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A Method for Human Systems Integration Requirements within Model Based Systems Engineering

Outline

- Background / Introduction
- Relational and Technological Capstone (RTC)
- RTC Phase 1
- SOCOM Task List
- RTC Phase 2
- Projected Contributions for SOCOM

The acquisition executive at SOCOM makes a key point in stating, “The operator is our platform” [O'Connell, M., 2018]**.**

Background and Introduction

Background

Kenneth Corl. is a doctoral student in the Department of Systems Engineering at Colorado State University. Professionally, he works as a Senior Principal Systems Engineer at G2 Ops, Inc. and recently retired from the US Navy after a 20-year career. Kenny holds a BS in Electrical Engineering from Clarkson University, an MBA from Hawaii Pacific University, and an MEng in Industrial Engineering from Pennsylvania State University.

Erika Gallegos, PhD. is an assistant professor in the Department of Systems Engineering at Colorado State University. Her research interests include human factors, operator cognition, safety, transportation systems, and technology adoption. She holds a BS in Civil Engineering from Oregon State University, and an MS and PhD in Civil Engineering from the University of Washington.

Background

- US Special Operations Command (SOCOM) is considered more effective at acquisitions than the larger U.S. military branches but are generally still held to the same statutory and regulatory acquisition requirements. [Purdy, J.A. and Schwartz, M., 2018]:
  - **Much smaller products of scale**
  - **Size of SOCOM (manpower, budget)**
  - **Areas of acquisition**

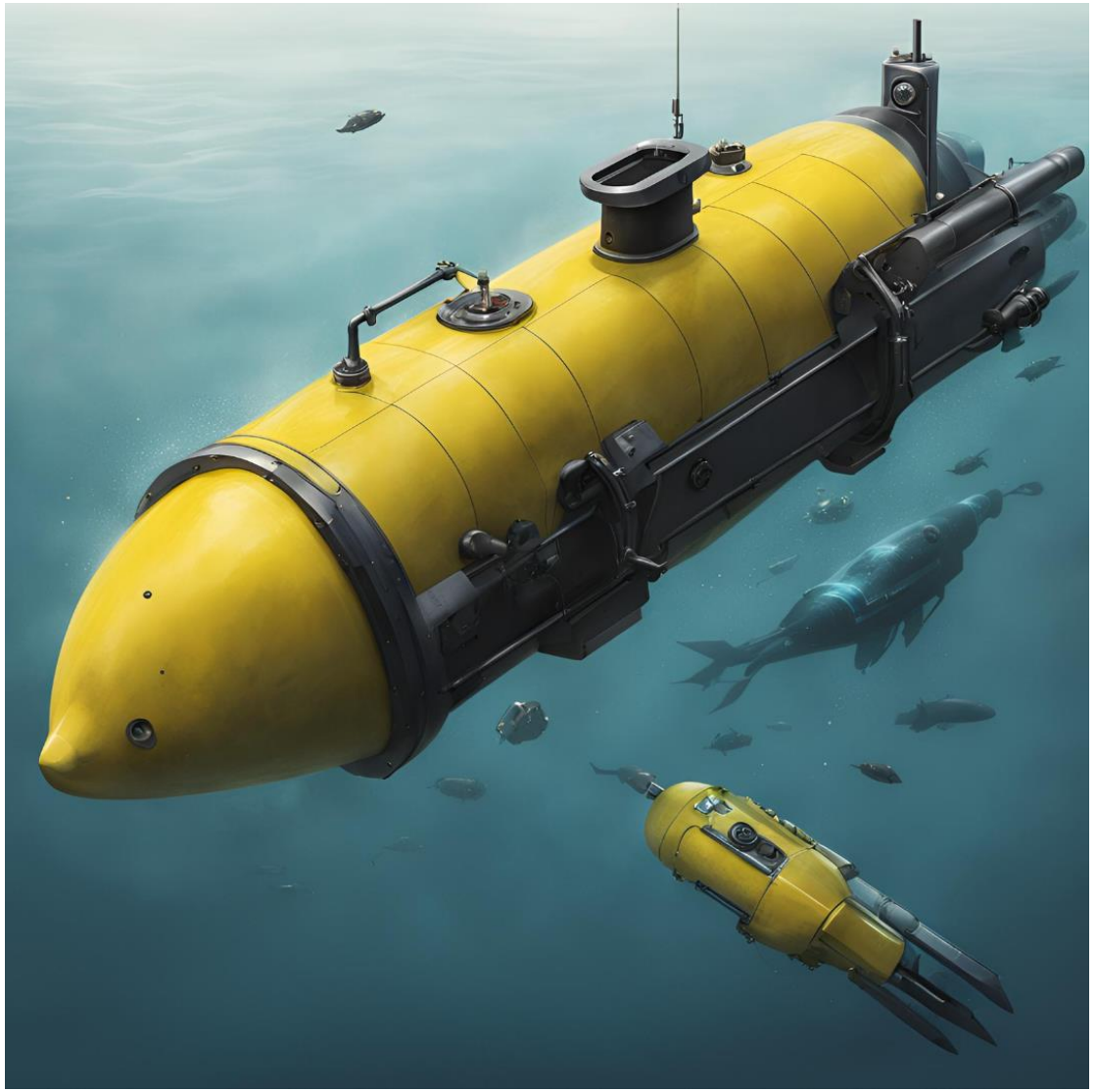
- By replicating DoD's way of doing acquisition, SOCOM continues to put the bulk of their attention on the platform and not on the warfighter, creating **a need for key improvements with regards to human-in-the-loop centered system design** early in the systems process lifecycle.

Introduction

- In addressing platform design, **modern efforts bring into the fold digital engineering**, which has become an important strategy in the defense domain for a comprehensive, more efficient Systems Engineering (SE) process toward new and existing platforms [Temin, 2022].
- Digital engineering becomes centered around **Model Based Systems Engineering (MBSE) and the Systems Modeling Language (SysML)** language [INCOSE, 2015] [Navy CIO, 2010].

