Applying trade-space analysis to modeling and simulation as a service (MSaaS)

A Study in applying established systems engineering methodologies in a novel setting

05/13/2021

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of ENGINEERING

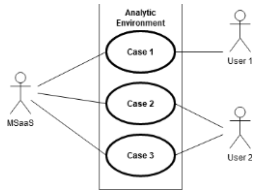
Problem Statement

The NATO STO Allied M&S as a Service Framework lacks an integrated analytic framework capable of supporting concept development and analysis of possible alternatives and trade-space analysis in procurement decisions.*

Hypothesis

A NATO MSaaS instance, integrated with an analytic environment, is suitable to support trade-space analysis by measuring the robustness of military systems.

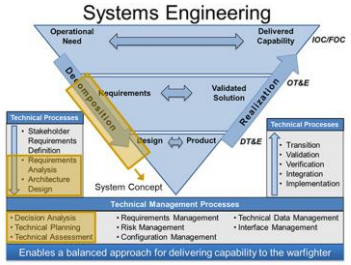
Goal 1: Extend a NATO MSaaS framework with an analytic environment.

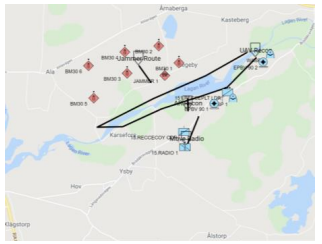


HELM

R Studio

Goal 2: Execute a simple trade-space analysis using an existing NATO MSaaS scenario.





	Sys A	Sys B
Conf A		
Conf B		

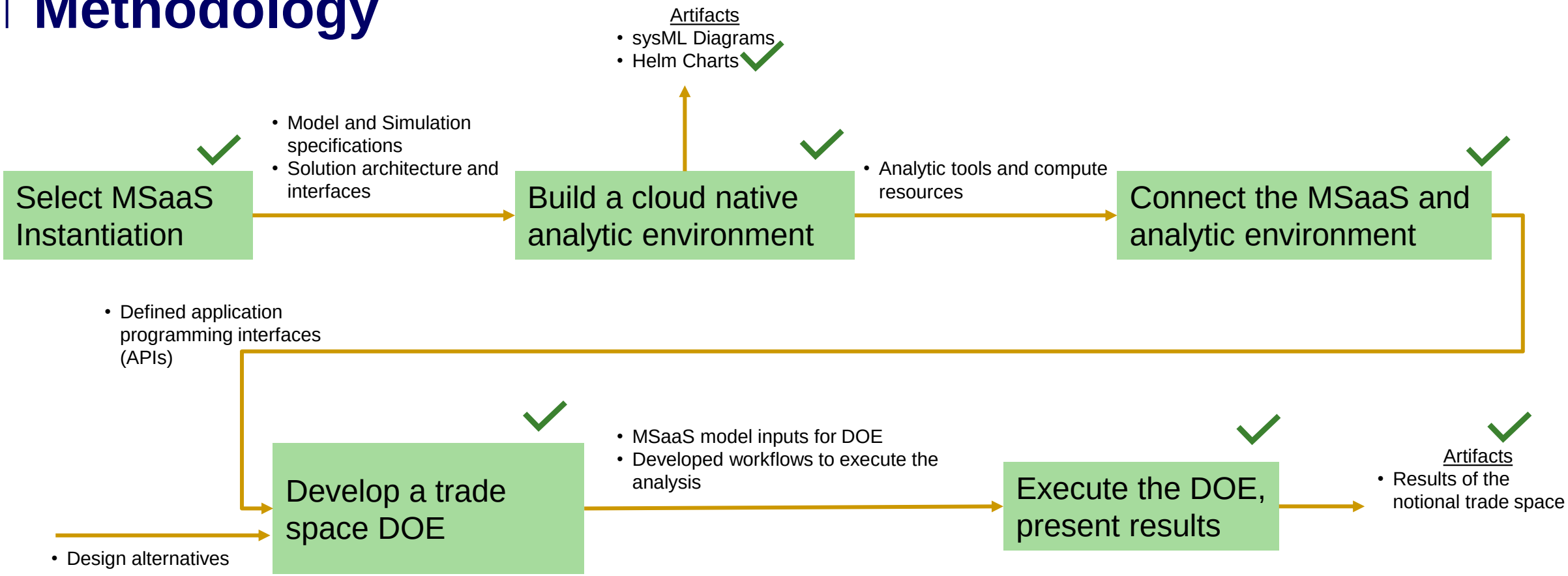
Significance of Study

The inherently scalable and interoperable nature of MSaaS and cloud native approaches have direct implications on the requirements analysis, architecture design, and analysis of alternatives steps of the Systems Engineering Life Cycle.

Study Questions (1/2)

- What are the challenges with integrating an MSaaS instance with an analytic environment?
- What information model supports communication between the MSaaS models, simulations, data stores, and analytic tools to support trade-space analyses.
- How could integrating MSaaS with an analytic environment support trade-space analysis?
- What are the benefits and risks of this approach?
- What are the limitations of this approach?

Methodology

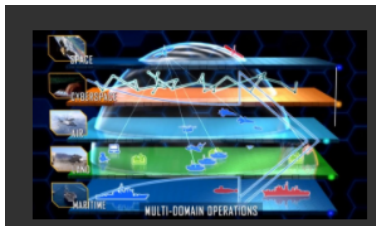


Select MSaaS Instantiation → Build a cloud native analytic environment → Connect the MSaaS and analytic environment → Develop a trade space DOE → Execute the DOE, present results

Methodology Traceability

	Select MSaaS Instance	Build a cloud native analytic environment	Connect the MSaaS and analytic environment	Develop a trade space DOE	Execute the DOE, present results
What are the challenges with integrating a MSaaS instance with an analytic environment?	X	X	X		
What information model supports communication between the MSaaS models, simulations, and data stores and analytic tools to support trade-space analyses	X	X	X		
How could integrating MSaaS with an analytic environment support trade-space analysis?			X	X	X
What are the benefits and risks of this?	X	X	X	X	X
What are the limitations of this?	X	X	X	X	X

Select an MSaaS Instantiation



Multi Domain Operations Sim

This chart deploys a DEVS-DMF simulation of multi-domain operations.
It includes a military movement model, a sensor model, and a radio network model. Once deployed, the simulations run in parallel until all of the runs are complete. It support defining a design point with a number of iterations.

aws RANCHER

- **Research instance**
  - Active developers (responsive changes and flexibility to experiment)
- **Existing model and simulation components**

