

Using **Conceptual Model Based Systems Engineering [MBSE]** to Increase the Effectiveness of System Acquisitions

National Defense Industrial Association [NDIA]

18th Annual Systems Engineering Conference – Track 2 Modeling & Simulation [Session 17905]
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ACKNOWLEDGMENTS

- **Eric C. Honour, PhD, CSEP**: "DANSE – Final Report on SoS Methodology and Tools", INCOSE SoS WG Series, June 26, 2015, Eric Honour
- **Garry Roedler**: "Iteration and Recursion", Systems Engineering Handbook , Fourth Edition, Figure 3.5, Garry Roedler
- **John O. Clark, CSEP, MSEE**: "SoSE from the SE Standards, INCOSE SE Handbook, and Dual V-Model Perspective", INCOSE Webinar 72, Feb 18, 2015, John Clark
- **Dr Kevin Forsberg**: Dual V-Model, The Center for Systems Management (CSM) Inc., Kevin Forsberg and Harald Mooz
- **L. Mark Walker, ESEP**: "Model Based Systems Engineering Initial Stages, Get It Right in the First Stages" Presented at INCOSE IS2015, Mark Walker
- **INCOSE**: Systems Engineering Handbook, Third & Fourth Edition

PROGRESS

➤ **Problem Statement**

- Individual System Acquisition in System of Systems Environments

➤ **Objectives**

- Increasing the Effectiveness of System Acquisitions

➤ **Offered Solution: Conceptual MBSE**

- Basis: SoS-VEE Model™
- MBSE Building Block
- MBSE Example

➤ **Proof of Concept**

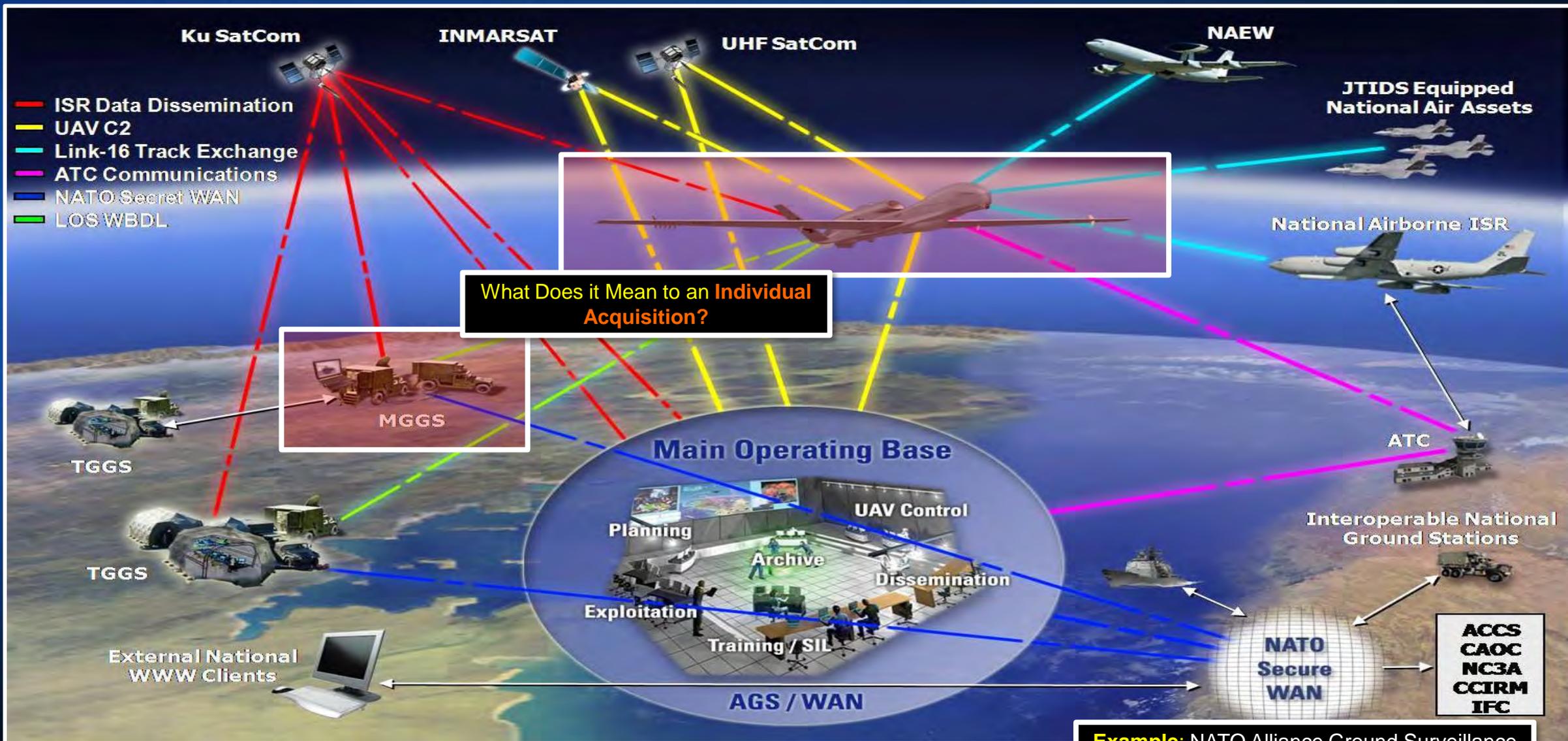
- Application to UAV in NATO AGS System

➤ **Summary**

- What Does it Mean to You

PROBLEM STATEMENT

STOVEPIPED ACQUISITIONS IN COMPLEX SYSTEM OF SYSTEM ENVIRONMENTS



Example: NATO Alliance Ground Surveillance (AGS) System

PROBLEM STATEMENT (CONT'D)

PROBLEM STATEMENT CHALLENGES OF STOVEPIPED ACQUISITIONS (CONT'D)

Bundeswehr: New machine gun MG5 makes problems

Sep 12, 2015 Panteres

The new machine gun the army causes problems: According to information obtained by SPIEGEL, the MG5 does not fit the guns of tanks and all-terrain vehicles. The conversion will cost millions.

Source: <http://panteres.com/2015/09/12/bundeswehr-new-machine-gun-mg5-makes-problems>

Bundeswehr: Neues Maschinengewehr MG5 passt nicht auf Panzer



New MG5 Does Not Fit MG3 Gun-Mount (Interface with Existing Tanks & ATVs)

Bundeswehrsoldat im Manöver: Neues Problemgewehr

Getty Images

Auch das neue Maschinengewehr der Bundeswehr bereitet Probleme: Laut Informationen des SPIEGEL passt das MG5 nicht auf die Lafetten von Panzern und Geländefahrzeugen. Die Umrüstung kostet Millionen.



MGG5

PROBLEM STATEMENT CHALLENGES OF STOVEPIPED ACQUISITIONS (CONT'D)

Germany axes Euro Hawk drone program

May 14, 2013 - 01:00PM | By AGENCE FRANCE-PRESSE | Comments

FILED UNDER

World News
Europe

BERLIN — Germany has canceled a planned "Euro Hawk" drone program over fears that European authorities will not certify them, a defense ministry source said Tuesday after reported European safety concerns.

German Euro Hawk Drone Cancelled

Germany had "no hope" of seeing the unmanned aircraft, part of a program that would have cost more than €1 billion (US \$1.3 billion), approved for use, said the source, speaking on condition of anonymity.

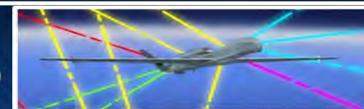
Lack of Anti-Collision System (Interface with Civilian Air Traffic Control)

The European Aviation Safety Agency has said it would certify the drones only to fly over unpopulated areas because of a lack of an anti-collision system to protect airliners, according to German press reports.

"The equipment is not ready for approval without immense expenditure," the source added.

Germany has already spent €508 million on a Euro Hawk prototype and was due to fork out a further €500 million on four more models.

Equivalent (in %) of ca. \$10 Billion Compared to US DoD Budget

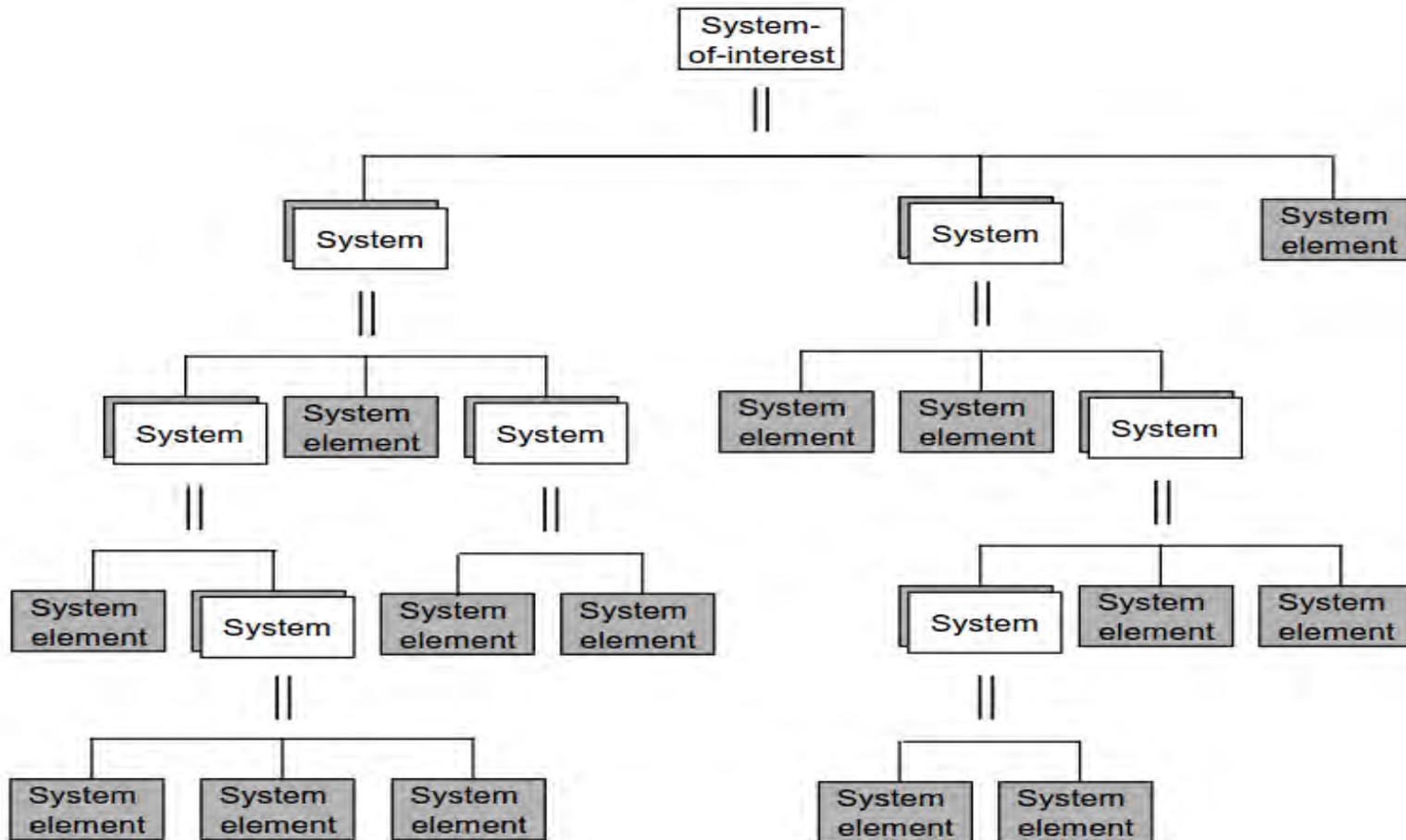
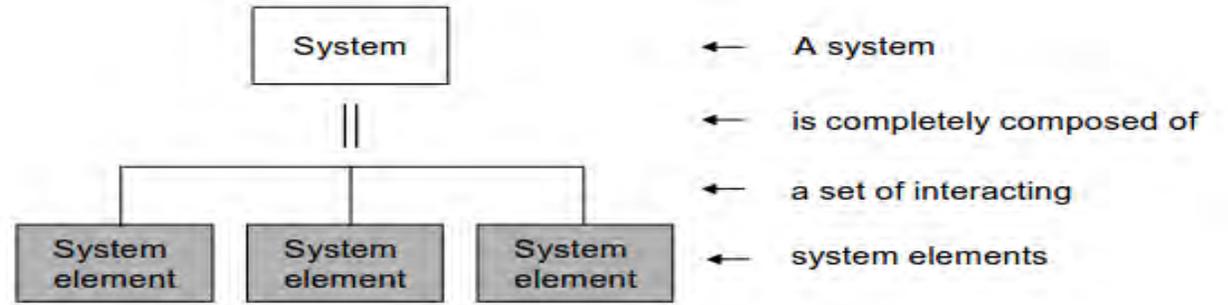


Source: The Pentagon Wars <https://www.youtube.com/watch?v=iDYpRhoZqBY>

SYSTEM OF SYSTEMS

THE BASICS

Hierarchy within a System
(Source: ISO/IEC 15288)

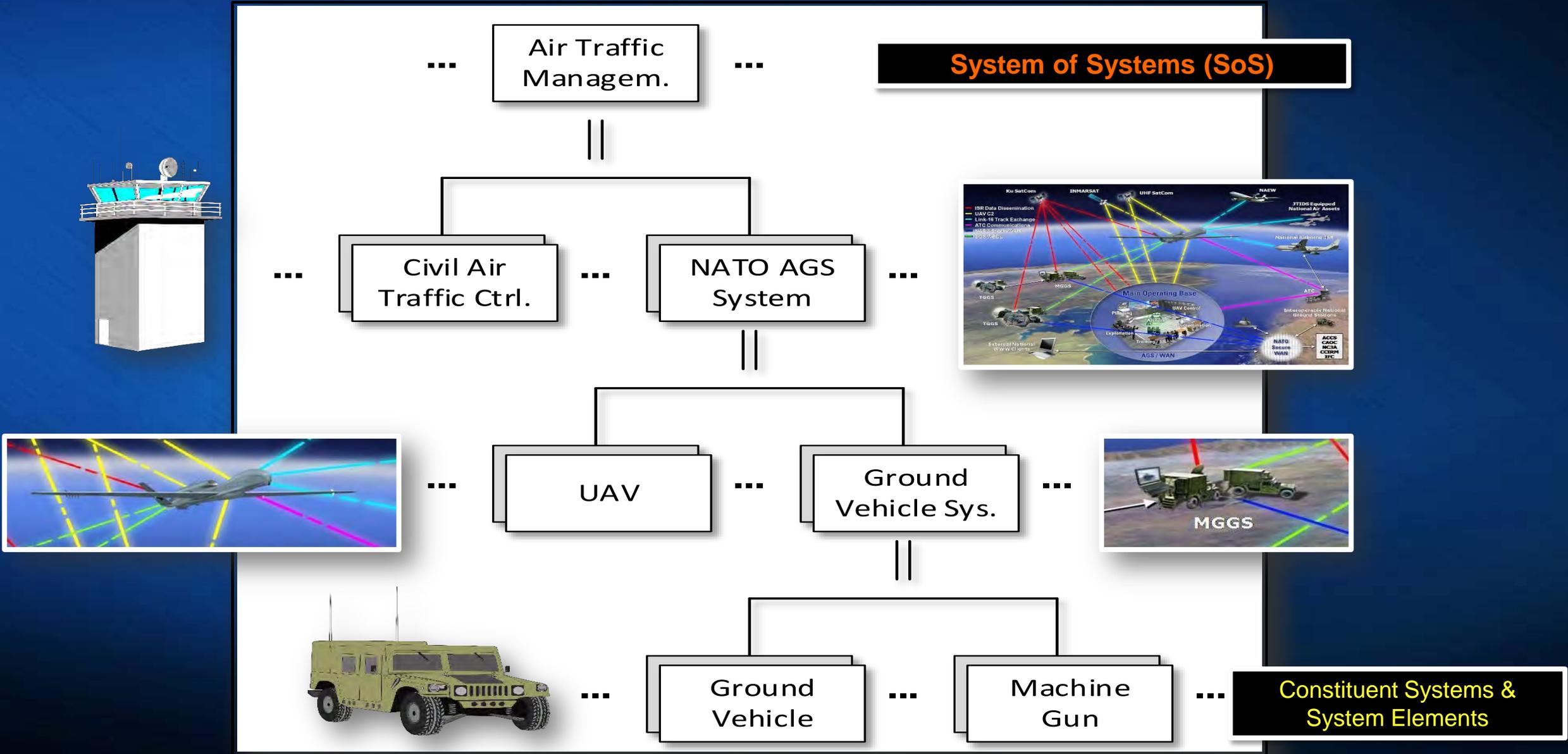


“Systems-of-Systems” (SoS) are systems-of-interest whose system elements are themselves systems, typically these entail large-scale interdisciplinary problems involving multiple, heterogeneous, distributed systems. These interoperating collections of component systems usually produce results unachievable by the individual systems alone. (Source: SE Handbook 3.2.2, Section 2.5 Systems-of-Systems).