Introduction

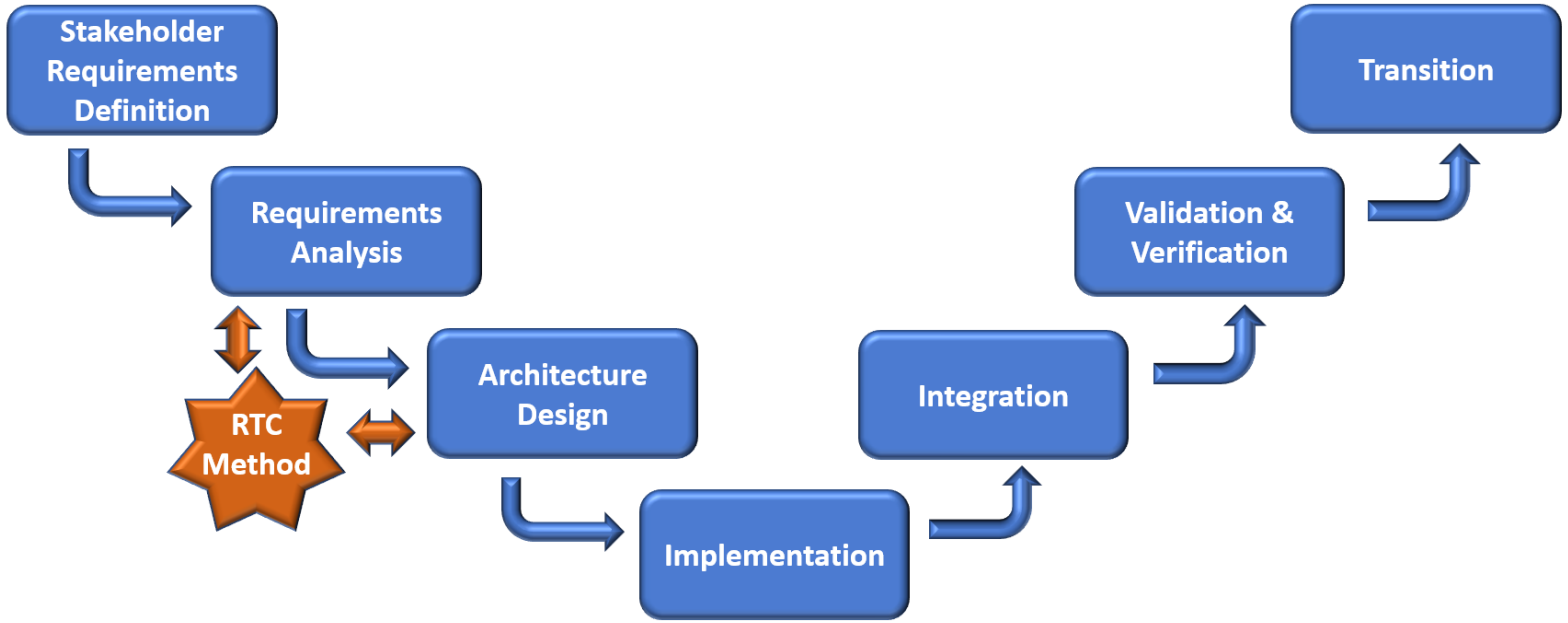
- With UUVs being utilized by SOCOM as an extension of their undersea operations, an initial set of requirements are made available with the following key characteristics [NAVSEA, 2020]:
  - 370 requirements provided via a UUV Performance Specification
  - **Only 6 of the 370 are HSI requirements**



Relational and Technological Capstone (RTC)

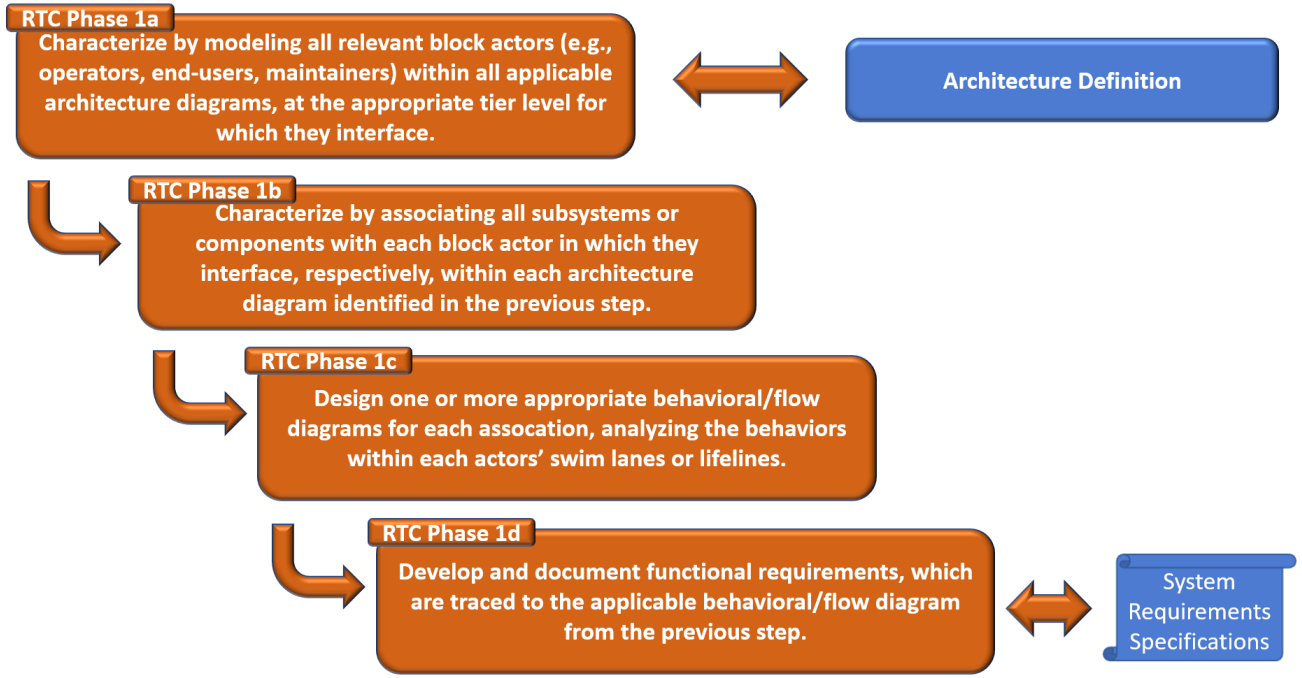
RTC Applied

Conceived and established through this research, **the Relational and Technological Capstone (RTC)** offers an MBSE-based, modular solution into the systems engineering process.