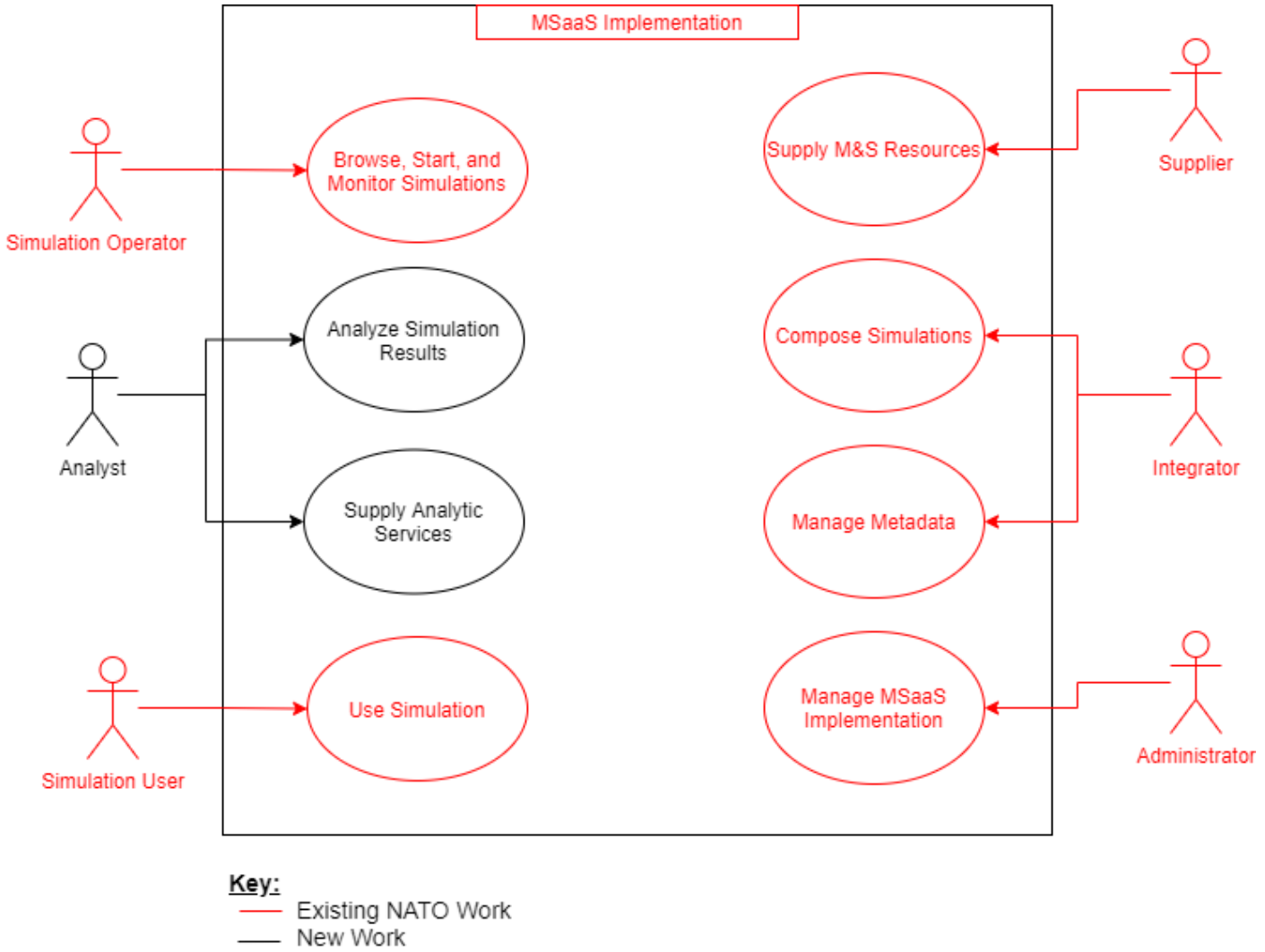
Select MSaaS Instantiation → Build a cloud native analytic environment → Connect the MSaaS and analytic environment → Develop a trade space DOE → Execute the DOE, present results

Integrating With Existing NATO Work

- The NATO MSG-164 has built their information model using UML's Use Case diagrams and Activity Diagrams.

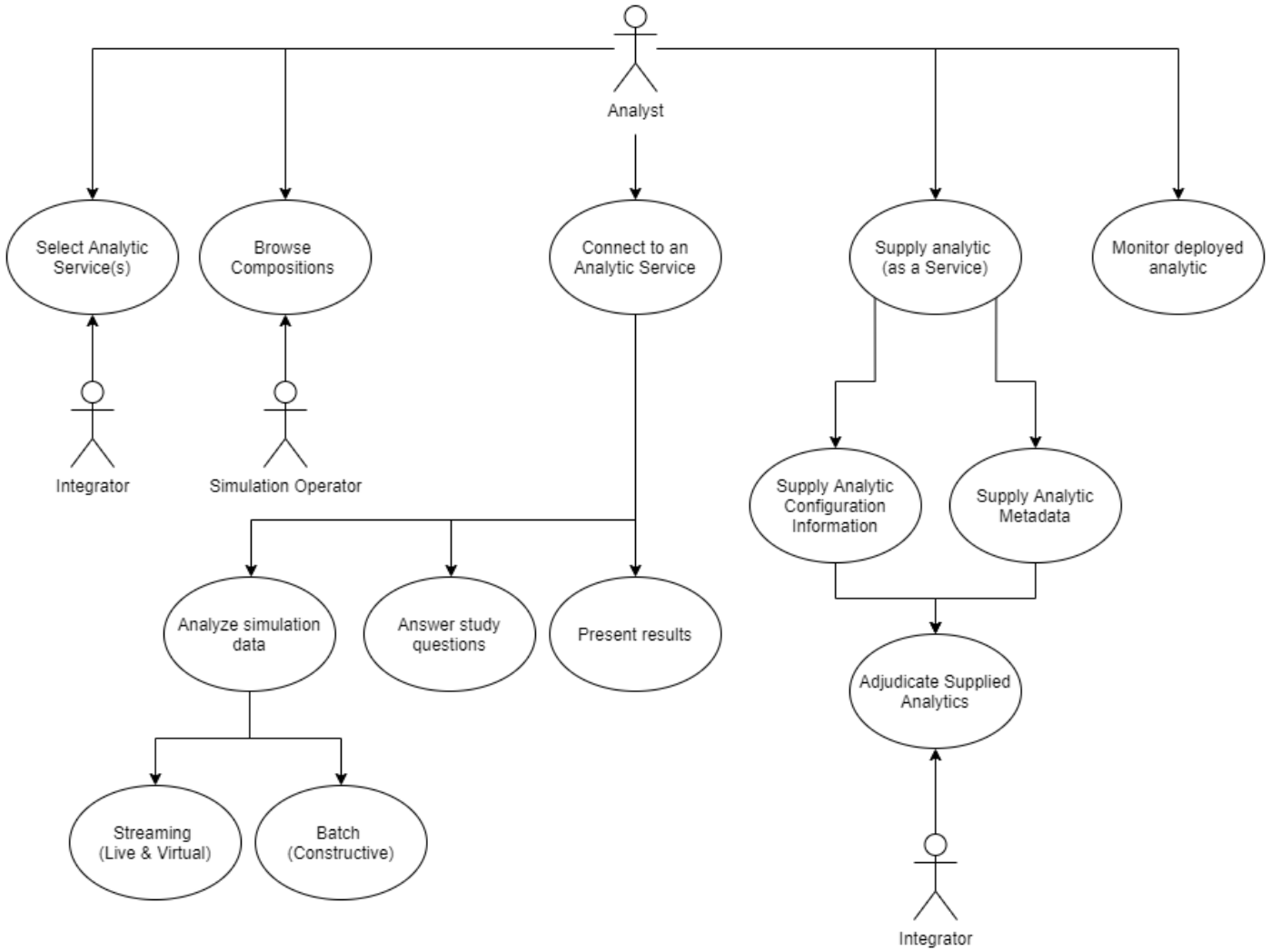
- In order to build on their existing work, I took their diagrams and extended them to include the roles and functions required by an analytic environment.