PROBLEM STATEMENT

NATO AGS SYSTEM PRESENTED AS A SYSTEM OF SYSTEMS



CHALLENGES OF SYSTEM OF SYSTEMS ENGINEERING (SoSE)

SoS CHALLENGES AS DEFINED BY JOHN CLARK



What is Different About SoSE?

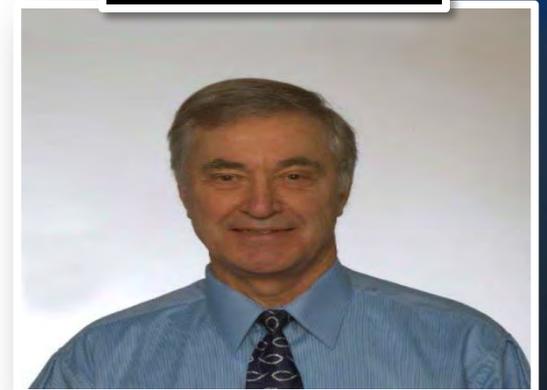


– My Perspective

J Clark

- ❖ The management (e.g., acquisition) processes are inadequate, not the technical (SE Standards) processes:
 - There is no god (no overall Program Manager) of a SoS (Dr Larry Pulman)
 - Acquisitions are stovepipes (single systems, not SoS)
 - Systems are directed to “integrate” with other systems, often after fielding
 - Suppliers don’t cooperate with each other (they believe it’s not in their best interest)
 - Acquirers don’t cooperate with each other for the same reason
 - SoS costs more up-front to develop (but saves much more later)
 - Interoperability is hampered by lack of SoSE

John Clark



UNDESIRABLE OUTCOMES

RESULTS OF STOVEPIPING OR SILO ENGINEERING



Source: http://i81.photobucket.com/albums/j236/dimitri_the_pirate/RedneckCarAirConditioner.jpg

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➤ Objectives

- Increasing the Effectiveness of System Acquisitions

➤ Offered Solution: Conceptual MBSE

- Basis: SoS-VEE Model™
- MBSE Building Block
- MBSE Example

➤ Proof of Concept

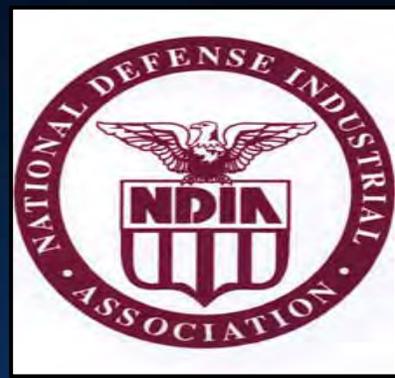
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➤ Summary

- What Does it Mean to You

OBJECTIVES

INCREASING THE EFFECTIVENESS OF SYSTEM ACQUISITIONS



ANNOUNCEMENT

A major conference focusing on improving acquisition and performance of Defense programs and systems, including net-centric operations and data/information interoperability, system - of - systems engineering and all aspects of system sustainment, will be convened in Fall of 2015. This conference is sponsored by the National Defense Industrial Association, Systems Engineering Division, with technical co-sponsorship by IEEE AES, IEEE Systems Council and the International Council on Systems Engineering, and is supported by the Office of the Deputy Assistant Secretary Defense for Systems Engineering in the Office of Under Secretary of Defense for Acquisition, Technology and Logistics and Office of the DoD Information Officer.

Improving Acquisition and Performance of Defense Programs & Systems

BACKGROUND

The Department of Defense continues to seek ways to improve the acquisition of military equipment and capability to assist the warfighter in protecting the U.S. and its allies, and help oppressed nations around the world in a complex environment of ever-changing threats and conditions. The Weapon Systems Acquisition Reform Act (WSARA) of 2009 defines Systems Engineering as a key player in helping effect improvements in defense acquisition and program execution, to achieve more effective and affordable military systems. Better Buying Power provided guidance on increasing efficiencies to “do more, without more”. Systems Engineering is the “umbrella” engineering function that serves as the key integrating function for these initiatives and successful program execution and helping maintain the balance between requirements, performance, cost, schedule, and overall effectiveness and affordability. Systems Engineering principles embody strong technical and risk/

Improve the Acquisition of Military Equipment

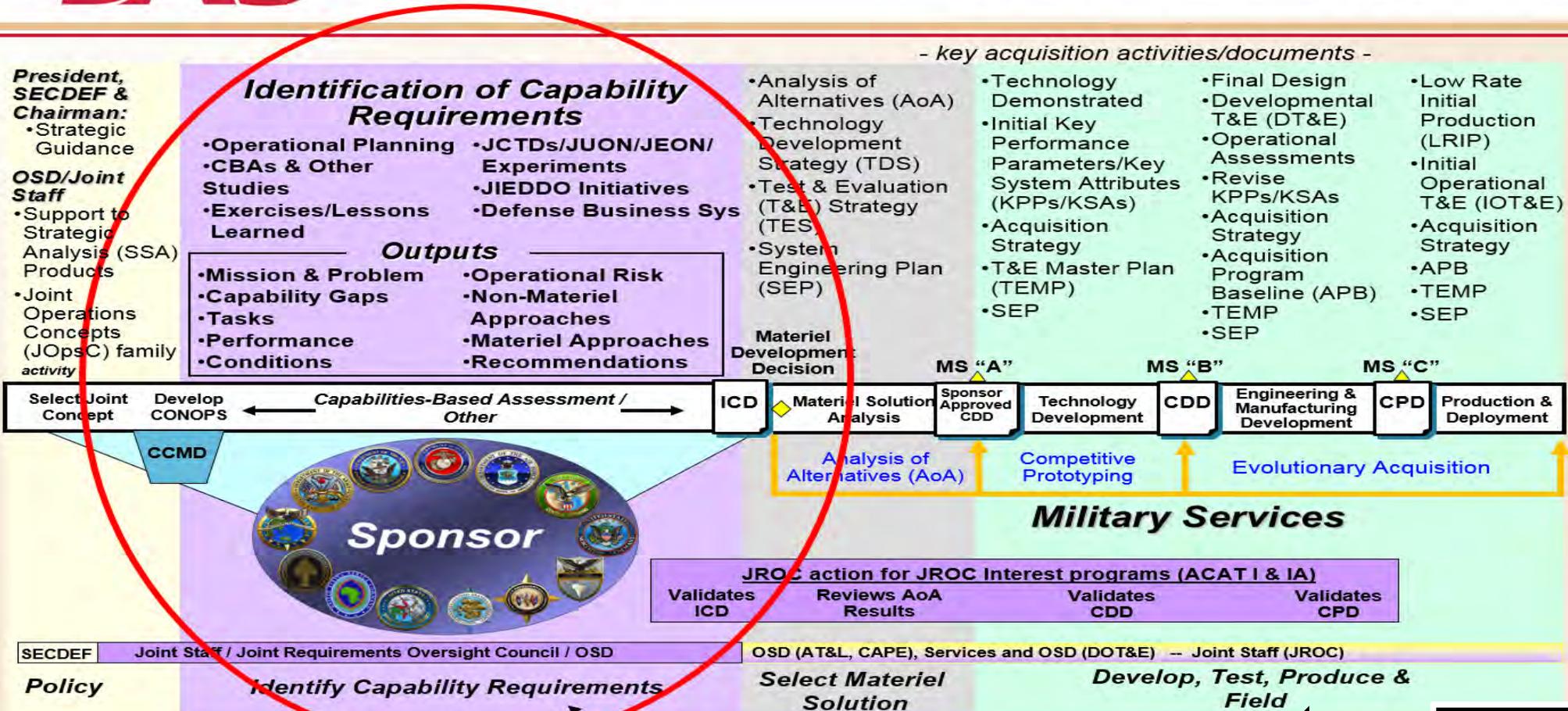
OBJECTIVES

GETTING IT RIGHT FROM THE BEGINNING

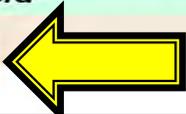
Joint Capabilities Integration Development System (JCIDS)



JCIDS and Acquisition



Getting the Front End Right is Key

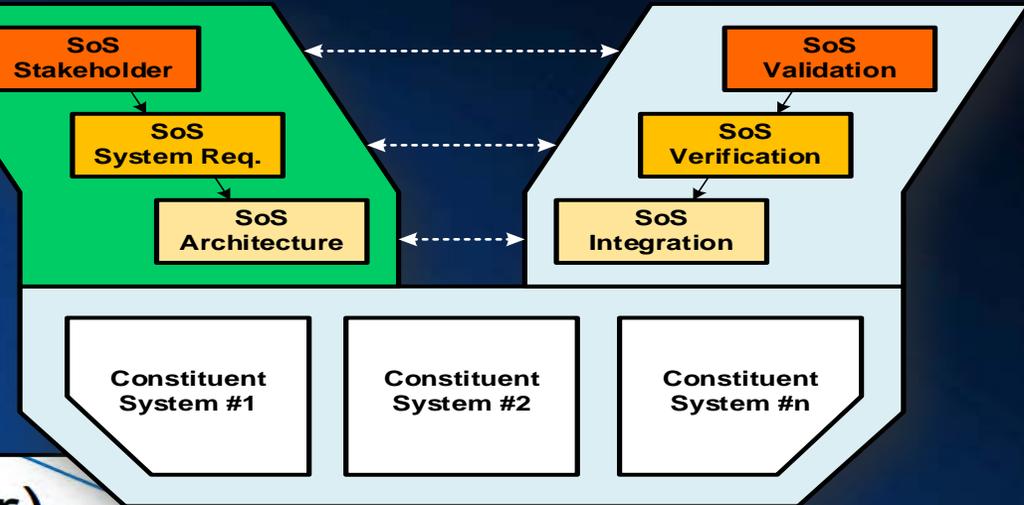


Getting it Right from the Beginning

OBJECTIVES

GETTING IT RIGHT IN THE FIRST STAGES*

Transitioning between Teams



Problem Statement (Purpose for Paper)-
Lack of Emphasis/Understanding of:



- **System Use Cases development with the Stakeholders/Users**
- **What should be done prior to a Request For Proposal**
 - And must be done first after receiving an RFP
- **Transitioning Knowledge/Info between 3 Teams:**
 - Pre-Development, Development, Operational Support Teams
- **Operational Concept Documents Critical Importance**
- **Establishing the First Baseline Products (Pre- RFP)**
- **The Method used to Implement MBSE and SysML, etc.**
 - Object Oriented Systems Engineering Method (OOSEM)

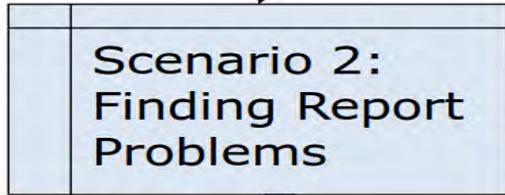
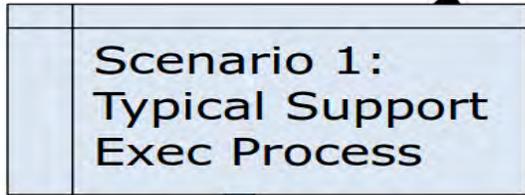
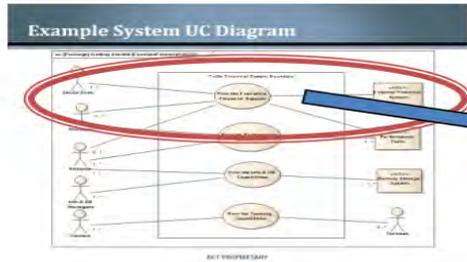
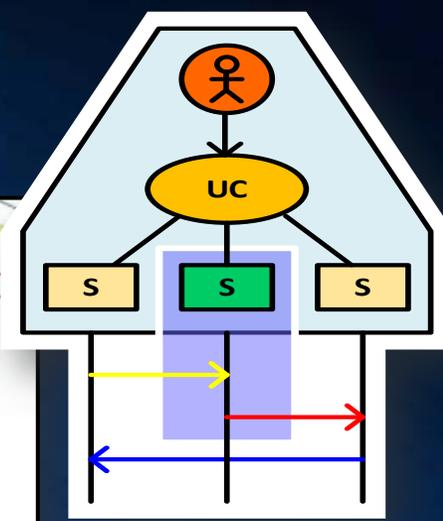
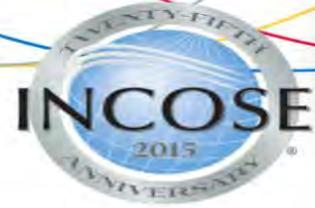


L. Mark Walker

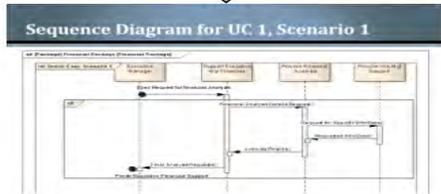
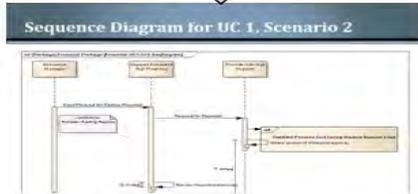
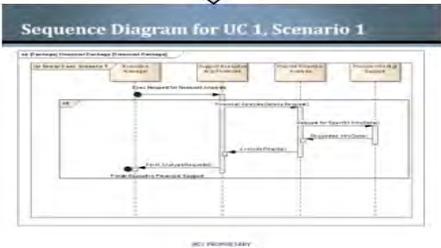
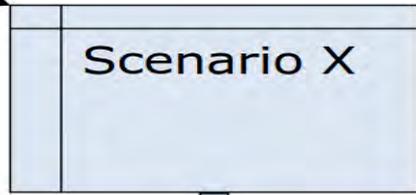
PROOF OF CONCEPT

GETTING IT RIGHT IN THE FIRST STAGES* (CONT'D)

SysUC, Scenarios and Sequence Diagrams



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Mark's paper emphasizes the critical importance of an integrated architecture being developed along with (in parallel) with requirements development and analysis.

We make you look good because we do it right the first time.

