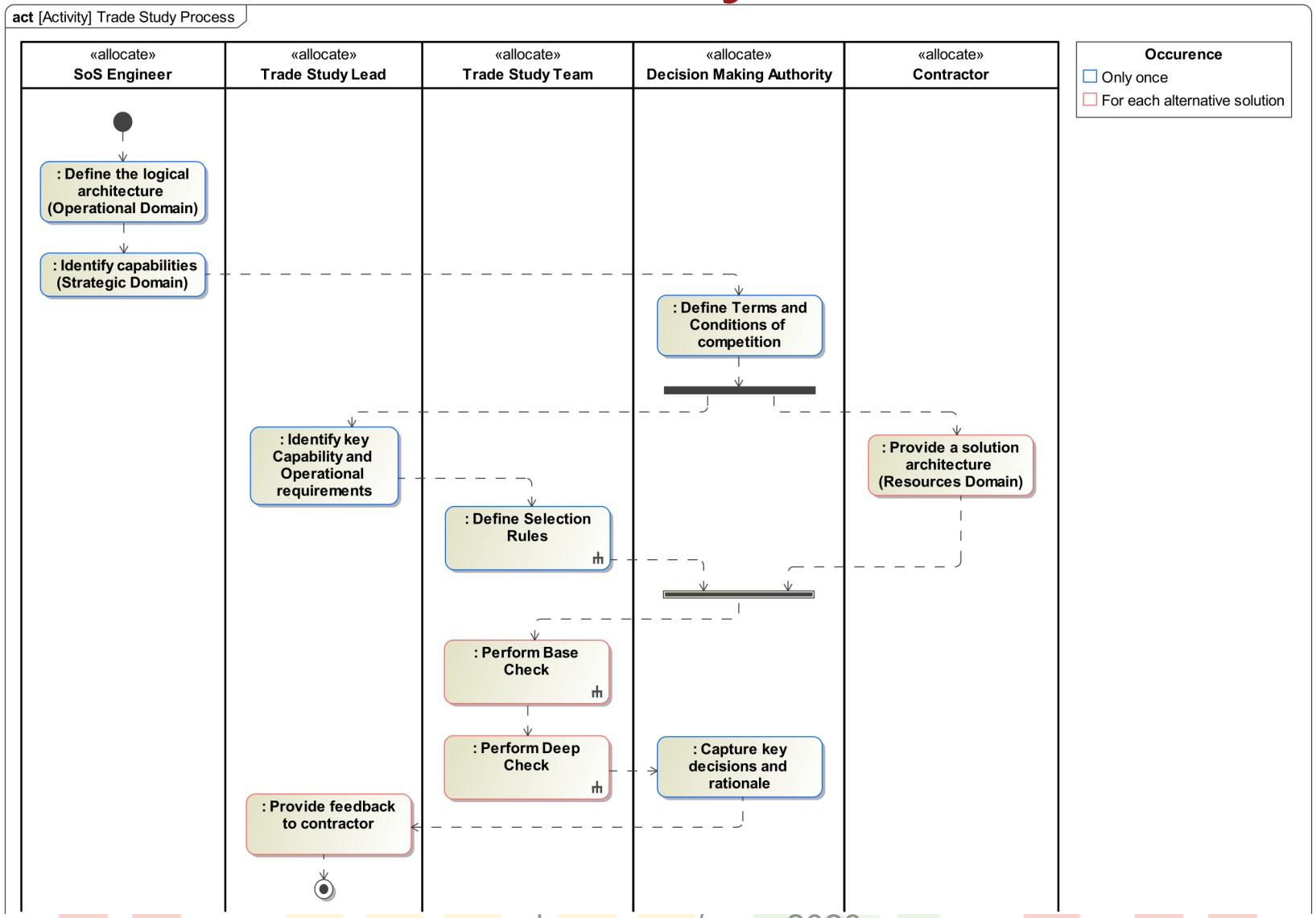


Provide feedback for contractor

- The end of the competition is announced.
- All participating contractors are informed about the results.
- Detailed feedback on the trade study results is provided for contractors.



UAF-based Trade Study Process



Conclusions

- Typically, trade study processes are not fully tailored for use in a model-based environment. In contrast, the Trade Study process proposed in this paper is strictly based on the principles of MBSE (by using UAF framework and language).
- Proposed process clearly defines the trade study process, determines what roles should be involved, and reveals what inputs are needed and what outputs must be presented at each step of the trade study.
- Since this paper focuses on the main flow of trade study, aside from the details, the next papers will present details about the Base Check and the Deep Check activities.
- Our long-term goal is to extend the proposed process to support the automated trade study analysis process for the system of systems architecture developed according to UAF principles.

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