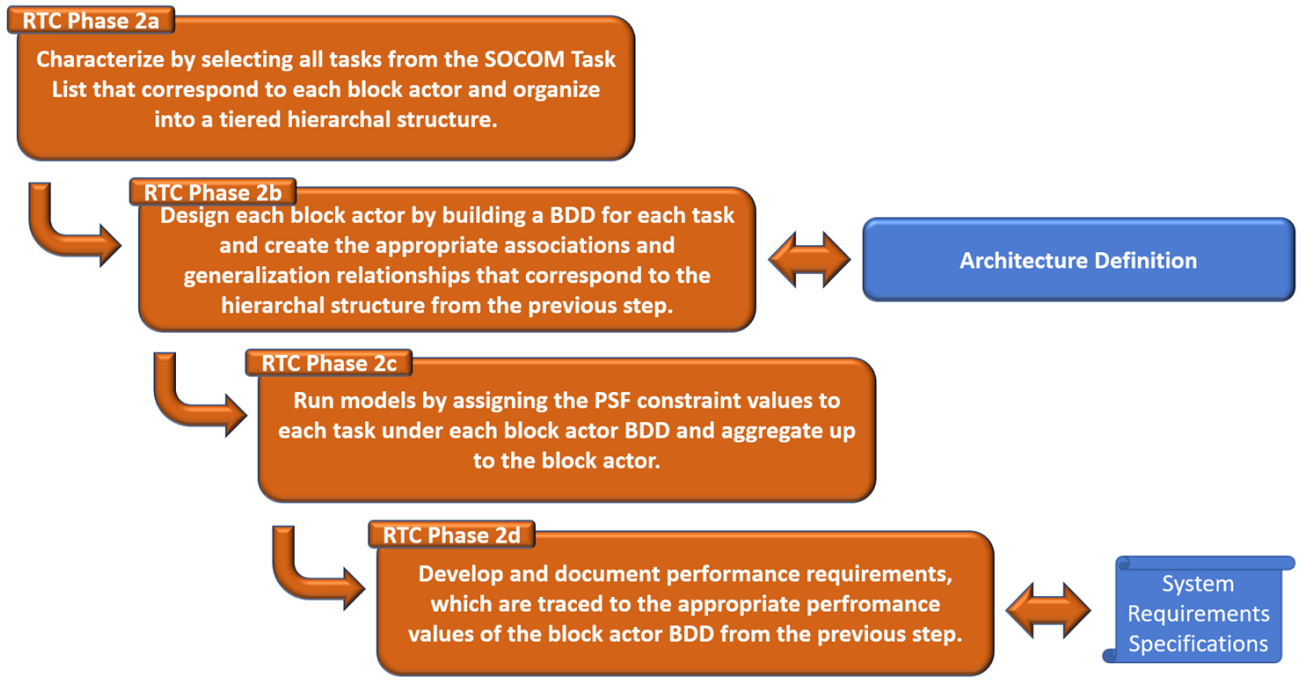
RTC Phase 1

Phase I of the RTC relies upon the human factors engineer to associate, design, and develop a series of model-based HSI requirements.



RTC Phase 2

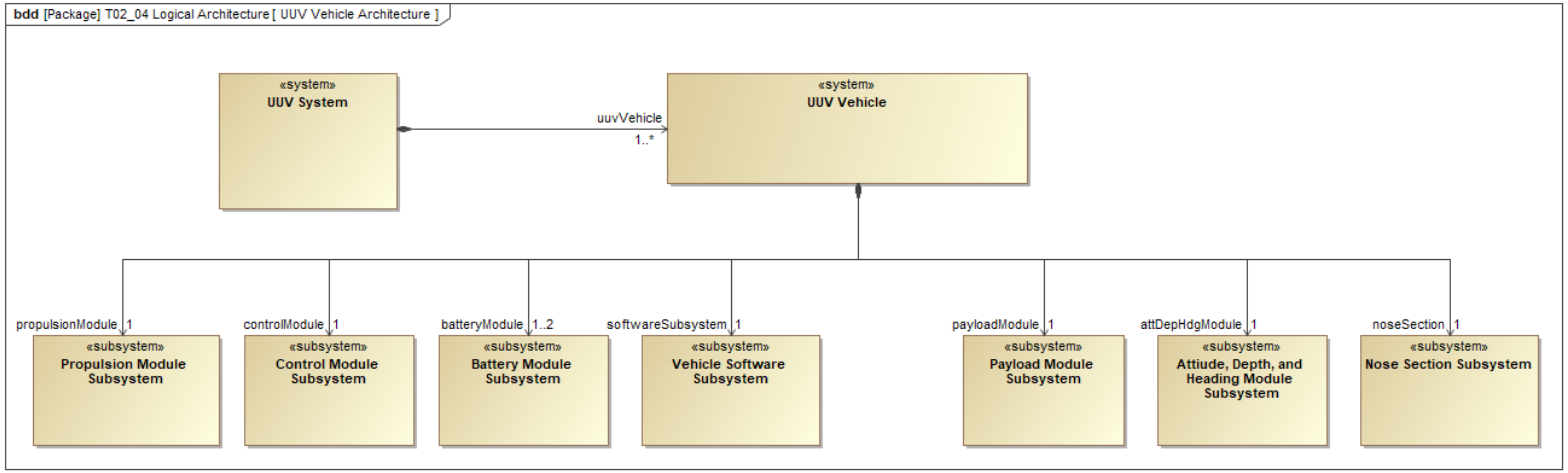
Phase II of the RTC relies upon the evolution of the SOCOM task list to enable the modeling of HSI performance requirements.