PROGRESS

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- Basis: SoS-VEE Model™
- MBSE Building Block
- MBSE Example

➤ Proof of Concept

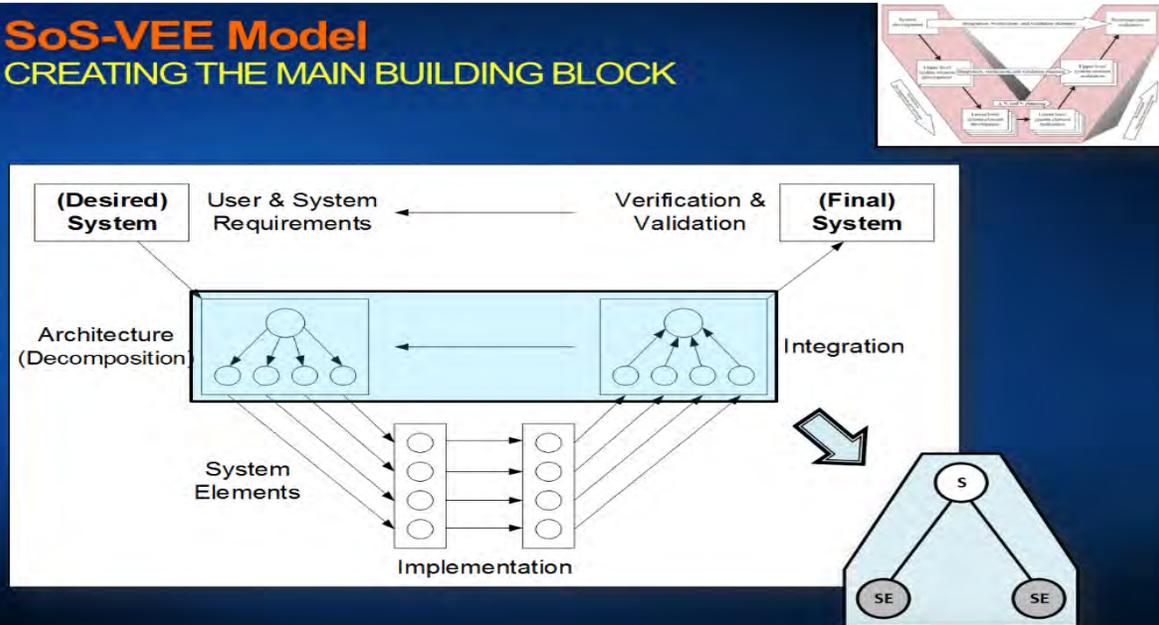
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➤ Summary

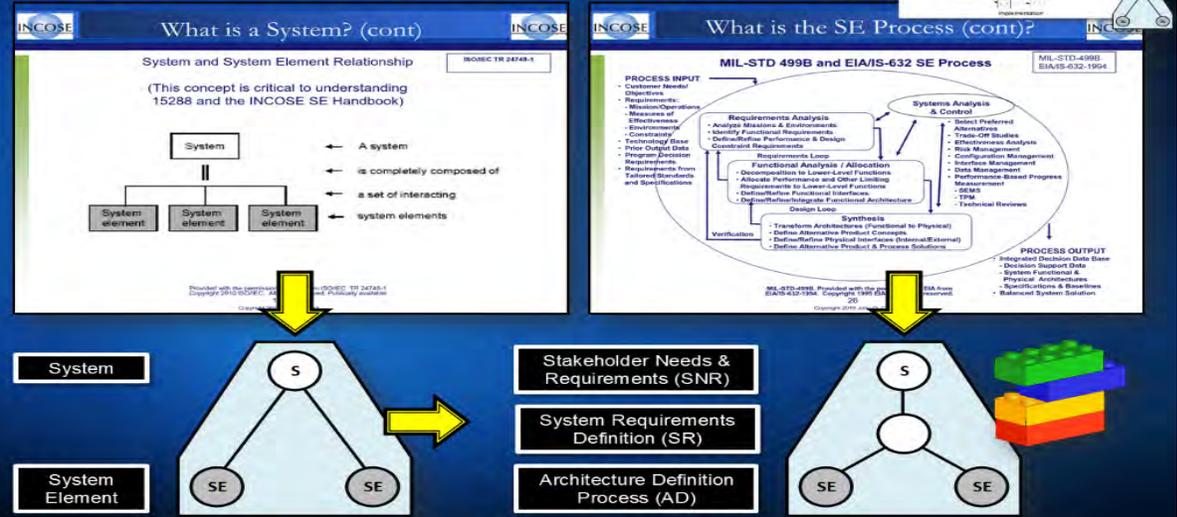
- What Does it Mean to You

CONCEPTUAL MBSE: SoS-VEE Model (Recap)

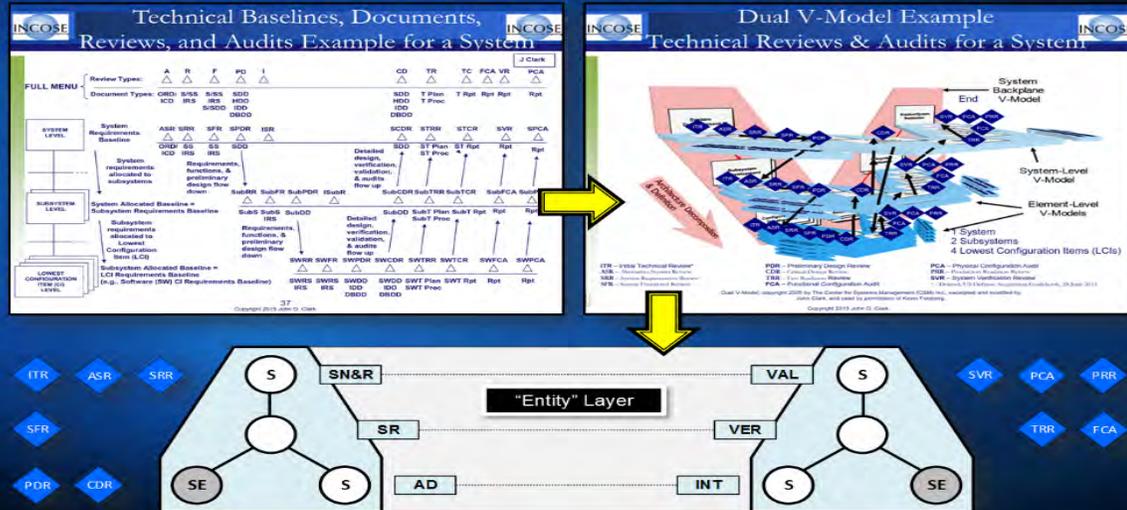
SoS-VEE Model CREATING THE MAIN BUILDING BLOCK



SoS-VEE Model CREATING THE MAIN BUILDING BLOCK (CONT'D)

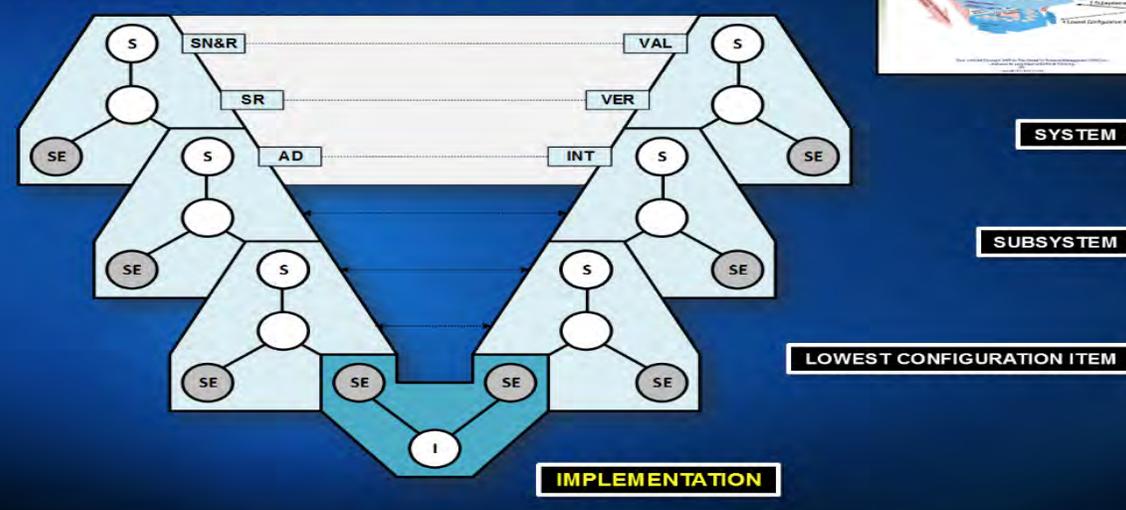


SoS-VEE Model ASSIGN REVIEW AND AUDIT MILESTONES



*Source: "SoSE from the SE Standards, INCOSE SE Handbook, and Dual V-Model Perspective", INCOSE Webinar 72, Feb 18, 2015, John Clark

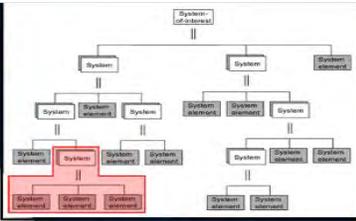
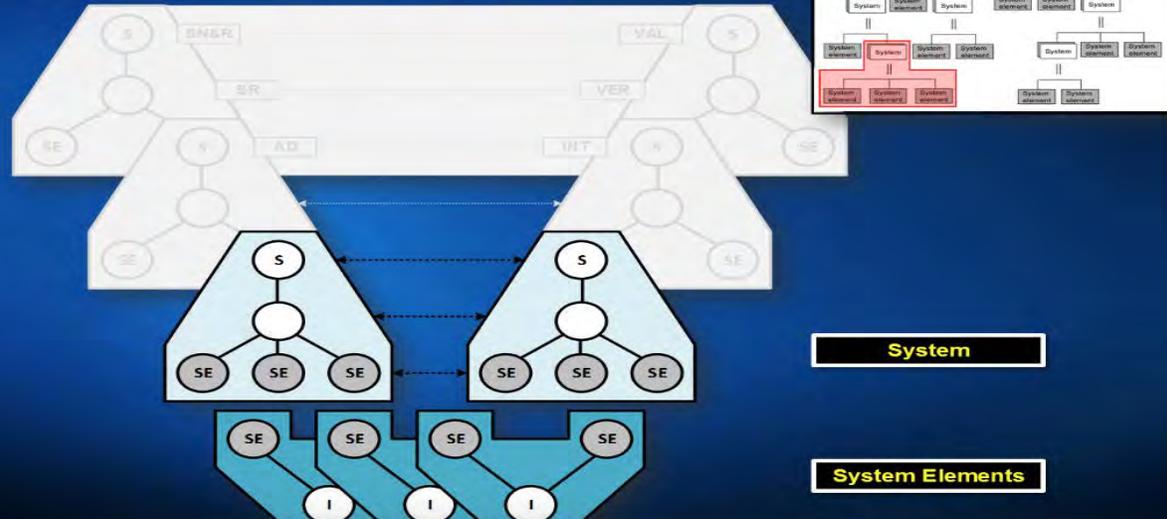
SoS-VEE Model IMPLEMENTING SYSTEM ELEMENTS



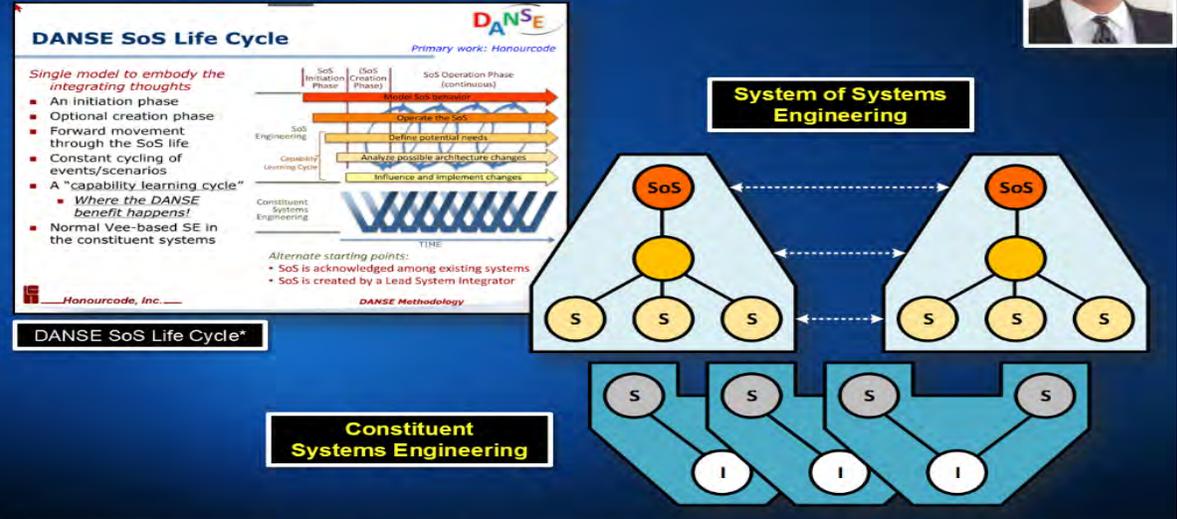
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CONCEPTUAL MBSE: SoS-VEE Model (Recap)

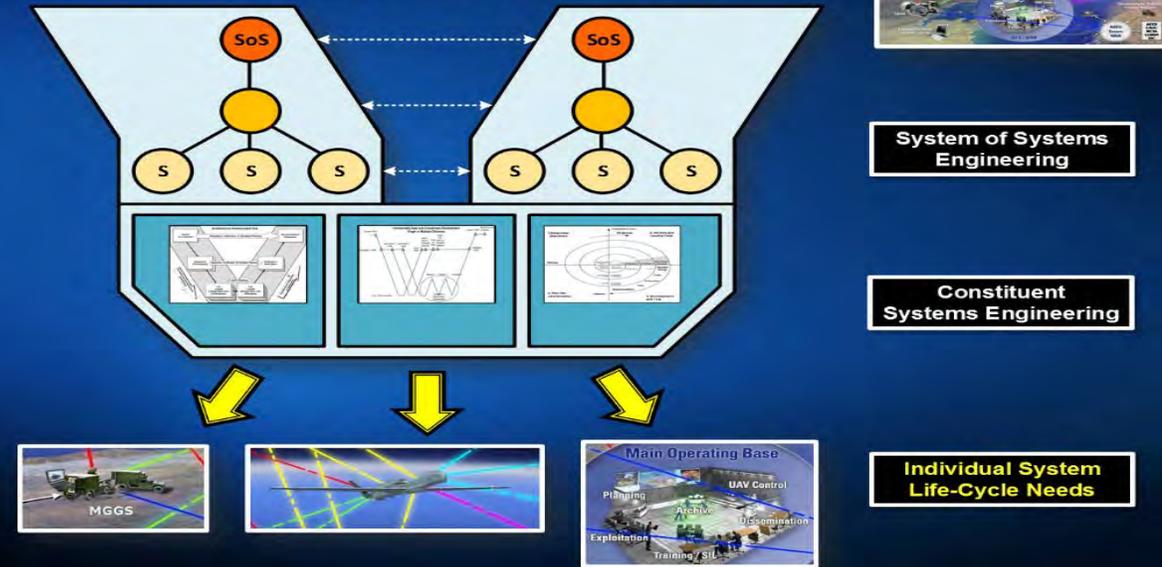
SoS-VEE Model SYSTEM WITH SEVERAL SYSTEM ELEMENTS