Modified MSaaS Use Case Diagram



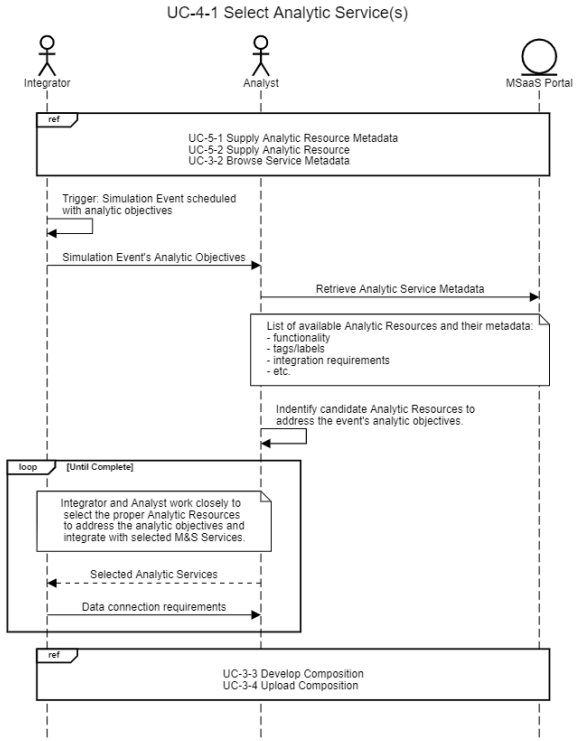
- **Analyst Roles**
  - Supply new Analytic Services/Resources
    - ABBs
    - Deployed Analytics
  - Address simulation event's analytic objectives.

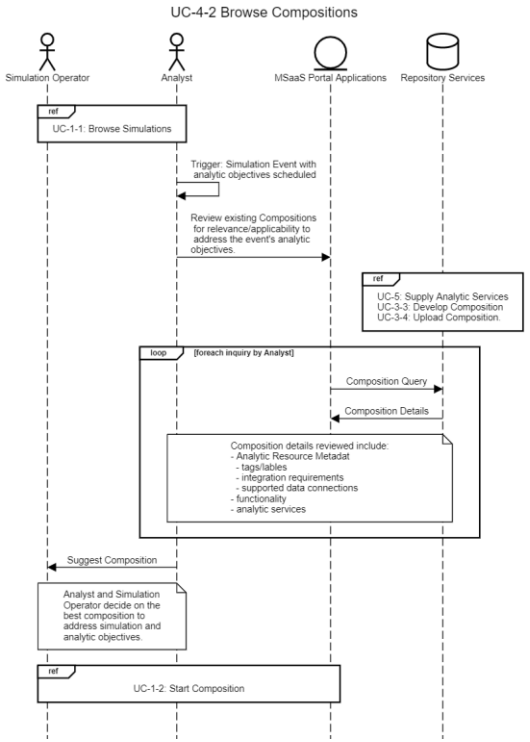
New “Analyze Simulation” Use Case

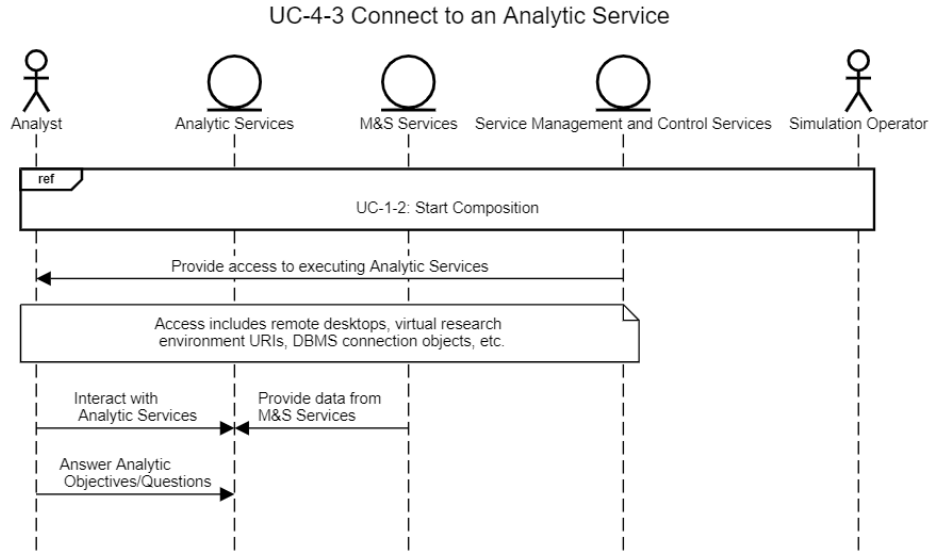


- **With Integrator**
  - Select and integrate analytic services → analytic objectives
  - Supply and register new analytic services
- **With Operator**
  - Browse compositions
- **Conduct analysis and monitor analytics**