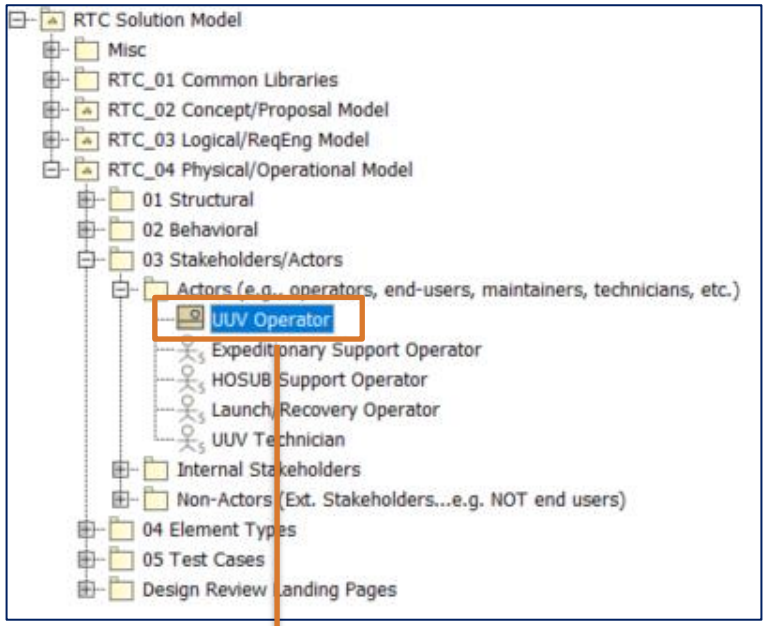


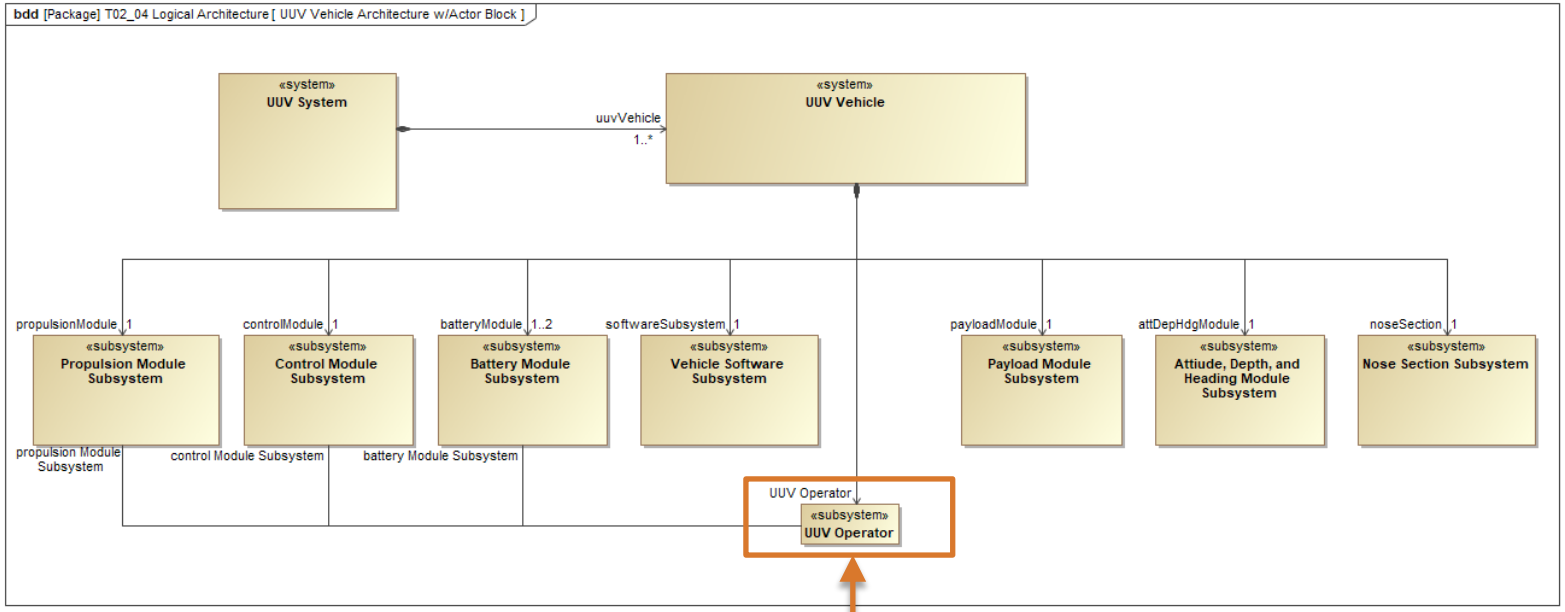
RTC Phase 1

RTC Phase 1

Block actor included as the subsystem design to lead into modeling, investigation and integration with the remaining subsystems. For this research, the block actor sampled is the UUV Operator.