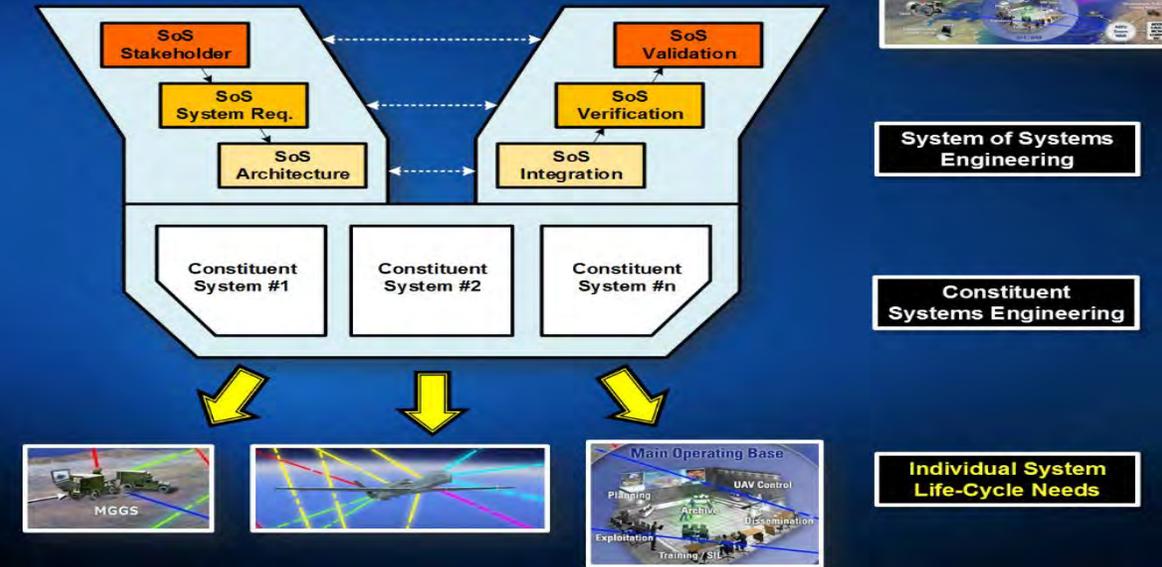
SoS-VEE Model DANSE SoS LIFE CYCLE vs. SoS-VEE



SoS-VEE Model INDIVIDUAL SYSTEM LIFE CYCLE NEEDS

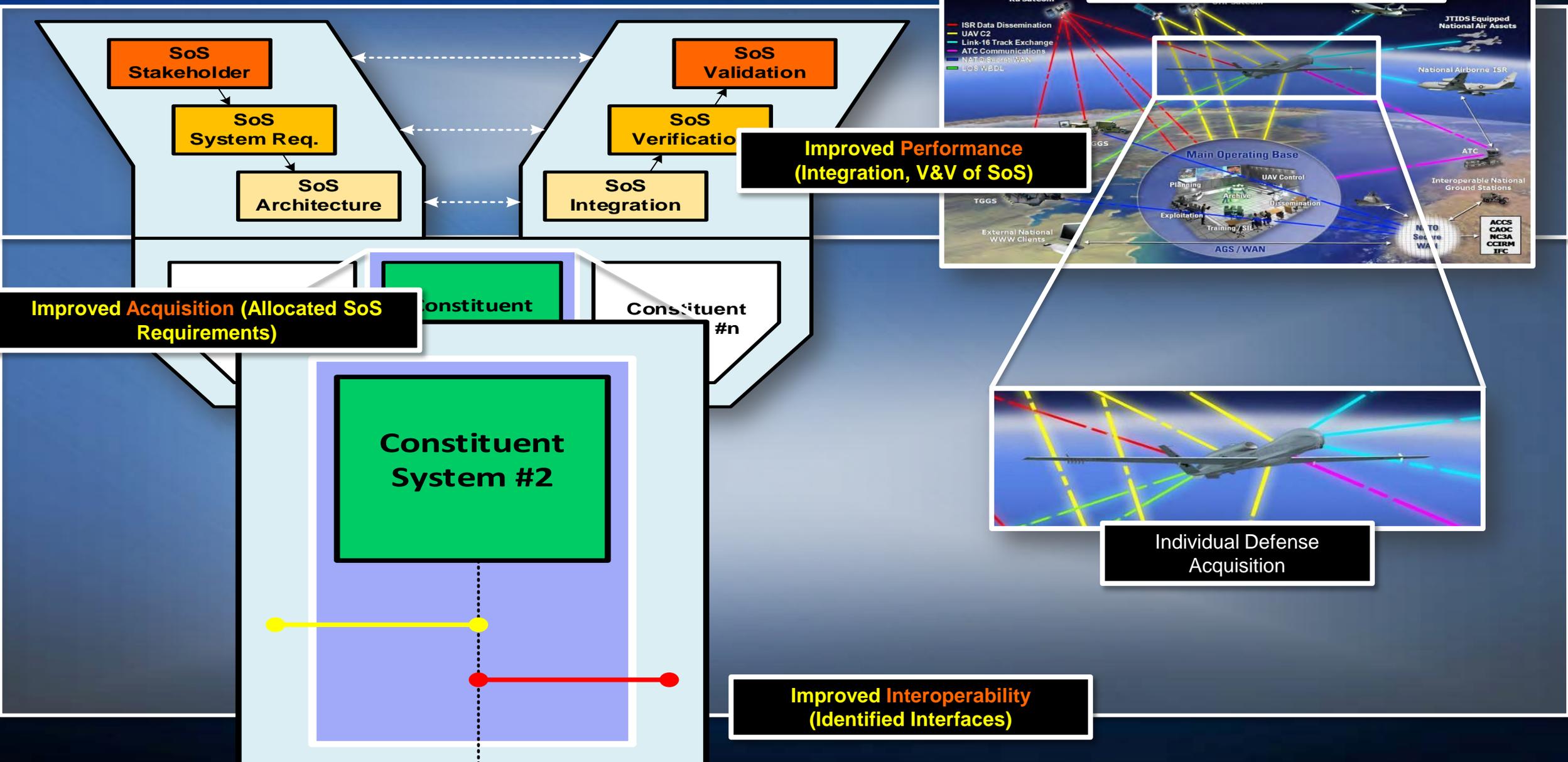


SoS-VEE Model INDIVIDUAL SYSTEM LIFE CYCLE NEEDS



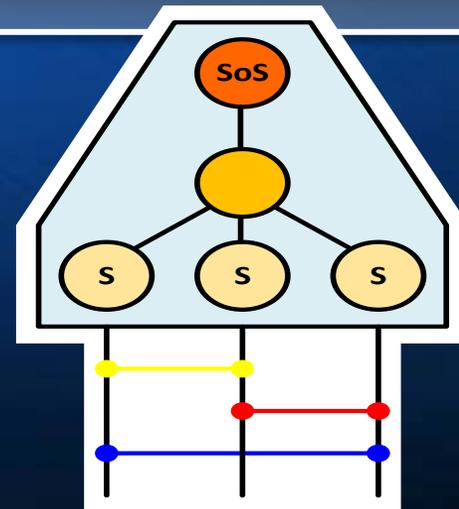
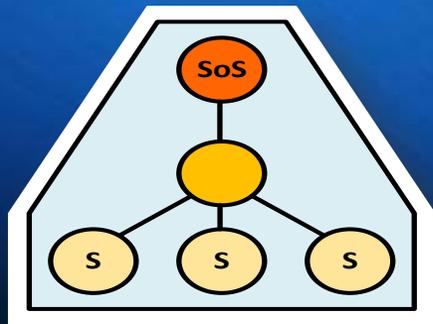
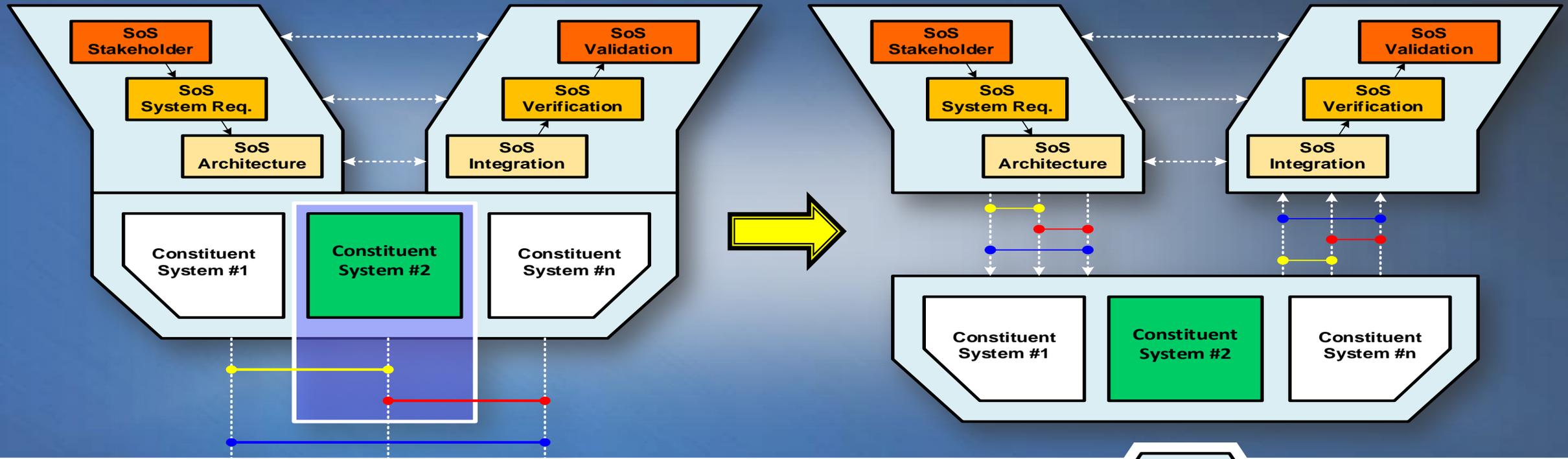
CONCEPTUAL MBSE

SE VS. SoSE USING SoS-VEE MODEL



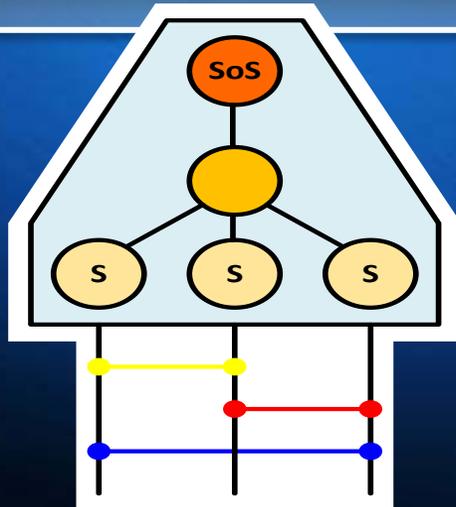
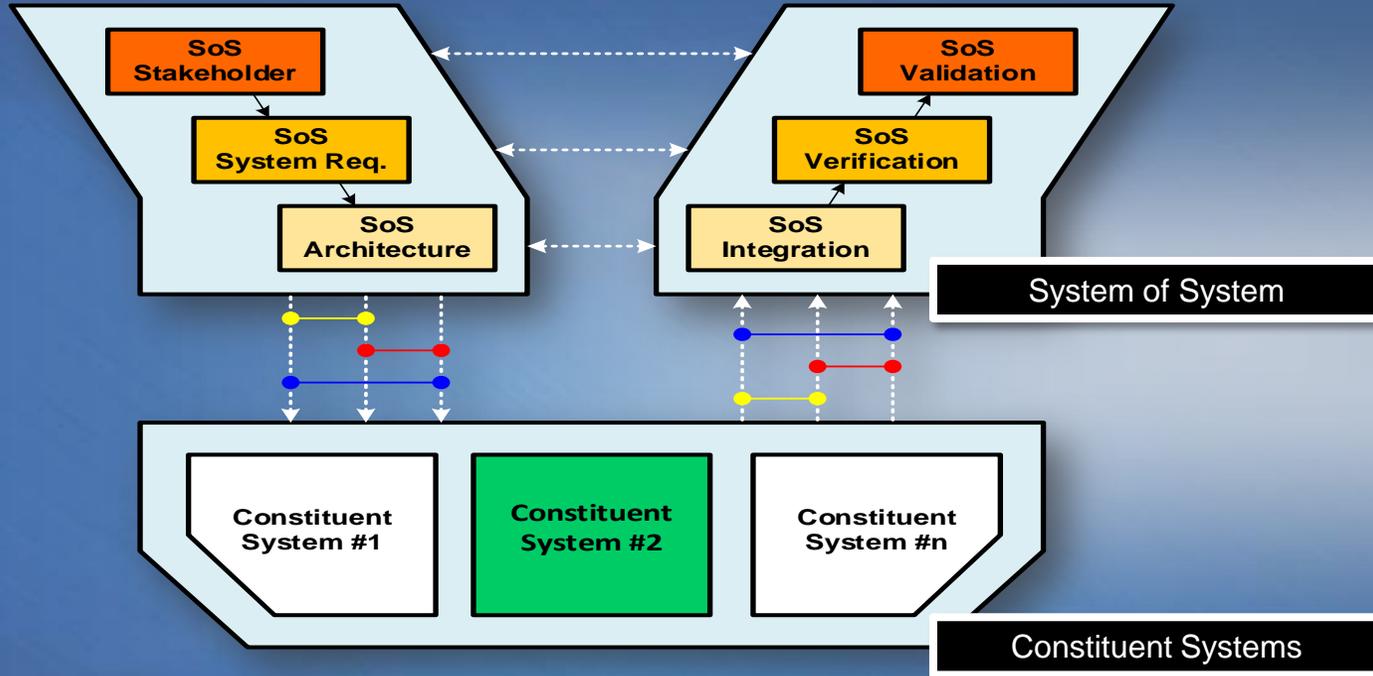
CONCEPTUAL MBSE

TRANSITIONING TO MBSE

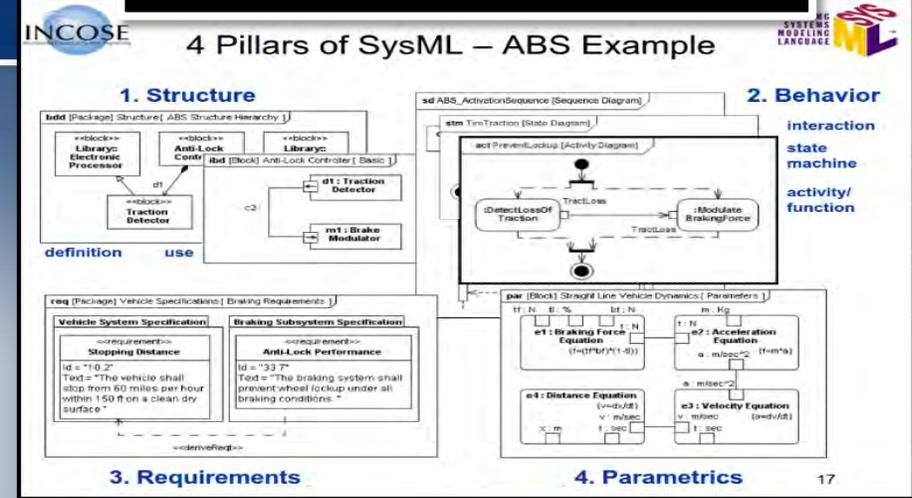


CONCEPTUAL MBSE

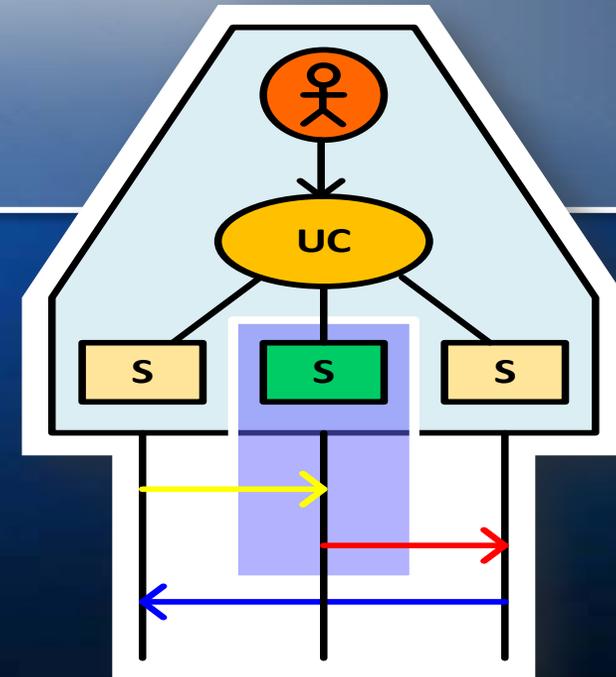
CREATING THE MBSE BUILDING BLOCK



Modeling of System of Systems to Define Constituent System Requirements and Interfaces