Sequence Diagrams



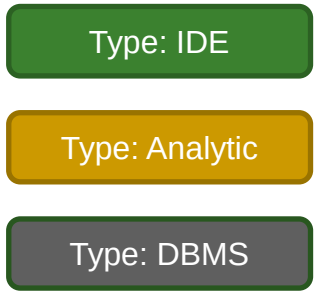




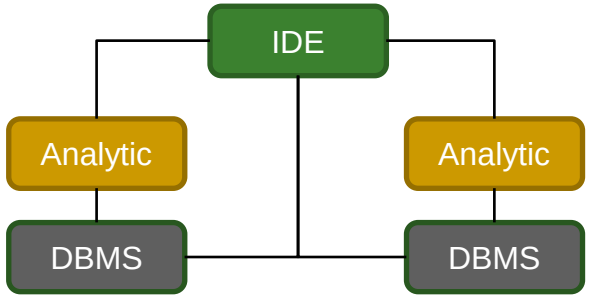
- **Sequence Diagrams show the actors and interactions within use cases.**
- **Further contribution to NATO STO MSaaS efforts.**

Build a Cloud Native Analytic Environment

Applicable Reference Architecture

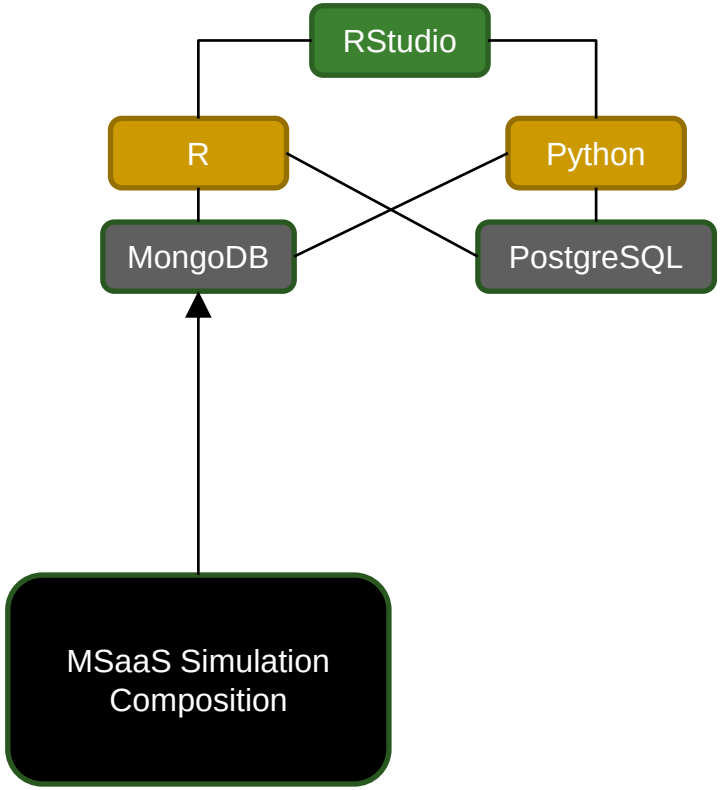


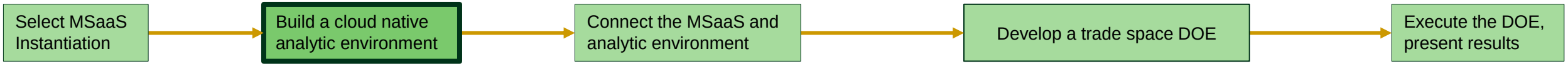
Architectural Building Block Types



Architectural Pattern Types

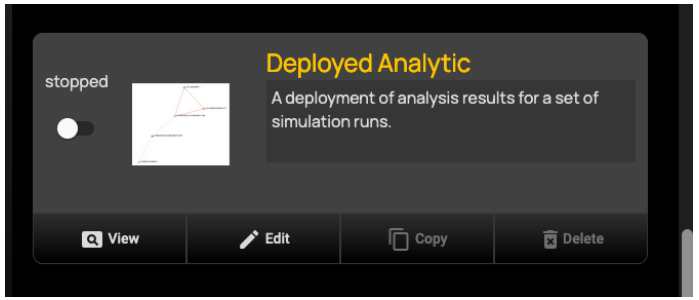
Implemented Architecture

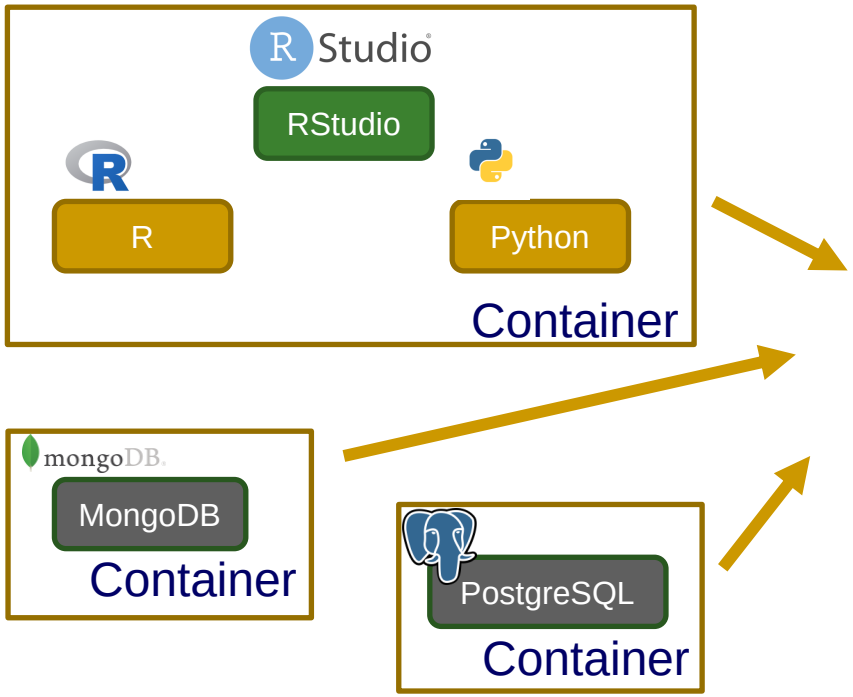




Implementation

1) Tightly bound ABBs built as Software Containers





2) Build

podman

buildah

3) Store

Name / Version tag

dockerhub

4) Integrate

Which & How

HELM

Source code available at:
Helm Chart: https://github.com/nkester/JHU-Thesis-Helm-Chart
Container: https://github.com/nkester/JHU-Thesis-RStudio-Container