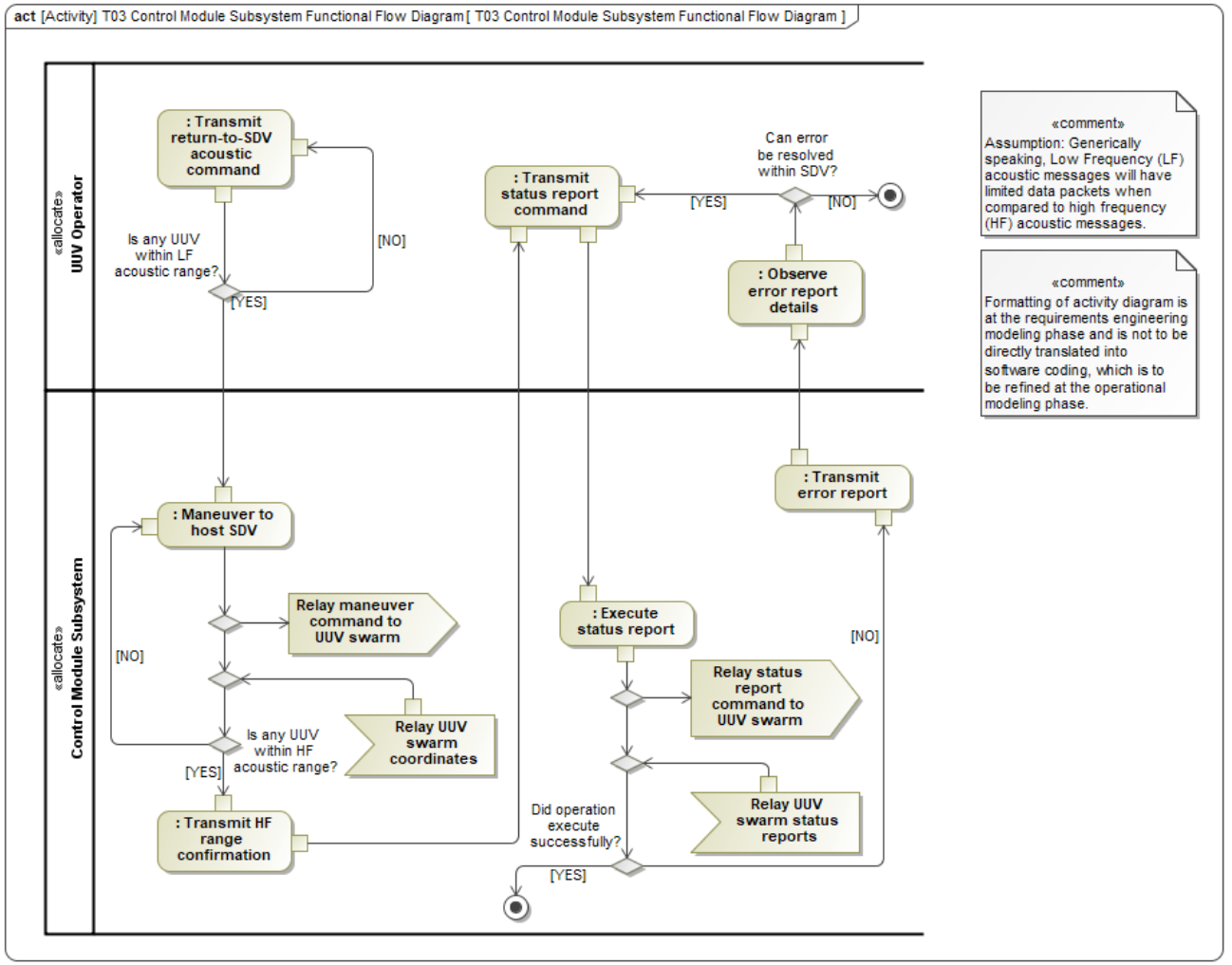




RTC Phase 1

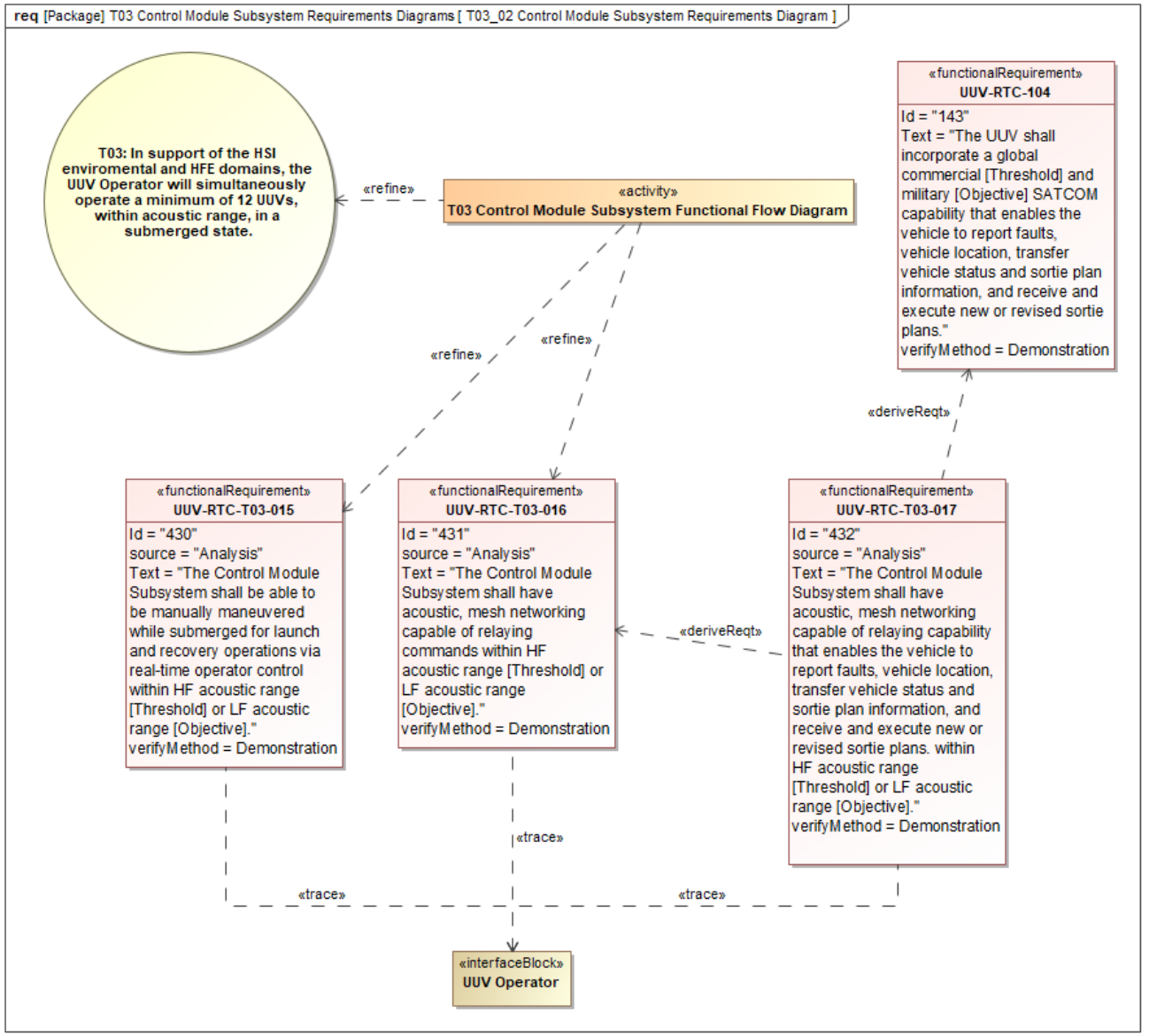
- With the block actor included, HSI priorities have been identified and prioritized to support both a standard to be considered for relational application and requirements development. An initial priority will be set to evaluate the block actor with each associated subsystem against the following, revised HSI Domains [Pew, 2008] [Dhillon, 1986] [INCOSE, 2015]:

  1) **Safety, Health, and Survivability**
  2) **Manpower**
  3) **Personnel**
  4) **Environment**
  5) **Human Factors Engineering**



RTC Phase 1

- Once use cases are defined to account for the applicable HSI Domains, behavioral diagrams are developed by the HFE to investigate and integrate new HSI friendly requirements into the UUV system.
- For this research, the three subsystems of the UUV Vehicle to be sampled with their respective behavioral diagram include:
  - Propulsion Module Subsystem: Use Case Diagram
  - Control Module Subsystem: Activity Diagram
  - Battery Module Subsystem: Sequence Diagram
- The resulting HSI requirements from each subsystem are captured in requirements diagrams to identify relationships and tabled for SME evaluation and feedback. **In total, 12 new functional HSI requirements to be incorporated into the SPS.**



SOCOM Task List

SOCOM Task List

- To bridge the progress made through Phase I of the RTC with Phase II of the RTC, the need to leverage a task list with SOCOM-related tasks is an identified prerequisite.
- A SOCOM task list comparable to the Universal Naval Task List (UNTL) does not presently exist.
- SOCOM task list advantages:
  - A task list can provide a hierarchal structure to tasks that can enable tiered modeling to exist with the operator, which expands upon the UUV System Architecture with Block Actor
  - Each task can be subjectively rated by SMEs to provide quantitative values, which may be aggregated through parametric modeling

Performance Shaping Factors

- Performance shaping factors (PSFs) have been referenced in a variety of applications to derive human error rates and risk analysis.
- Some common examples of PSFs being applied are in:
  - **Nuclear power plant operations**
  - **NASA**
- In both instances, the use of PSFs is to support Human Reliability Analysis (HRA)
- Each PSF listed comprise of both common factors found in research and SOCOM-applicable factors.