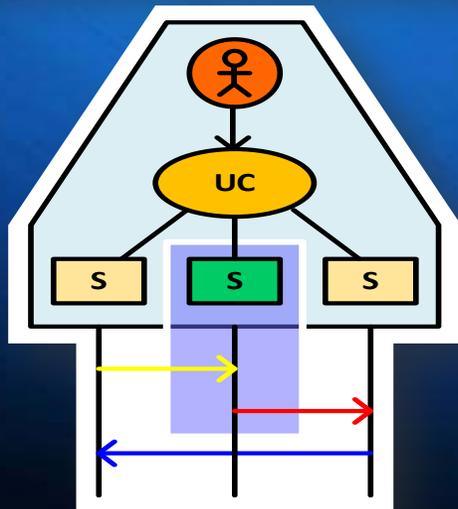
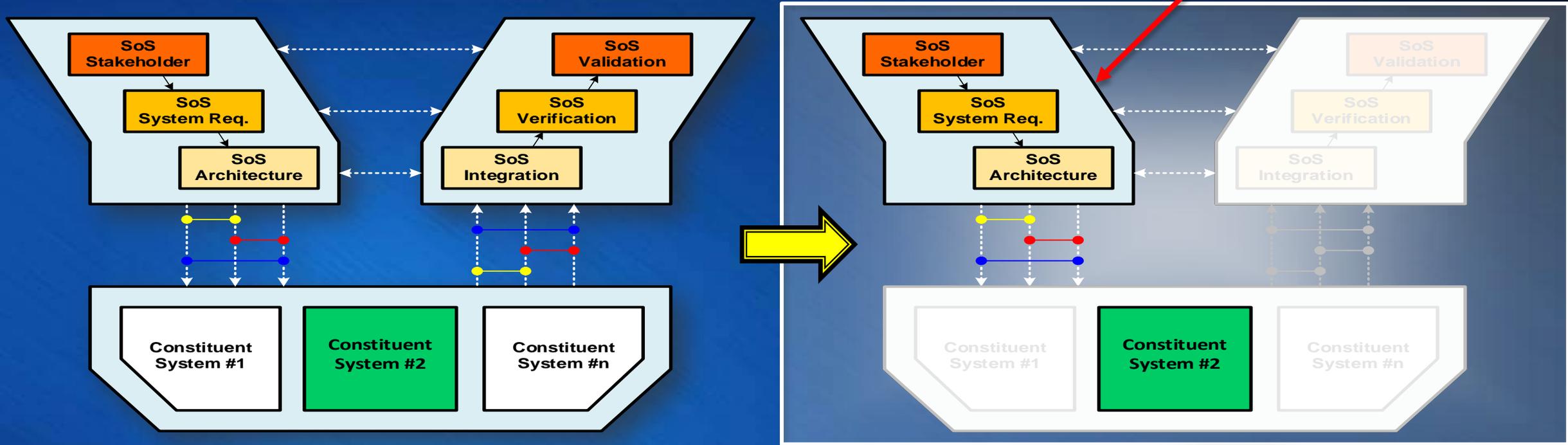
Source: INCOSE-OMGSysML-Tutorial-Final-090901



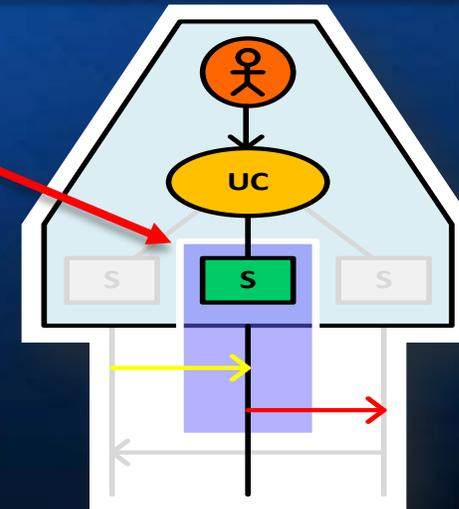
CONCEPTUAL MBSE

MBSE DURING CONCEPTUAL DESIGN

Conceptual MBSE – Application of Model Based Systems Engineering by **Acquirer During Conceptual Design**



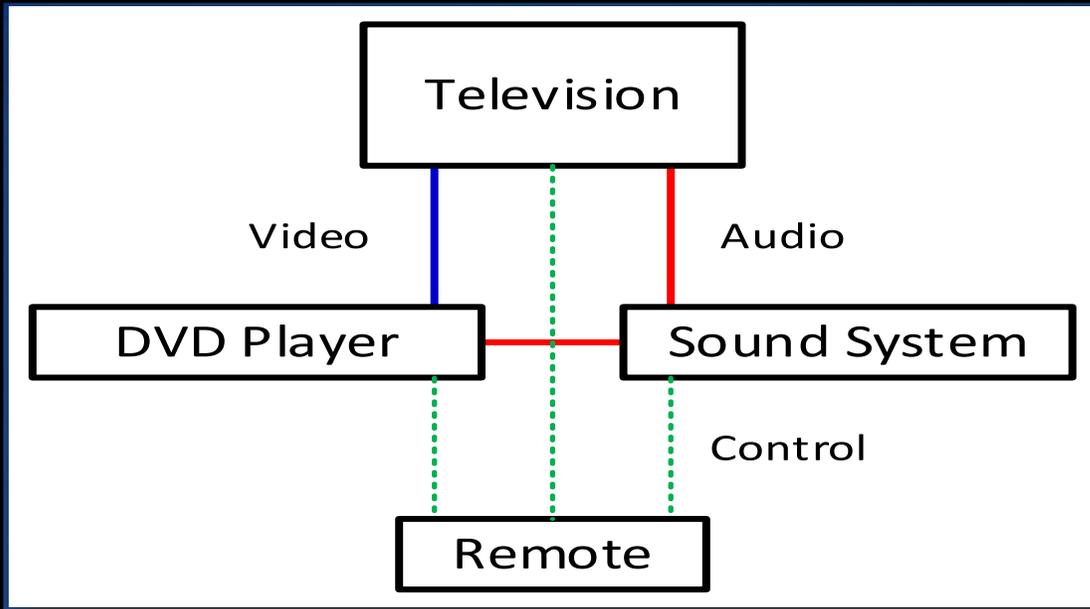
Determine Applicable **System Requirements & Interfaces** for System to be Acquired



CONCEPTUAL MBSE

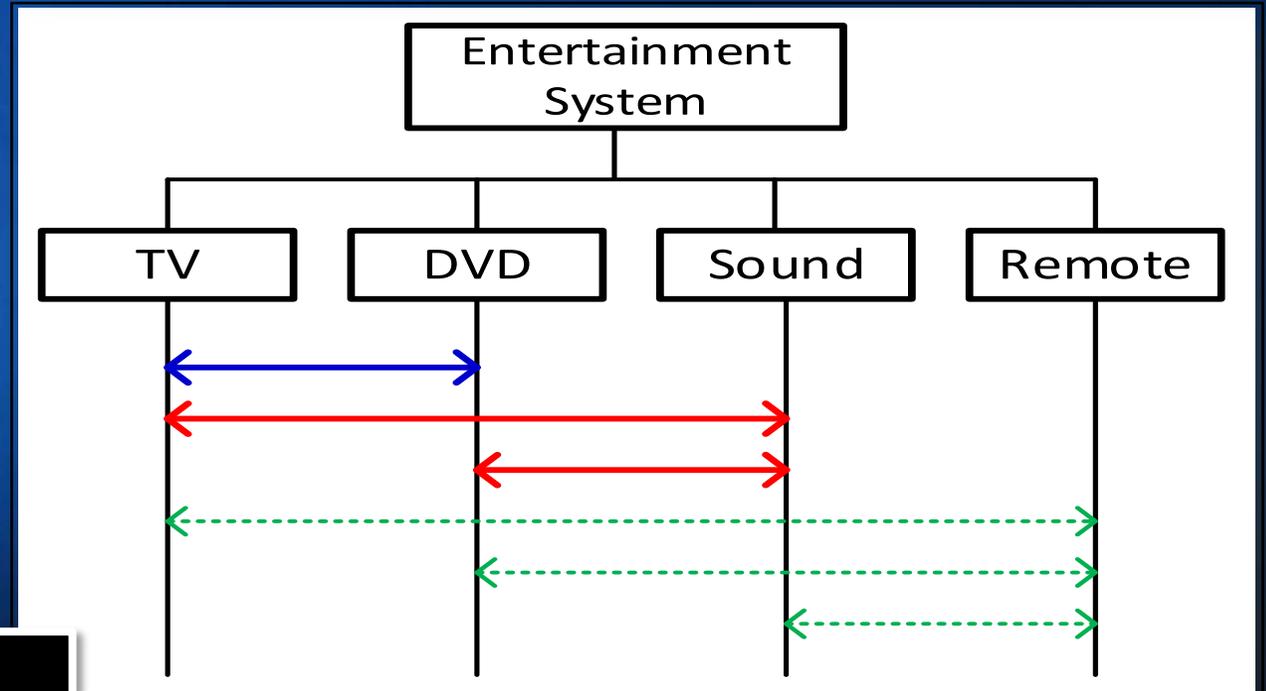
MBSE EXAMPLE – ENTERTAINMENT SYSTEM

Interface (N2)
Chart



System
Architecture

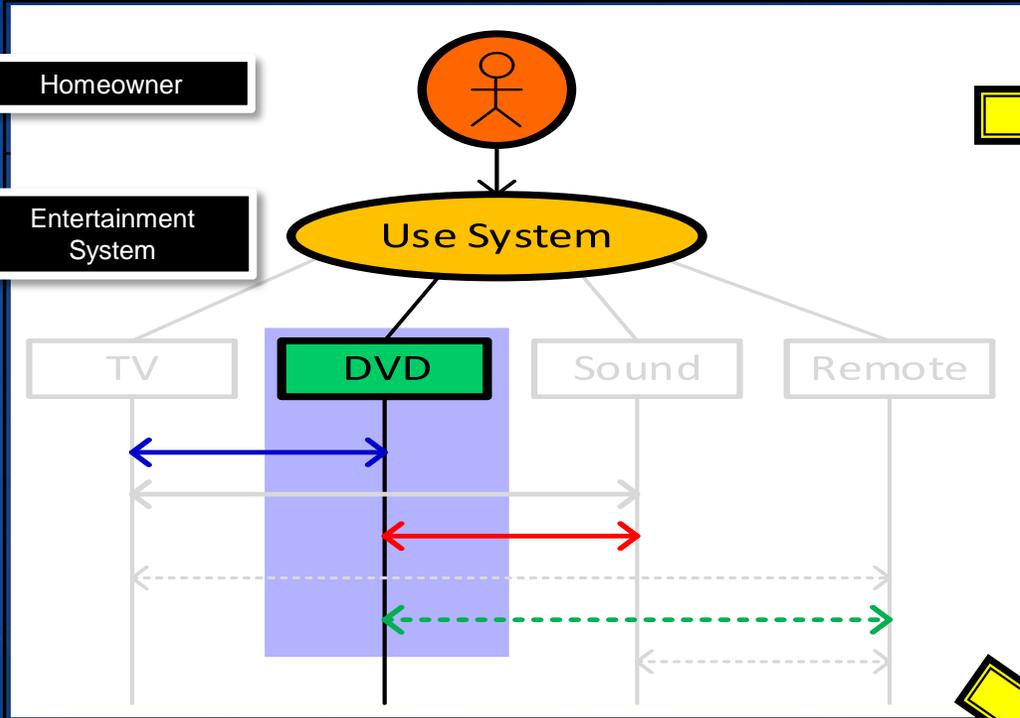
	TV	DVD	Sound	Remote
TV	---		X	
DVD	X	---	X	
Sound			---	
Remote	X	X	X	---



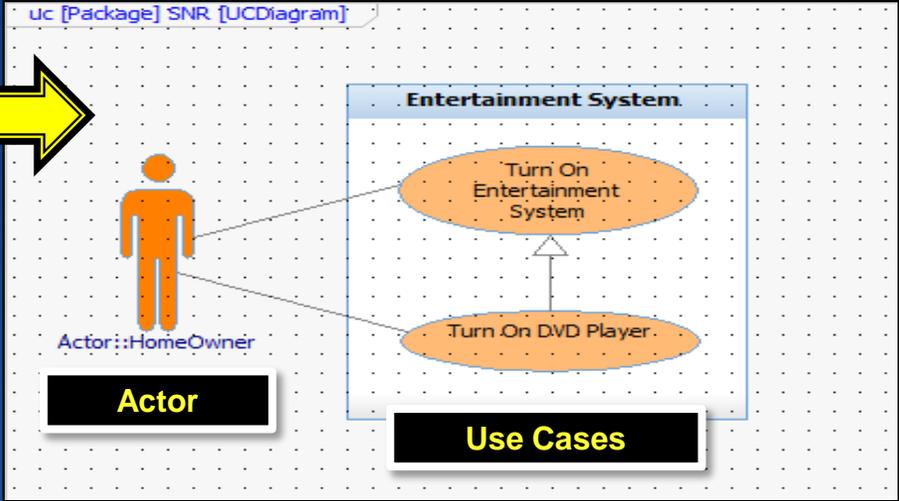
Interface Diagram
(Alternative)