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Connect the MSaaS and Analytic Environment

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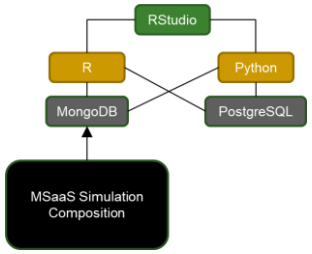

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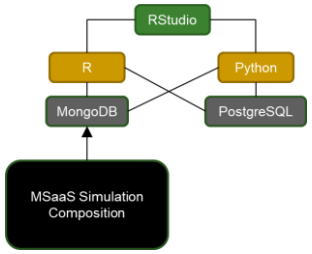

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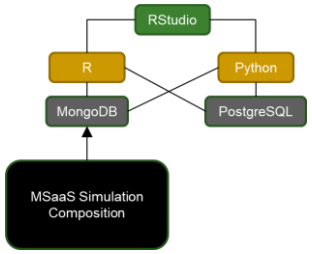
RStudio



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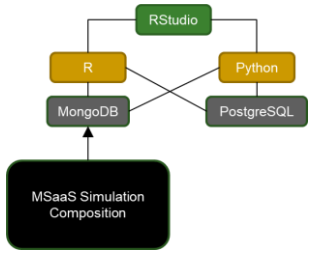

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Input data

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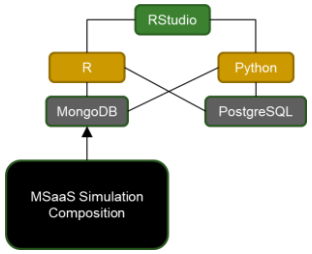

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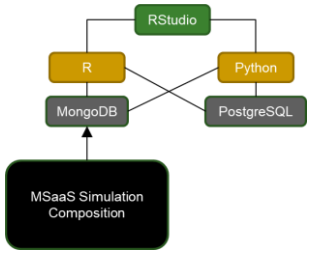
Run Data



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mongoDB.

Run Data

mongoDB.

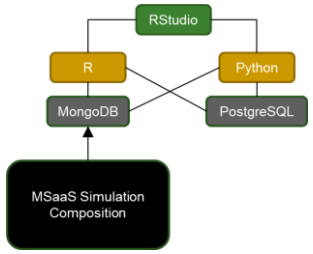
Raw Data

R Studio®

Structured/Tidy Data

Version Control

aws RANCHER



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Challenges Integrating MSaaS with an Analytic Env

- **Interaction between the Analyst and Integrator is important.**
  - Described in the information model.
  - Data structures and formats produced by the MSaaS composition is unique.
  - Documentation, integration, and customization of simulation outputs is important and iterative.

Key:
Goal 1: Extend NATO MSaaS with an Analytic Environment
Goal 2: Execute a simple trade-space analysis

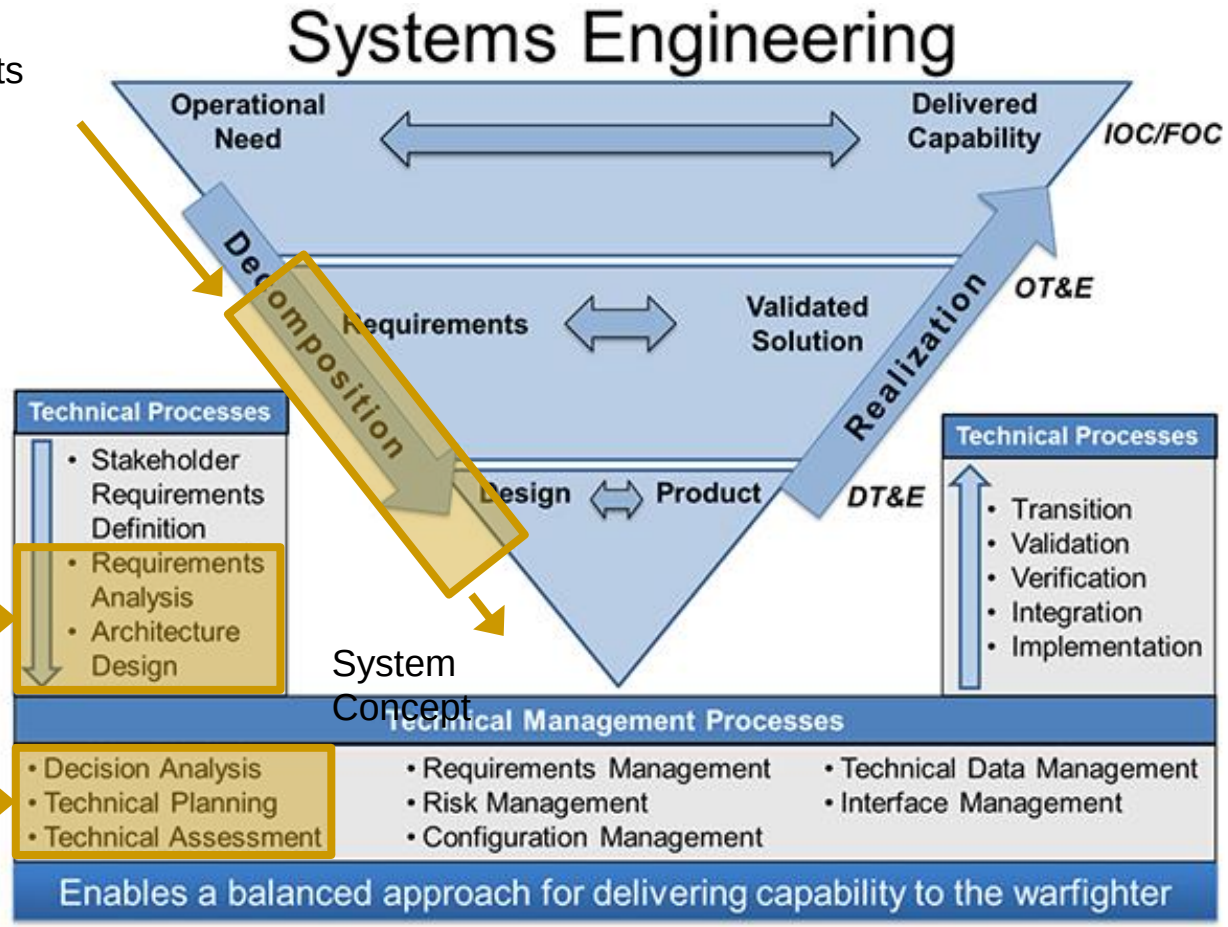
Develop a Trade Space DoE

Operational Requirements
Design Alternatives /
Opportunities

Scope of this research:

- Trade Space Analysis
- M&S to support:
  - Requirements Analysis
  - Architecture Design
  - Analysis of Alternatives

Allows Systems Engineers and Analysts to explore more designs and alternatives



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Design of Experiments Structure

What this is not:

- Not intended to describe a complex DoE or draw meaningful conclusions as to which sensor type is best.