Performance Shaping Factor	Label	Rating Description
Task Training	PSF01	How much instruction, practice, or mentoring is required IOT perform the task?
Task Experience	PSF02	How much exposure and familiarity are required IOT perform the task?
Mental Acuity to Perform Task	PSF03	What level of response stimulus is required IOT perform the task?
Motor Skills to Perform Task	PSF04	What level of gross and fine motor skills are required IOT perform the task?
Stress of Performing Task	PSF05	How much mental tension, worry, or concern exists when performing the task?
Task Complexity	PSF06	How sophisticated or complicated is the system in relation to performing the task?
Actor Interfaces During Task (including orientation)	PSF07	How unintuitive, impractical, or unusable are the human interactions with the system when performing the task?
Task Safeguards	PSF08	How much risk, exposure, or jeopardy is the system or end-user subject to when performing the task?
Input Control Capability During Task	PSF09	How difficult or inoperable are the dynamic, interactive interfaces (e.g. joystick, throttle, etc.) to manipulate while performing a task?
Task Feedback and Alarms	PSF10	How limited or nonobvious are the system responses, alarms or signals while performing the task?

SOCOM Task List

- With the tasks identified, the next step is determining how the PSFs are calculated with **the overall objective of getting each task down to one value.**
- Ao aligns with the PSF goals within this SOCOM task list and the RTC. The most important aspect of these is how Ao is utilized as a measure of effectiveness in the specifications of requirements of military systems [Prior, 2008].

$$Ao = \frac{Uptime}{Uptime + Downtime}$$

$$Performance = \frac{Capacity}{Capacity + Commitment}$$

- In a more RTC-aligned phrasing, the design of the RTC equation is formulated around the concept that the summation of each PSF makes up the overall performance of the task.

$$P_{RTC} = \frac{C_A}{C_A + C_O}$$

$$P_{RTC} = \frac{10}{10 + \left(\sum_{i=1}^{10} PSF_i\right)}$$

SOCOM Task List

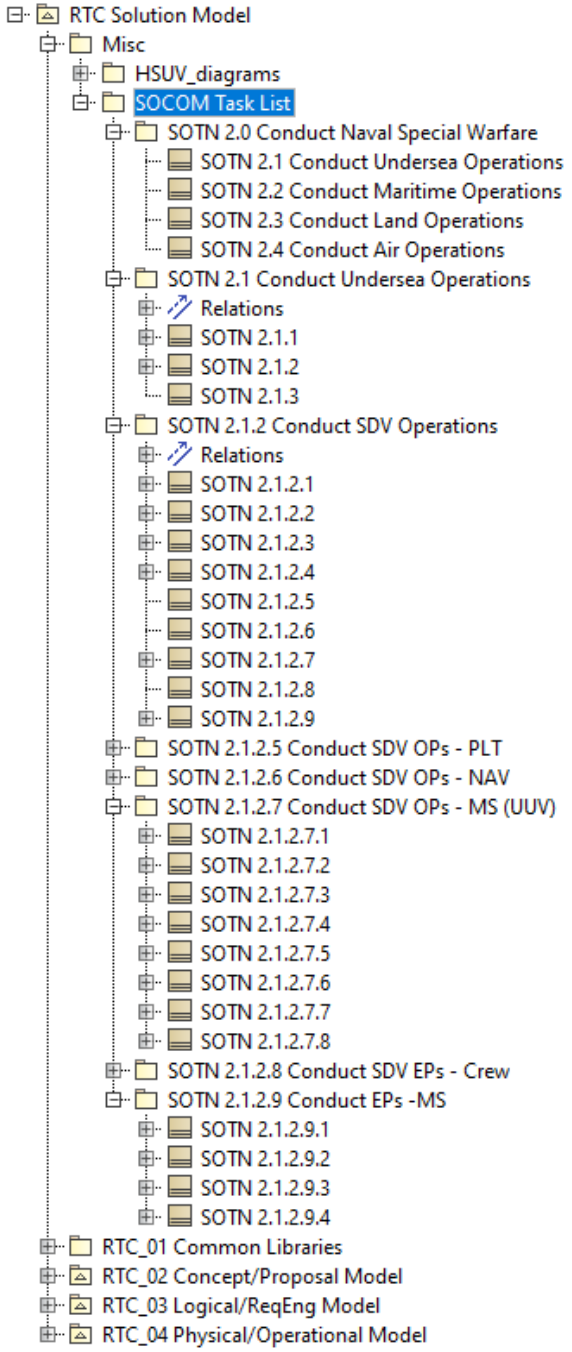
- The three main jobs required for **a non-pressurized manned submersible** is a pilot, navigator, and one, or more Mission Specialists (MSs):
  - **UUV tasks will be structured under the MS due to the ancillary, specialized role** an MS plays in SDV operations
- Tasks are derived from the UNTL to **flow down to the SDV OPs and EPs** for the SOCOM task list used in this research.

Task	Task Training	Task Experience	Mental Acuity to Perform Task	Motor Skills to Perform Task	Stress of Performing Task	Task Complexity	Actor Interfaces During Task	Task Safeguards	Input Control Capability During Task	Task Feedback and Alarms	P_{RTC}	C_A
												10
SOTN 2.1 Conduct Undersea Operations	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	User Rating Input
												P_{RTC} Adjustment
SOTN 2.1.1 Conduct Combat Swimmer Operations	3	3	3	6	4	4	3	4	2	5	**N/A**	User Rating Input
	0.3	0.3	0.3	0.6	0.4	0.4	0.3	0.4	0.2	0.5	**0.730**	**P_{RTC} Adjustment**
SOTN 2.1.2 Conduct SEAL Delivery Vehicle (SDV) Operations	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	User Rating Input
												P_{RTC} Adjustment
SOTN 2.1.2.1 Conduct S-C Mix1 SEAL Delivery Vehicle (SDV) Operations	7	5	6	1	6	7	6	6	5	7	**N/A**	User Rating Input
	0.7	0.5	0.6	0.1	0.6	0.7	0.6	0.6	0.5	0.7	**0.641**	**P_{RTC} Adjustment**
SOTN 2.1.2.2 Conduct S-C Mix2 SEAL Delivery Vehicle (SDV) Operations	8	6	7	1	7	8	7	7	5	7	**N/A**	User Rating Input
	0.8	0.6	0.7	0.1	0.7	0.8	0.7	0.7	0.5	0.7	**0.613**	**P_{RTC} Adjustment**