CONCEPTUAL MBSE

USING SYSML TO CREATE USE CASE & SEQUENCE DIAGRAMS

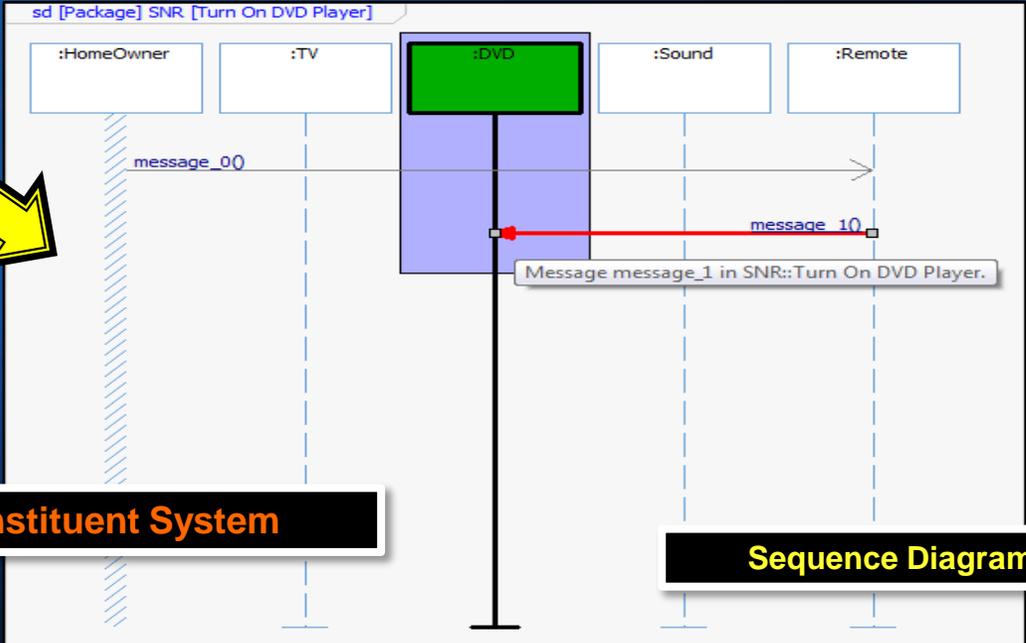


Entertainment System of Systems



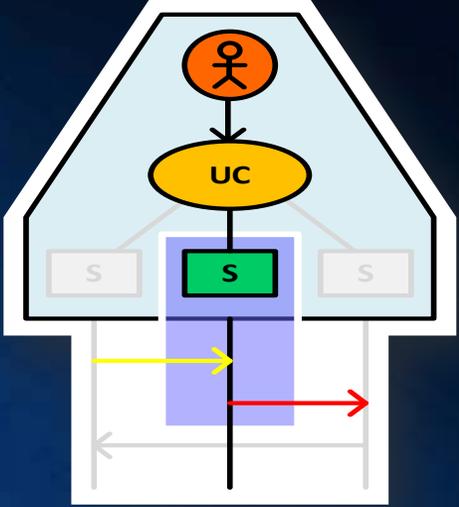
Actor

Use Cases



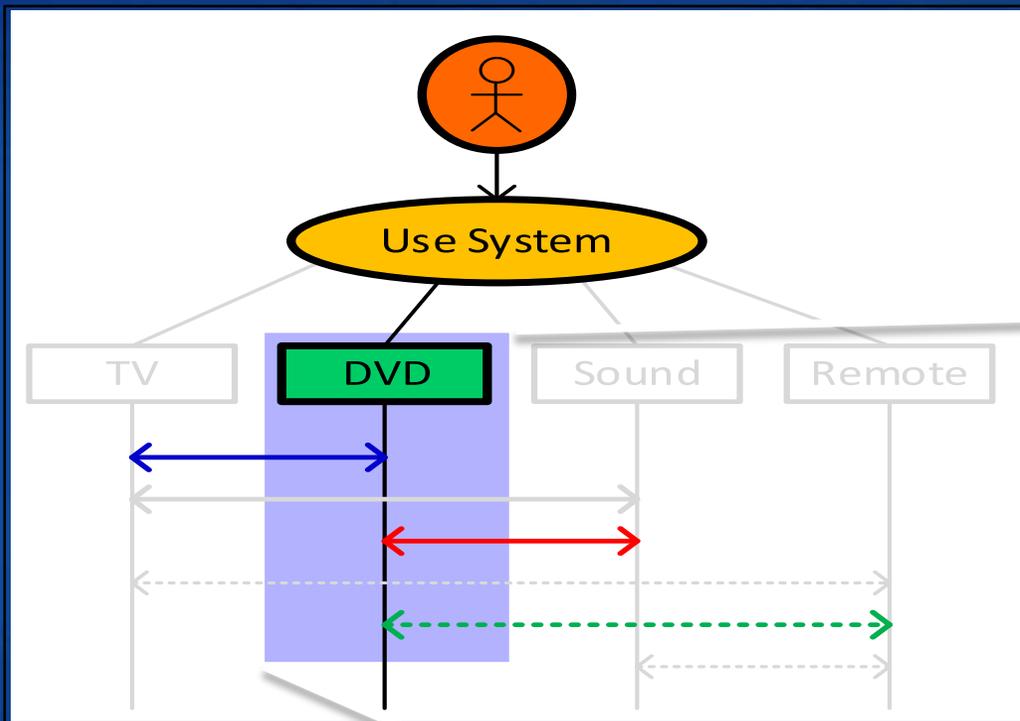
Constituent System

Sequence Diagram



CONCEPTUAL MBSE

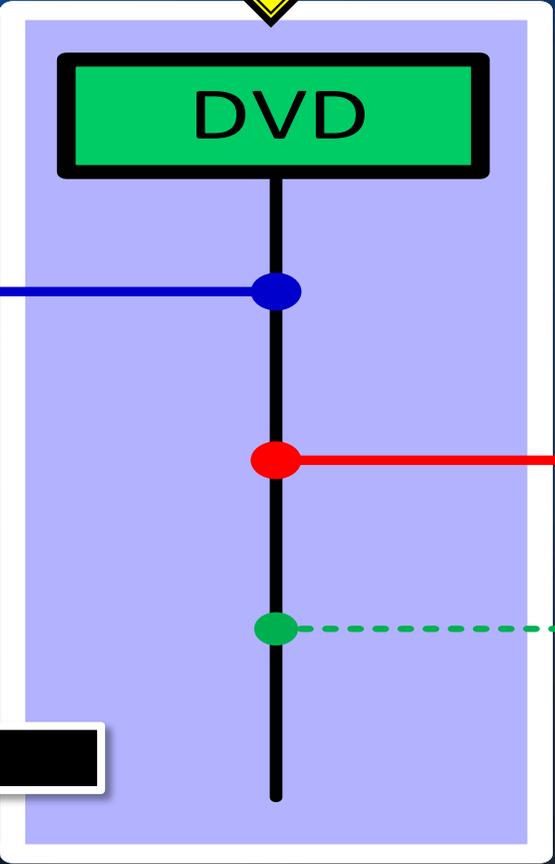
CONSTITUENT SYSTEM REQUIREMENTS & INTERFACES



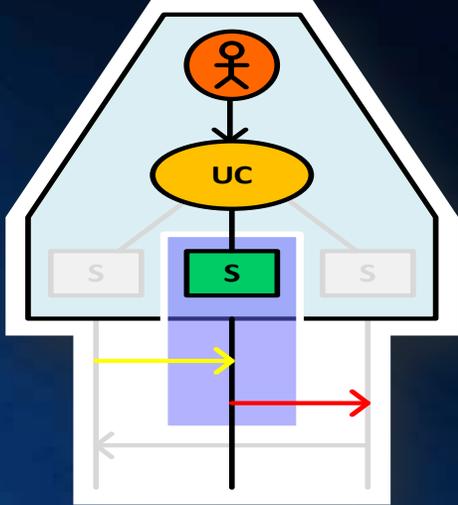
Entertainment System of Systems

Constituent System

Applicable **System** Requirements



Applicable **Interface** Requirements



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➤ **Proof of Concept**

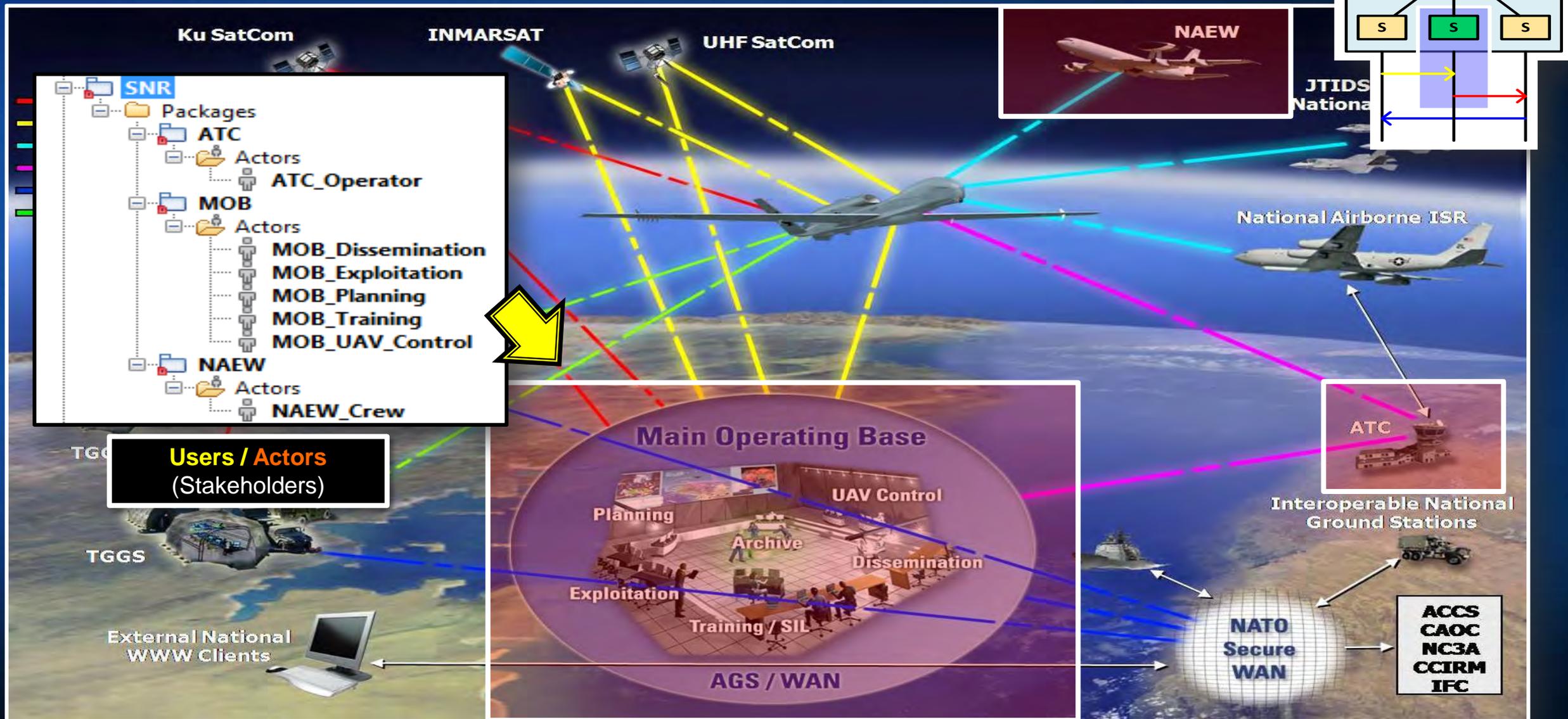
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➤ Summary

- What Does it Mean to You

APPLICATION TO NATO AGS SYSTEM

IDENTIFYING ACTORS OF THE SYSTEM



APPLICATION TO NATO AGS SYSTEM

OPERATIONAL CONCEPT (STAKEHOLDER REQS.)



Scenario X.Y – UAV Operation

Users / Actors
(Stakeholders)

Background

The NATO-owned and -operated AGS core capability will enable the Alliance to provide persistent surveillance over wide areas from high-altitude long-endurance (HALE) aircraft, operating at considerable stand-off distances and in any weather or light condition. Using advanced radar sensors, these systems will continuously detect and track moving objects throughout observed areas and will provide radar imagery of areas of interest and stationary objects. (Source: http://www.nato.int/cps/en/natolive/topics_48892.htm#)

http://www.nato.int/cps/en/natolive/topics_48892.htm

Scenario X.Y-Z: Detect and Track Moving Object

Why

Scenario Description ...

User / Actor	Location	Role and Responsibilities
Continuously		
N/A	UAV	<ul style="list-style-type: none"> • Detects & Track Moving Objects • Provides Radar Imagery • ...
Detects Object of Interest		
Object of Interest	UAV	<ul style="list-style-type: none"> • Detects Object of Interest • Reports Object of Interest to Main Operating Base • ...
UAV Control	MOB	<ul style="list-style-type: none"> • Processes Information Reported from UAV • Communicates with MOB Dissemination • ...
Dissemination	MOB	<ul style="list-style-type: none"> • Communicates with JTIDS (Joint Tactical Information Distribution System) Equipped National Air Assets • Dispatches JTIDS Equipped National Air Assets • ... • ...
...

When

Operating Scenarios
(Stakeholder Language)

Who

Where

What

APPLICATION TO NATO AGS SYSTEM

DERIVING FUNCTIONAL REQUIREMENTS



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Scenario X.Y-Z: Detect and Track Moving Object

Scenario Description ...

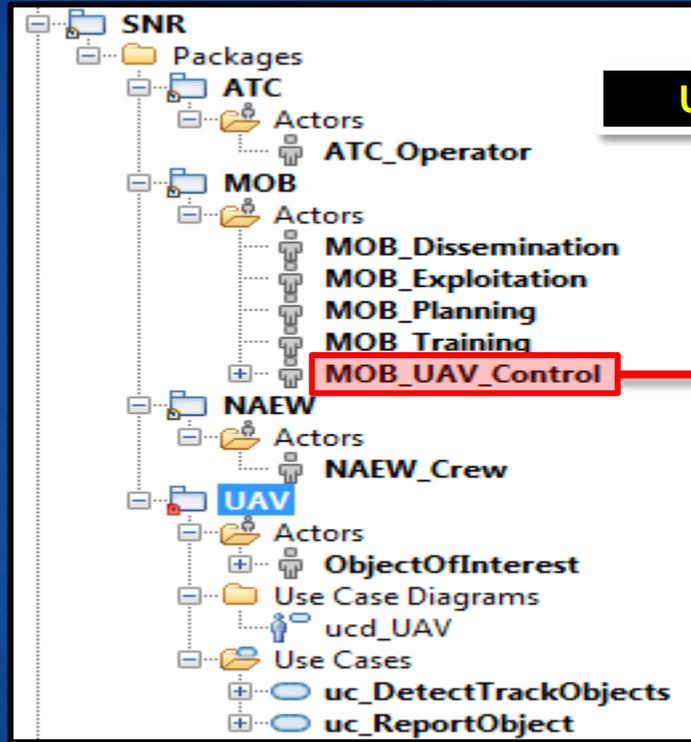
User / Actor	Location	Role and Responsibilities
Continuously		
N/A	UAV	<ul style="list-style-type: none">• Detects & Track Moving Objects• Provides Radar Imagery• ...
Detects Object of Interest		
Object of Interest	UAV	<ul style="list-style-type: none">• Detects Object of Interest• Reports Object of Interest to Main Operating Base• ...
UAV Control	MOB	<ul style="list-style-type: none">• Processes Information Reported from UAV• Communicates with MOB Dissemination• ...
Dissemination	MOB	<ul style="list-style-type: none">• Communicates with JTIDS (Joint Tactical Information Distribution System) Equipped National Air Assets• Dispatches JTIDS Equipped National Air Assets• ...
...	...	<ul style="list-style-type: none">• ...

[FR #001]: The UAV shall be able to detect and track objects of interest.

[FR #002]: The UAV shall be able to report objects of interest to the MOB.