What this is:

- Intended to demonstrate the utility and suitability of this approach to conducting trade-space analysis.
- Performance data is generated using real models and simulations, running with true terrain data, but notional sensors.

Iterations	3

	Light Level	Visibility
Experiment #1	+	+
Experiment # 2	-	-
Experiment # 3	+	-
Experiment # 4	-	+

System Configurations (Sensor Packages)	Description
A	Unaided Human Eyes
B	Night Vision
C	Thermal

Experiment Design

Experiments: Environmental Conditions

Experiment	Light		Visibility		Iterations	Parallel	Run Time (min)
1	+	Clear Daylight	+	Clear	3	3	8
2	-	Clear Moonless Night	-	Hazy	3	3	8
3	+	Clear Daylight	-	Hazy	3	3	8
4	-	Clear Moonless Night	+	Clear	3	3	8

Systems under test

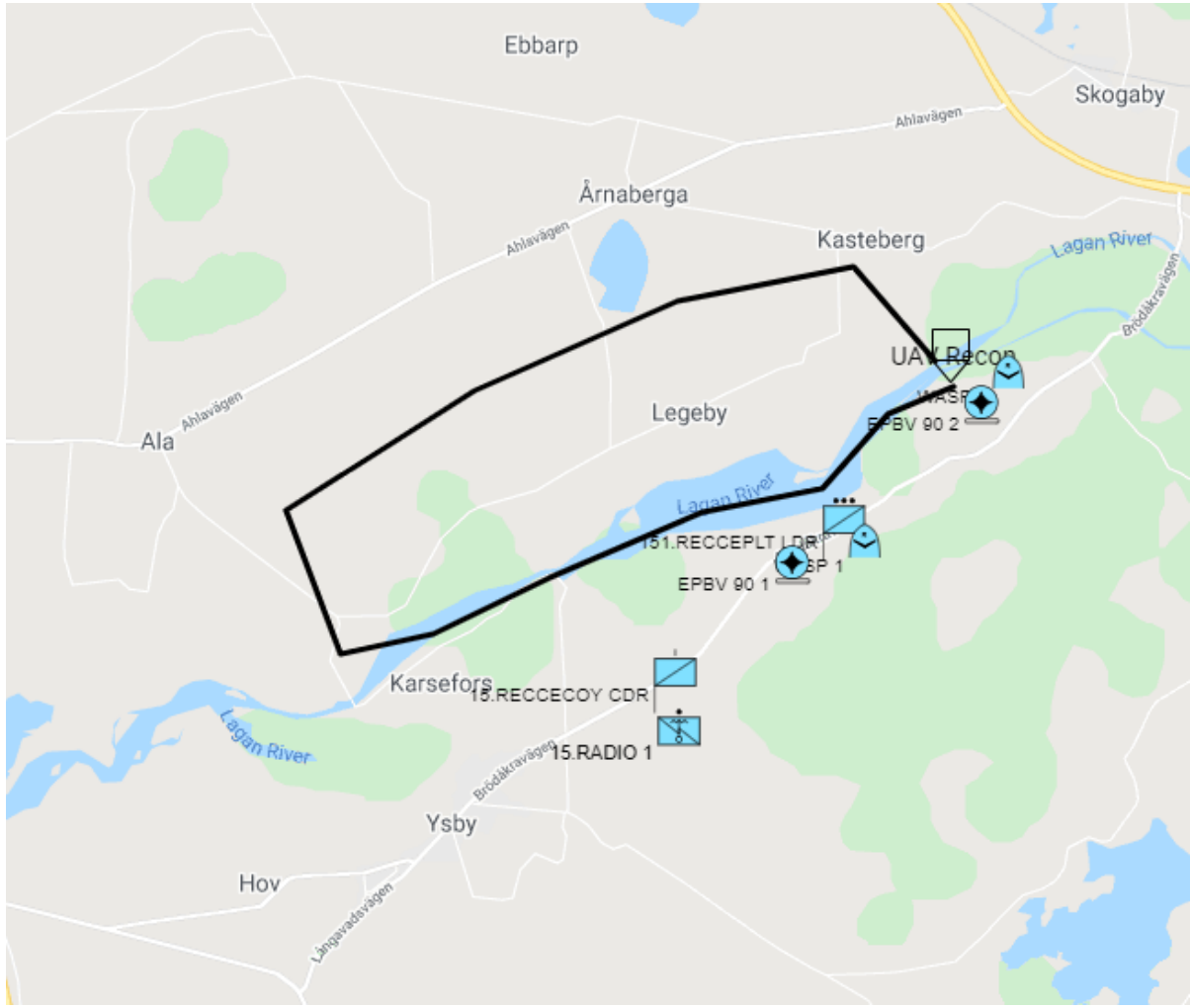
System	Entity	Sensor Package	Day Sight	Night Sight
A	WASP 1	"vehicle passenger"	"eyes"	"eyes"
B	WASP 1	"vehicle commander"	"binoculars"	"nvg"
C	WASP 1	"uav sights"	"heloDaySight"	"hunterFLIR"