RTC Phase 2

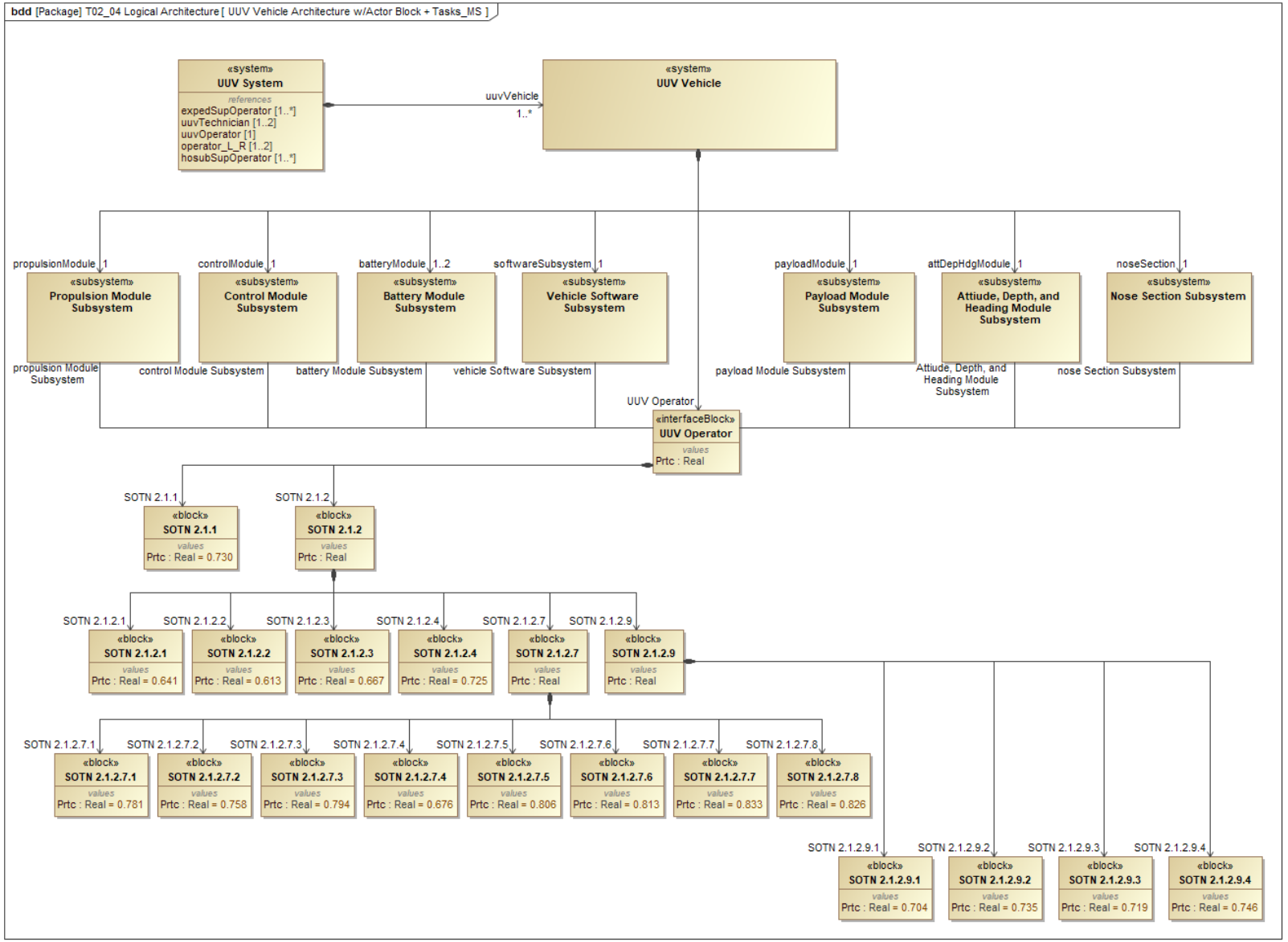
RTC Phase 2

- Organization of tasks from the SOCOM Task List into a model containment tree.
- Applying the P_{RTC} equation values for each task as value properties to all task list block elements.



RTC Phase 2

- Under the UUV Operator, expansion of UUV System Architecture BDD with each parent and child task from the SOCOM Task List.
- Creation of associations linking each UUV Operator task in a Reliability Block Diagram (RBD) construct.