APPLICATION TO NATO AGS SYSTEM

IDENTIFYING USE CASES (SYSTEM FUNCTIONS)



Users / Actors

Scenario X.Y – UAV Operation

Background
 The NATO-owned and -operated AGS core capability will enable the Alliance to perform persistent surveillance over wide areas from high-altitude long-endurance (HALE) aircraft, operating at considerable stand-off distances and in any weather or light condition. Using advanced radar sensors, these systems will continuously detect and track moving objects throughout observed areas and will provide radar imagery of areas of interest and stationary objects. (Source: http://www.nato.int/cps/en/natolive/topics_48892.htm#)

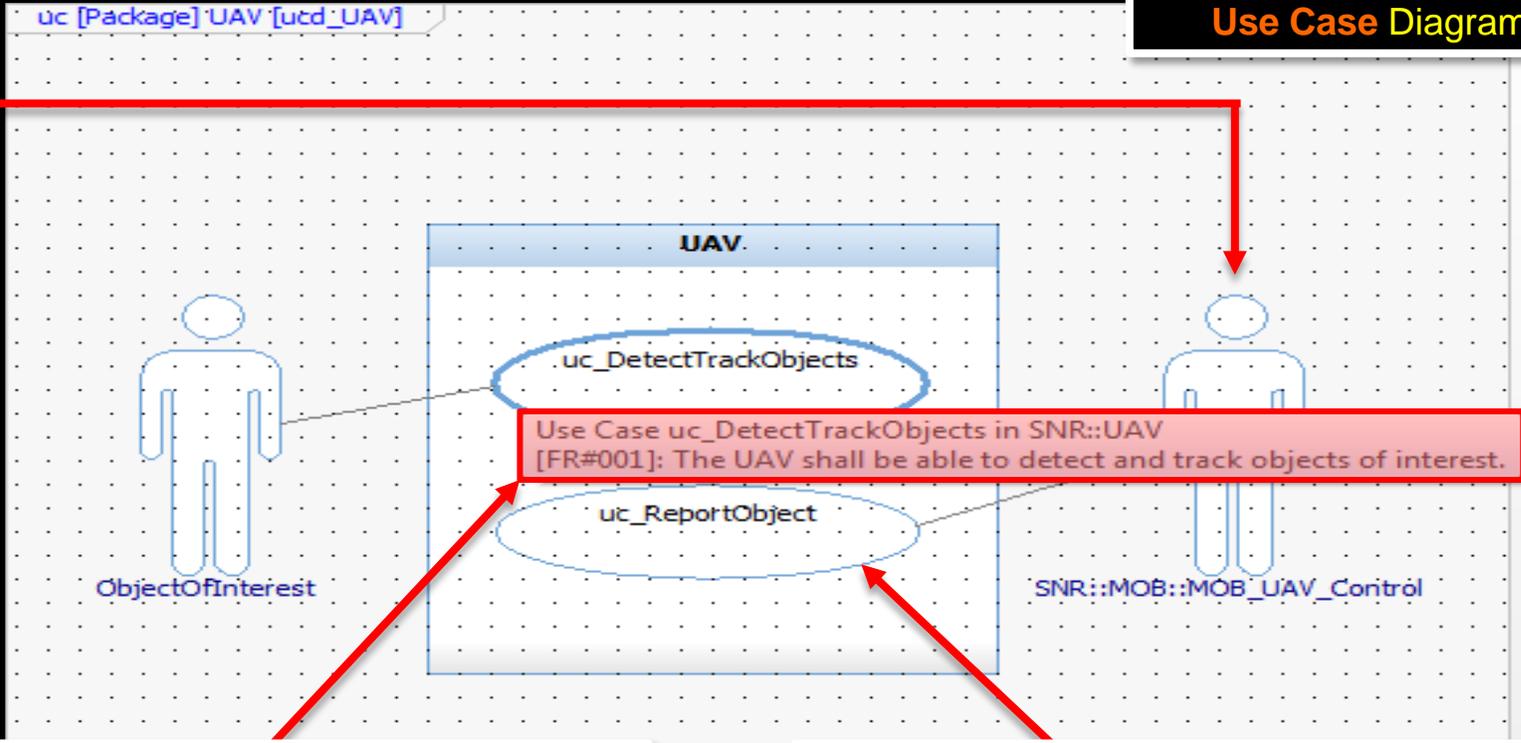
Scenario X.Y-Z: Detect and Track Moving Object

Scenario Description ...

User / Actor	Location	Role and Responsibilities
Continuously	UAV	<ul style="list-style-type: none"> • Detects & Track Moving Objects • Provides Radar Imagery
Detects Object of Interest	UAV	<ul style="list-style-type: none"> • Detects Object of Interest • Reports Object of Interest to Main Operating Base
UAV Control	MOB	<ul style="list-style-type: none"> • Processes Information Reported from UAV • Communicates with MOB Dissemination
Dissemination	MOB	<ul style="list-style-type: none"> • Communicates with JTIDS (Joint Tactical Information Distribution System) Equipped National Air Assets • Dispatches JTIDS Equipped National Air Assets

[FR #001]: The UAV shall be able to detect and track objects of interest.

[FR #002]: The UAV shall be able to report objects of interest to the MOB.



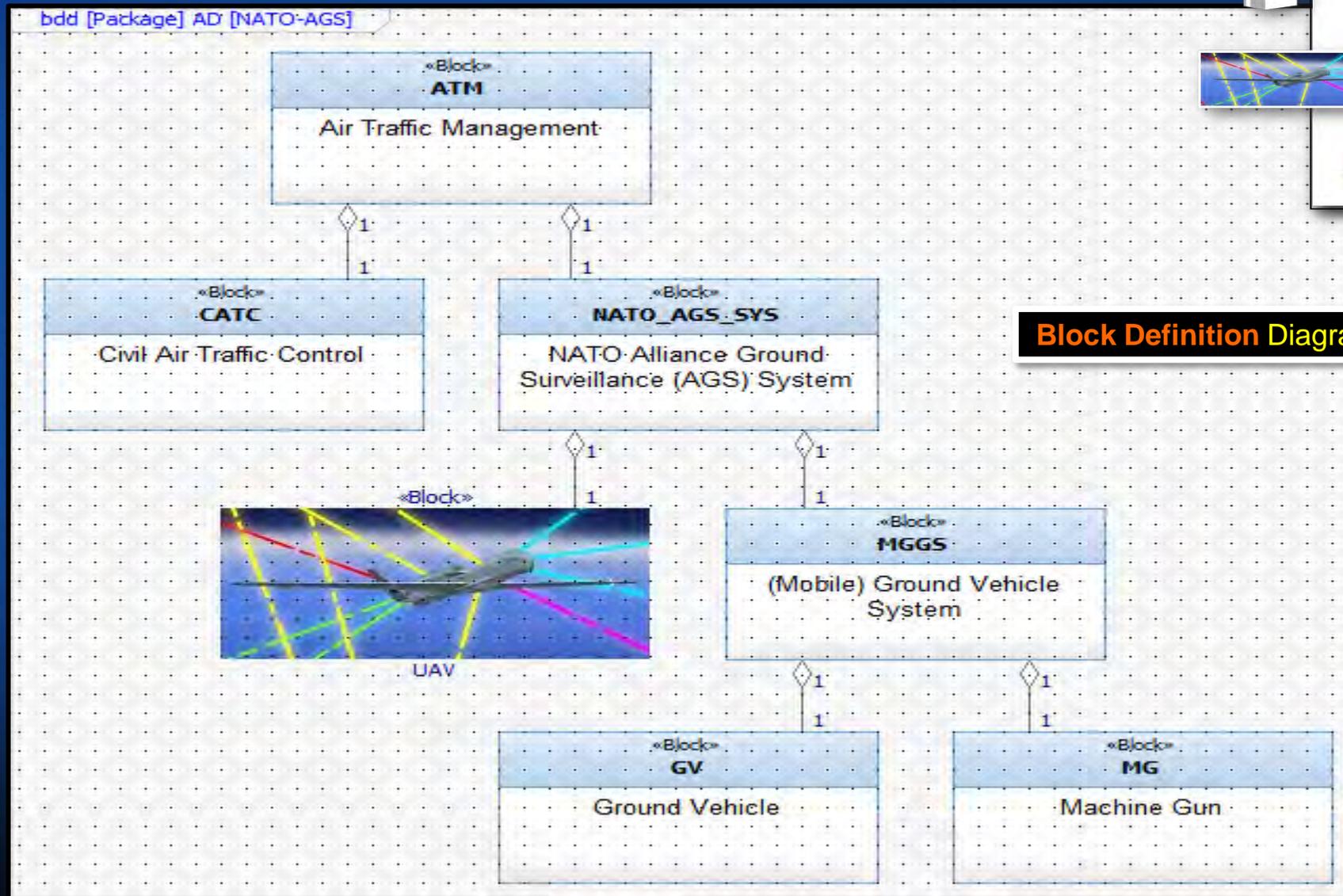
Use Case Diagram

[FR #001]: The UAV shall be able to detect and track objects of interest.

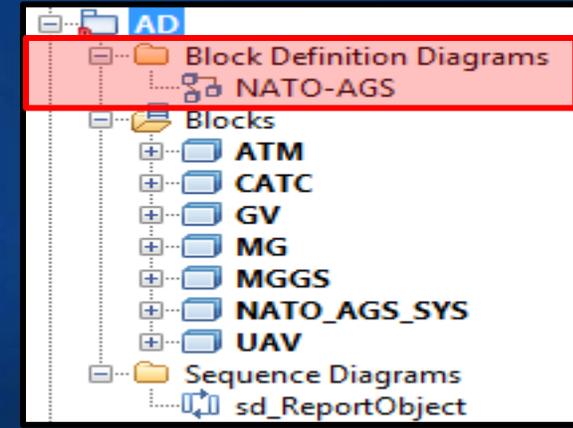
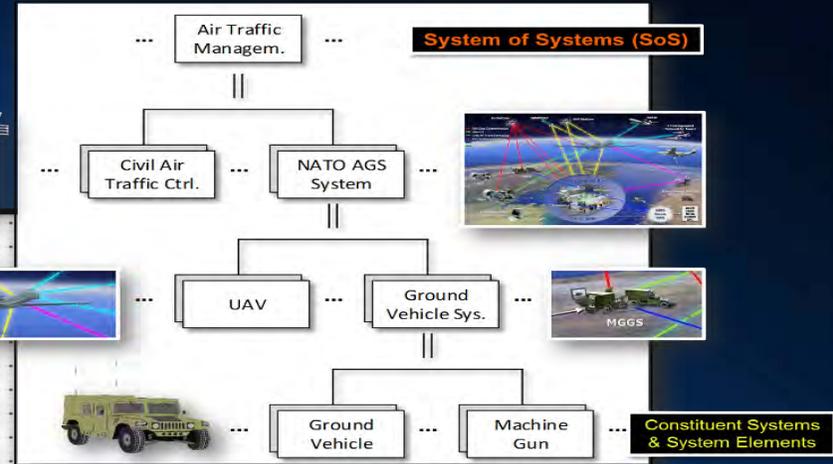
[FR #002]: The UAV shall be able to report objects of interest to the MOB.

APPLICATION TO NATO AGS SYSTEM

PRESENTING THE HIERARCHY



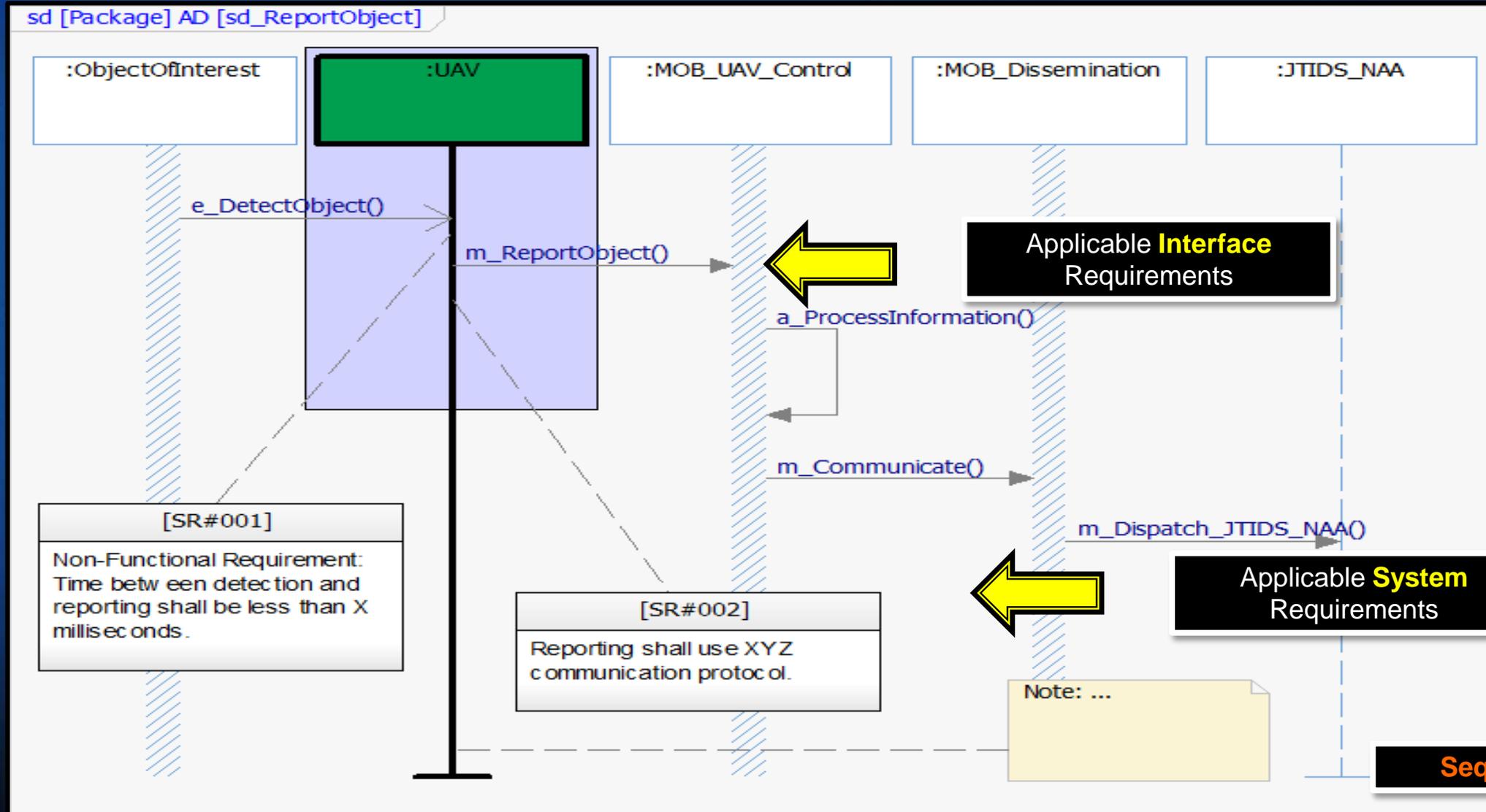
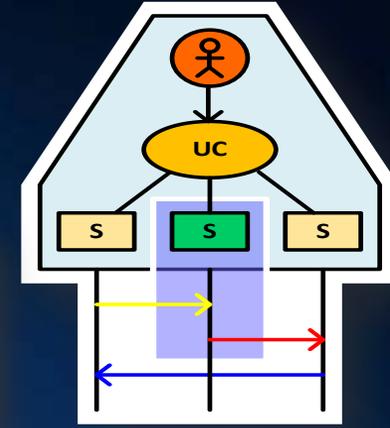
Block Definition Diagram