Design Points

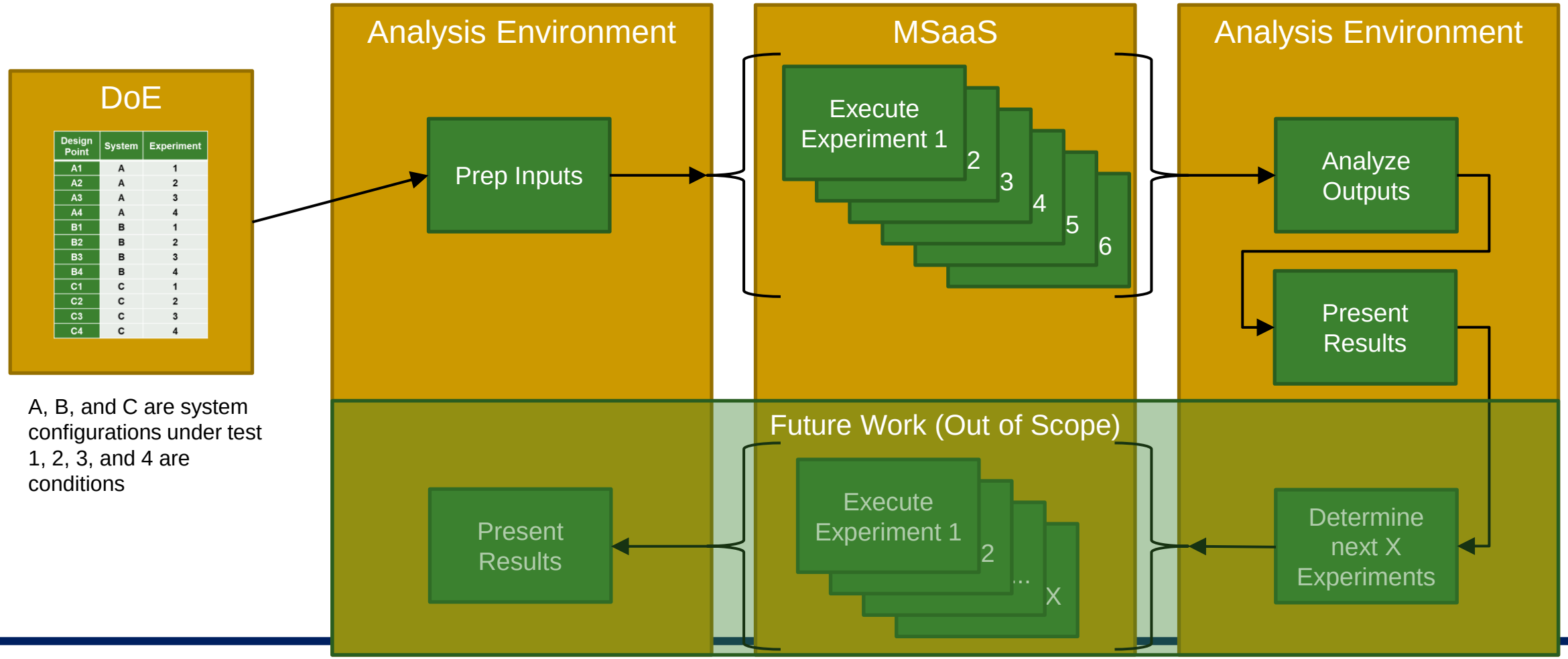
Design Point	System	Experiment
A1	A	1
A2	A	2
A3	A	3
A4	A	4
B1	B	1
B2	B	2
B3	B	3
B4	B	4
C1	C	1
C2	C	2
C3	C	3
C4	C	4

Scenario


Årnaberga
Kasteberg
Lagan River
Ahlavägen
Brödåkravägen
15
BM30 2
BM30 4
Jammer Route
BM30 6
BM30 1
Legeby
Ala
BM30 3
JAMMER 1
EW
BM30 5
Karsefors
Ysby
Hov
Långavadsvägen
Klägstorp
Ålstorp


Ebbarp
Skogaby
Ahlavägen
Årnaberga
Kasteberg
Lagan River
Brödåkravägen
Legeby
Ala
EPBV 90 2
151.RECCEPLT LDR
EPBV 90 1
Karsefors
15.RECCECOY CDR
15.RADIO 1
Ysby
Hov
Långavadsvägen

Execute the DoE and Present Results



- A, B, and C are system configurations under test
- 1, 2, 3, and 4 are conditions

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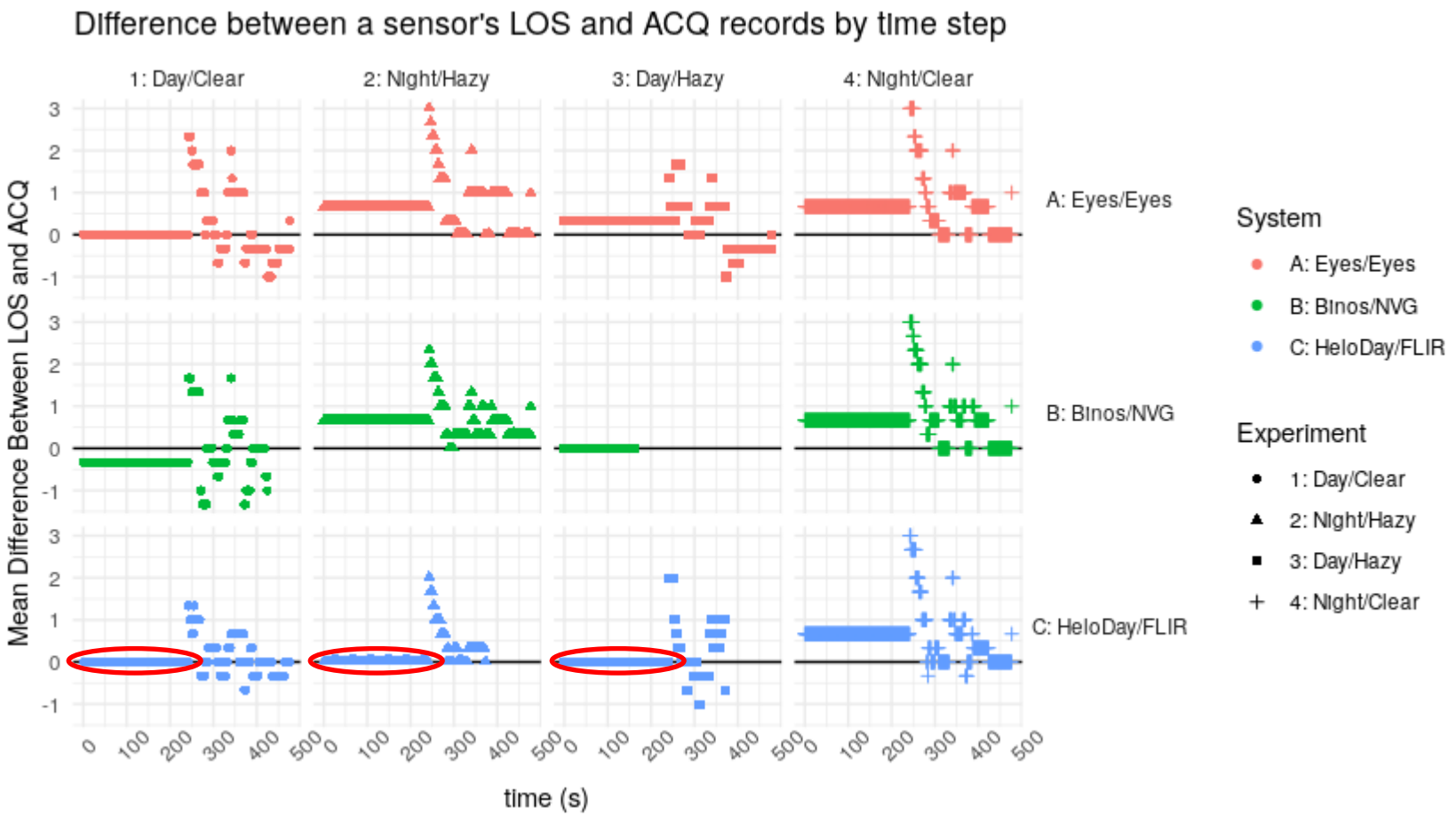
LOS - ACQ by Experiment and System