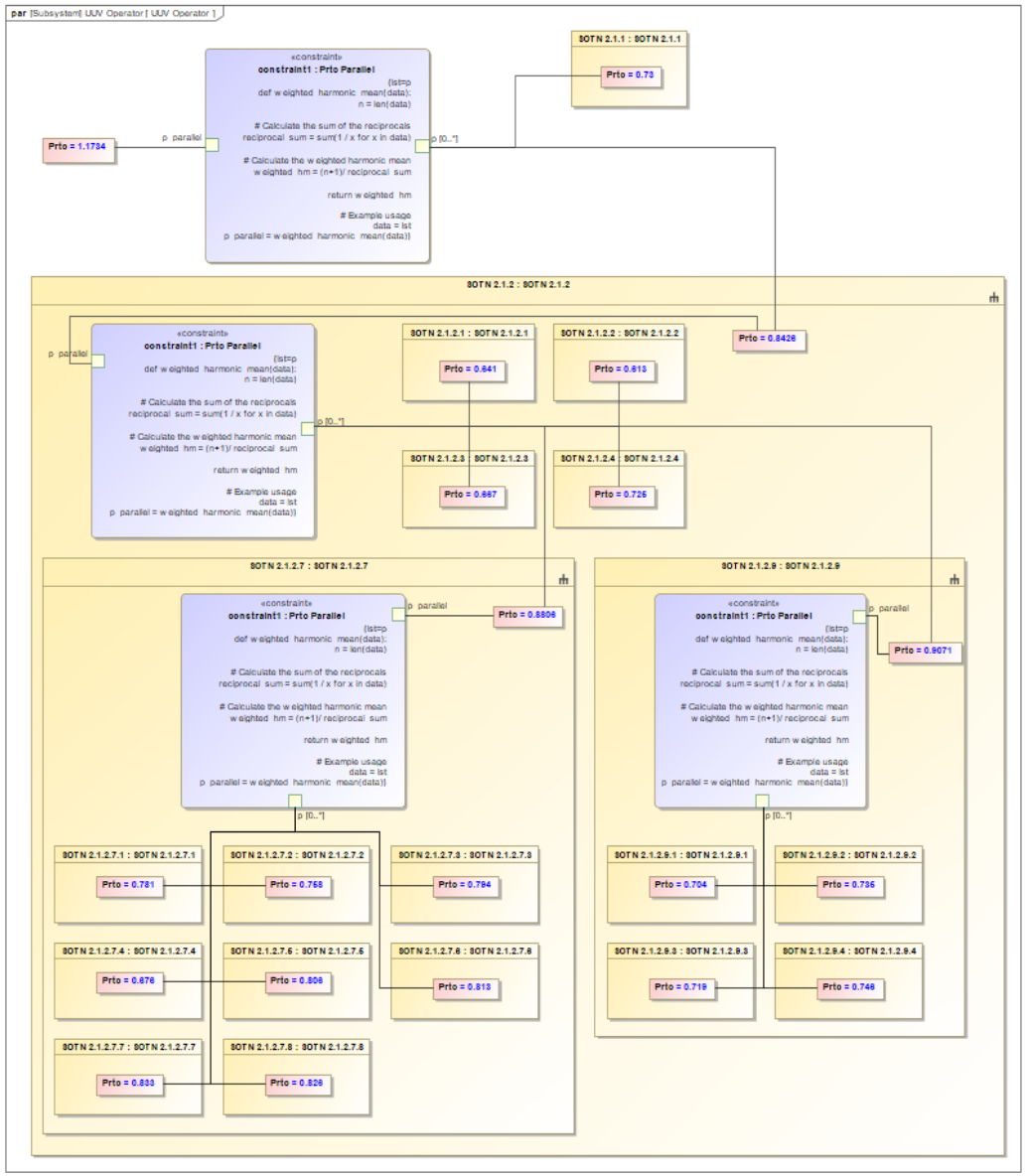
SOCOM Task List

- With a P_{RTC} value identified for each task in the SOCOM task list, a constraint value is required to aggregate all P_{RTC} values up to the operator subsystem block and account for the number of parallel tasks under each operator.
- More tasks applied at the same tier level (or set of tasks) is viewed as added complexity for the operator to understand and accomplish. The P_{RTC} Aggregated equation must account for a progressively lower scoring as more tasks are assigned.

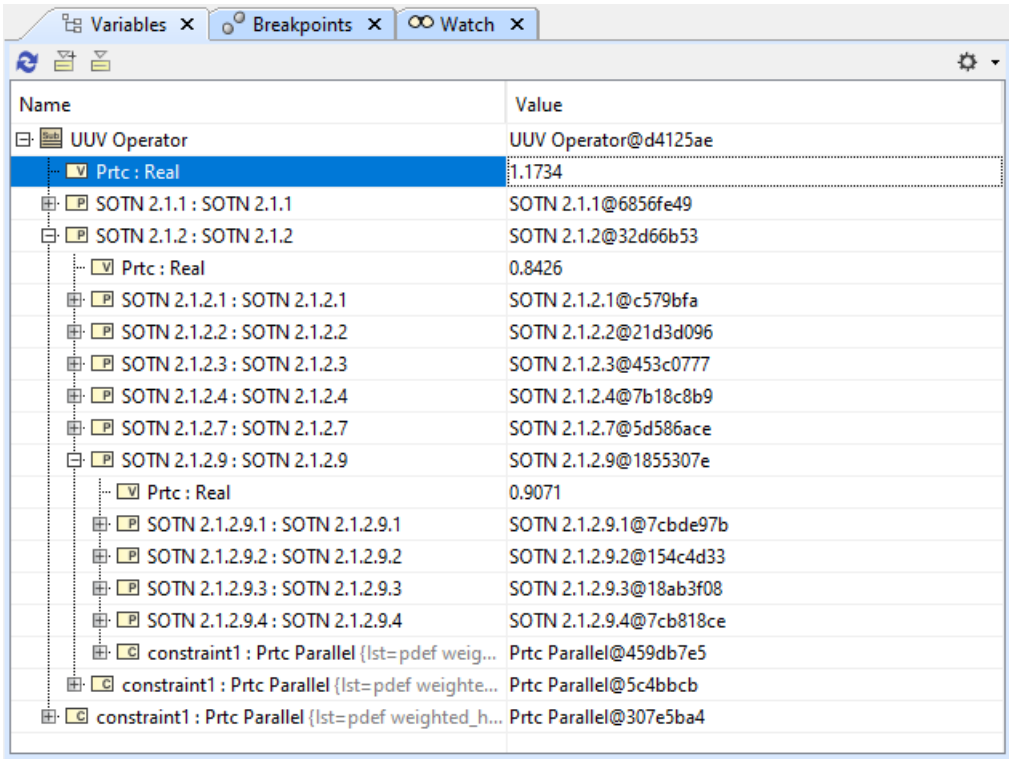
$$WHM = \frac{n}{\sum_{i=1}^{n} \frac{1}{x_i}}$$

$$P_{RTC}\ Aggregated = \frac{n+1}{\sum_{i=1}^{n} \frac{1}{x_i}}$$

- While several candidate equations provided a level of acceptability for the purpose of a P_{RTC} aggregated value, the formula that provide the foundation is the weighted harmonic mean with an edit to account parallel tasks.



- With the P_{RTC} aggregated formula developed, incorporating it into a parametric model is done with the Python programming language.
- In using the Cameo Systems Modeler Simulation Toolkit plugin, the parametric diagram can be computed for each P_{RTC} aggregated constraint block.



RTC Projected Contributions

Projected Contributions

By addressing each topic area, RTC seeks to both advance the human-in-the-loop discipline and help an elite military community where it's servicemembers are their most exploited asset.

We anticipate the proposed human-in-the-loop centered, SOCOM-friendly MBSE methodology delivers the following upgrades and improvements for SOCOM:

- **The human-in-the-loop-centered MBSE methodology** is generalized for diverse applications across SOCOM acquisition programs, projects, and equipment.
- **The human-in-the-loop-centered MBSE architecture** immerses SOCOM operators into any system of interest to capture the characteristics and attributes of the warfighter.
- **The SOCOM Task List** will be developed for all OPs and EPs throughout the SOCOM community.
- **The Performance Shaping Factor (PSF) data** aligns mission-related tasks with individual characteristics to quantify and measure the warfighter for all SOCOM task list items.
- **The human-in-the-loop-centered MBSE methodology** links the PSF data from the SOCOM task list into the human-in-the-loop architecture.
- **Community-wide value in the use of MBSE and human factors across SOCOM acquisition.**

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