- **Orientation**
  - Columns = Expr
  - Row = System
  - Y = 0; LOS = ACQ
- **Take Aways**
  - Sys C consistently shows Diff = 0 across expriments. Conclude Sys C is more robust.*
- **Anomalies**
  - ACQ > LOS
    - Likely acquisition by multiple sensors on a vehicle.
  - Experiment 4 shows no change??

Source Code: https://github.com/nkester/modSim

* Statistical significance not tested

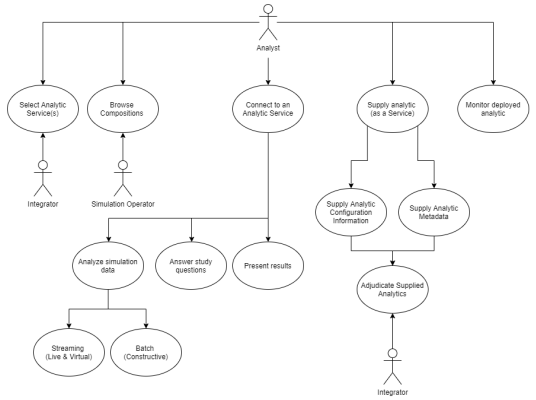
CONCLUSION

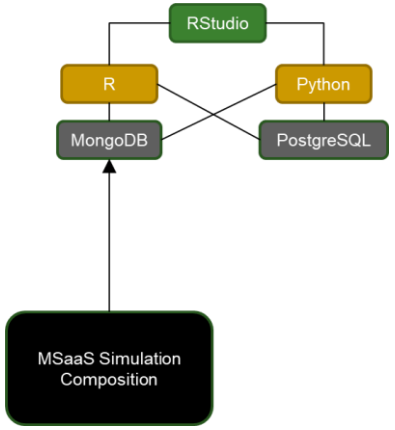
The “Why”

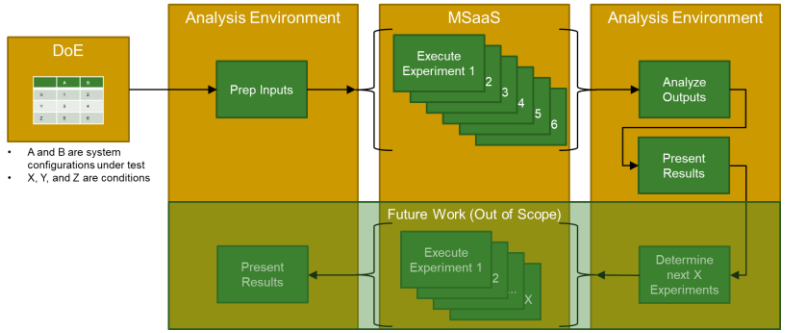
- **Problem**
  - The NATO STO Allied M&S as a Service Framework lacks an integrated analytic framework capable of supporting concept development and analysis of possible alternatives in procurement decisions.
- **Hypothesis**
  - A NATO MSaaS instance, integrated with an analytic environment, is suitable to support trade-space analysis by measuring the robustness of military systems.

The “So”

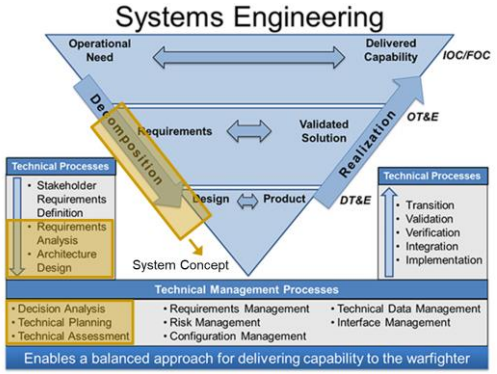
- **Goal 1:** Extend a NATO MSaaS framework with an analytic environment.

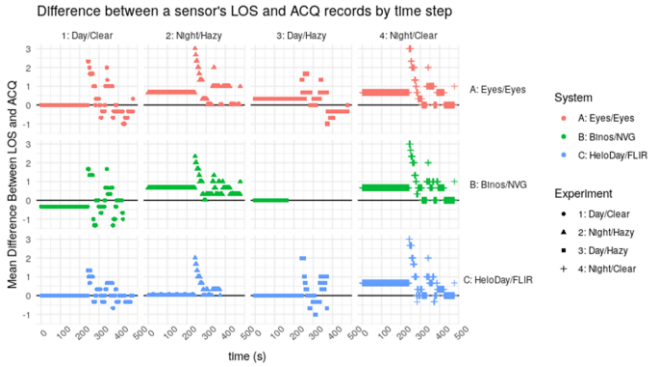






- **Goal 2:** Execute a simple trade-space analysis using an existing NATO MSaaS scenario.





Sensor C is best

The “So What”

- Successfully integrated a cloud based analytic environment with a NATO MSaaS instance.
- Demonstrated the ability to execute trade-space analyses using MSaaS and the analytic environment.
- Described how the scalability and modularity of MSaaS makes it suitable for this type of application.

Hypothesis:

A NATO MSaaS instance,

integrated with an analytic environment,

is suitable to support trade-space analysis

by measuring the robustness of military systems.

Potential Conferences and Journals:

1) *INFORMS Journal on Computing*

Applicable Areas: 1) Modeling: Methods and Analysis, 2) Simulation, 3) Software Tools

2) Journal of Defense Modeling and Simulation
3) Military Operations Research Journal
4) IEEE Systems Journal
5) NATO M&S as a Service Lecture Series

QUESTIONS