Model View Architecture Definition

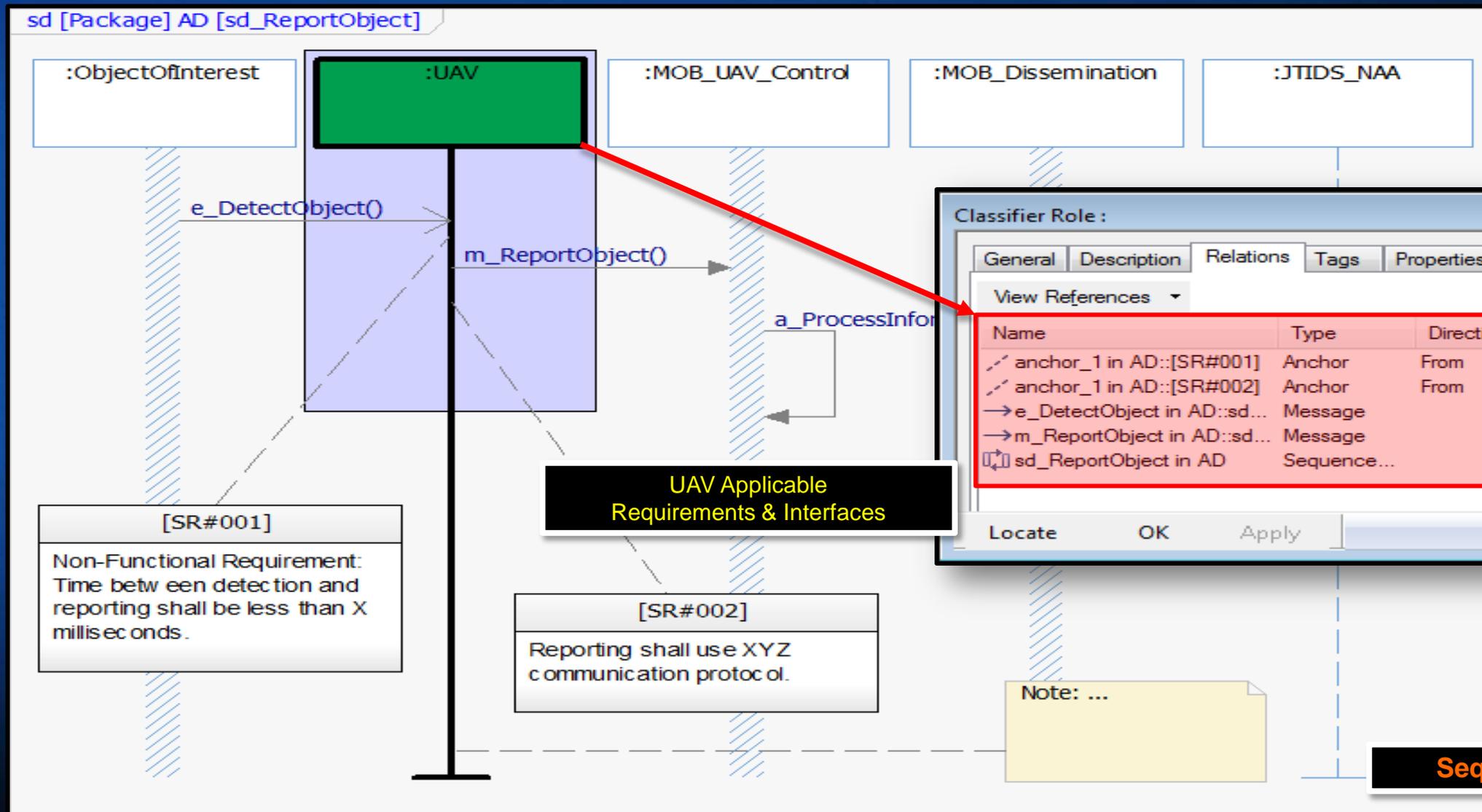
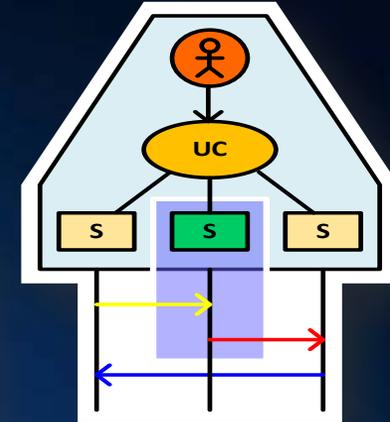
APPLICATION TO NATO AGS SYSTEM

SEQUENCE DIAGRAM



APPLICATION TO NATO AGS SYSTEM

SEQUENCE DIAGRAM (CONT'D)



Classifier Role :

General Description Relations Tags Properties

View References

Name	Type	Directi...	From/...	Data
anchor_1 in AD::[SR#001]	Anchor	From	[SR#001]	
anchor_1 in AD::[SR#002]	Anchor	From	[SR#002]	
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→ m_ReportObject in AD::sd...	Message			
sd_ReportObject in AD	Sequence...			

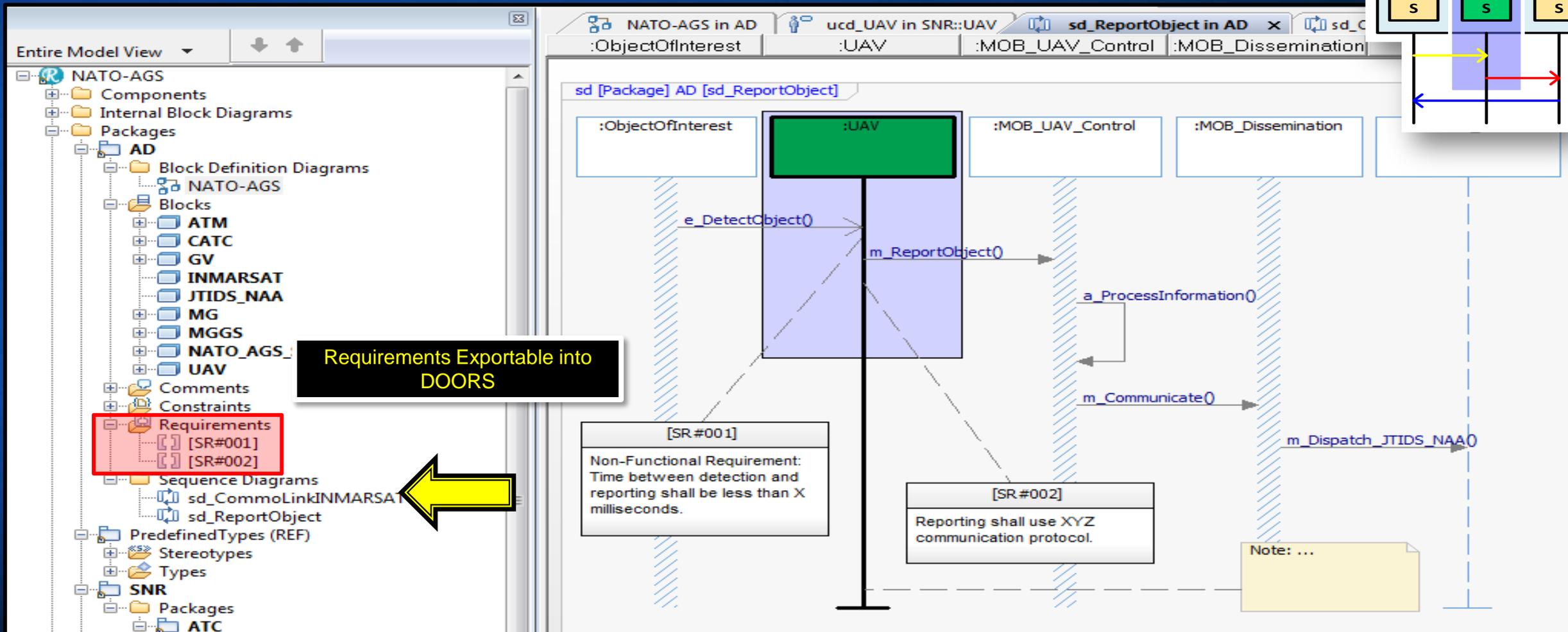
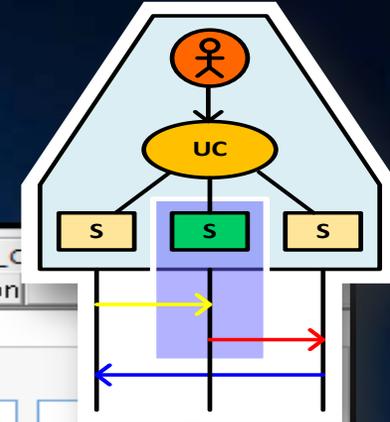
Locate OK Apply

UAV Applicable Requirements & Interfaces

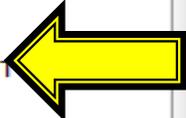
Sequence Diagram

APPLICATION TO NATO AGS SYSTEM

INPUT INTO THE ACQUISITION PROCESS



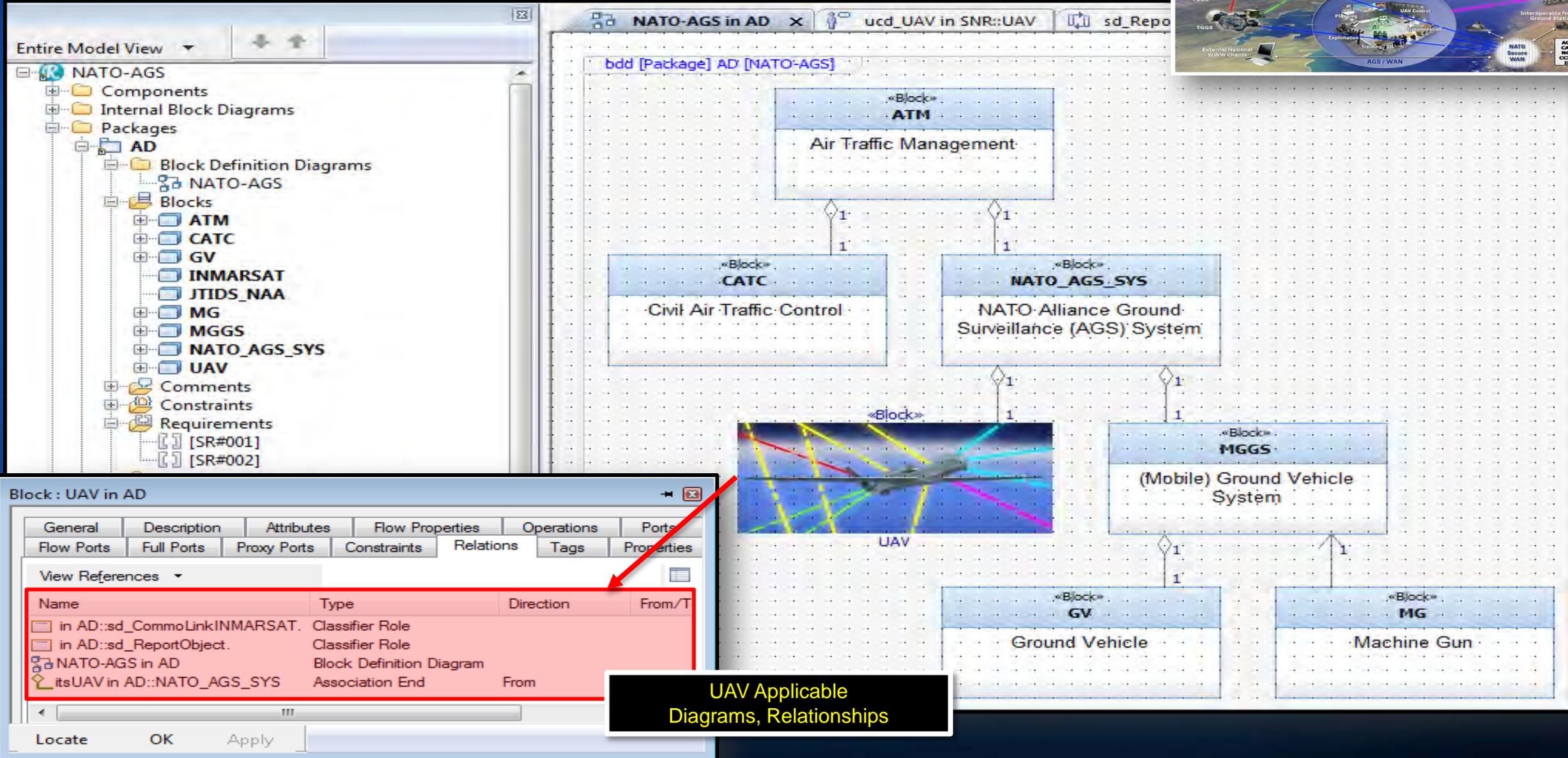
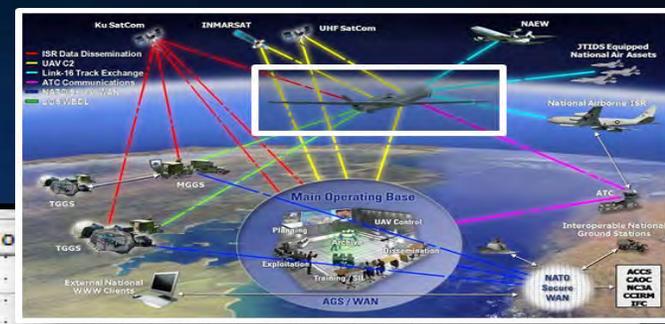
Requirements Exportable into DOORS



Use Requirements as Basis for V&V of Acquisition RFP

APPLICATION TO NATO AGS SYSTEM

UNIFIED MODEL INFORMATION APPLICABLE TO UAV



PROGRESS

➤ Problem Statement

- Individual System Acquisition in System of Systems Environments

➤ Objectives

- Increasing the Effectiveness of System Acquisitions

➤ Offered Solution: Conceptual MBSE

- Basis: SoS-VEE Model™
- MBSE Building Block
- MBSE Example

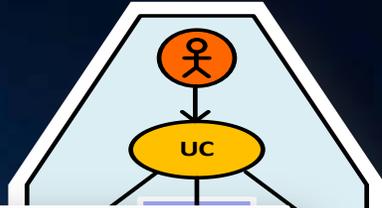
➤ Proof of Concept

- Application to UAV in NATO AGS System

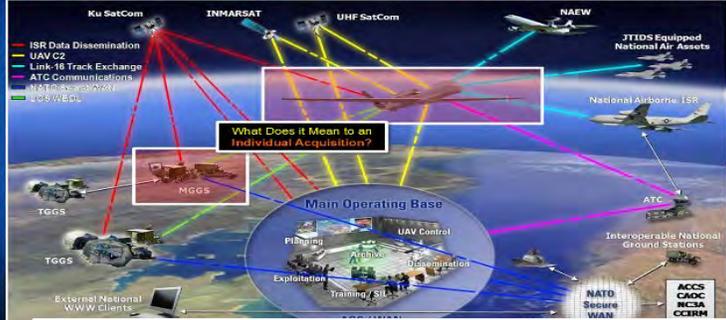
➤ Summary

- What Does it Mean to You

CONCEPTUAL MBSE SUMMARY



PROBLEM STATEMENT STOVEPIPED ACQUISITIONS IN COMPLEX SYSTEM OF SYSTEM ENVIRONMENTS



OBJECTIVES INCREASING THE EFFECTIVENESS OF SYSTEM ACQUISITIONS



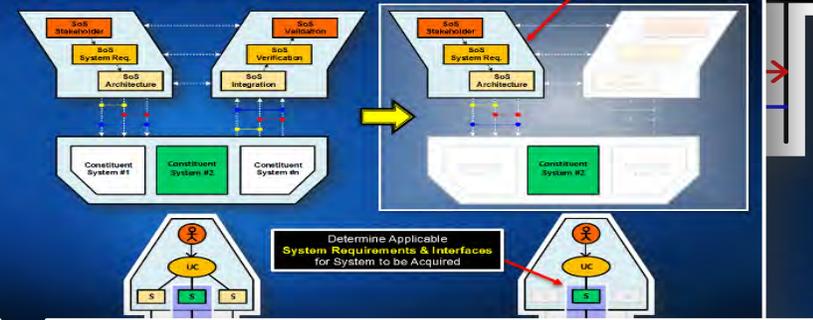
ANNOUNCEMENT
A major conference focusing on improving acquisition and performance of Defense programs and systems, including net-centric operations and data/information interoperability, system - of - systems engineering and all aspects of system sustainment, will be convened in Fall of 2015. This conference is sponsored by the National Defense Industrial Association, Systems Engineering Division, with technical co-sponsorship by IEEE AES, IEEE Systems Council and the International Council on Systems Engineering, and is supported by the Office of the Deputy Assistant Secretary Defense for Systems Engineering in the Office of Under Secretary of Defense for Acquisition, Technology and Logistics and Office of the DoD Information Officer.

Improving Acquisition and Performance of Defense Programs & Systems

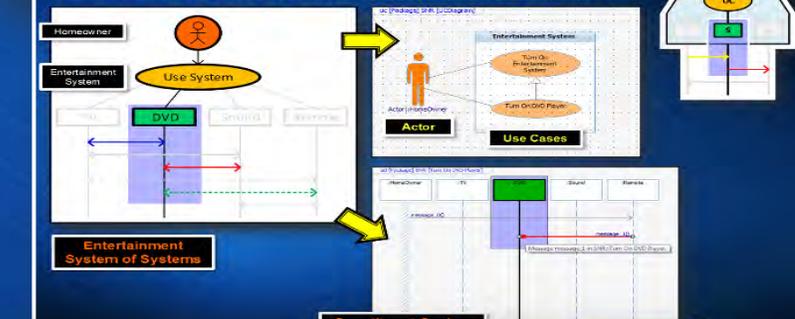
BACKGROUND
The Department of Defense continues to seek ways to improve the acquisition of military equipment and capability to assist the warfighter in protecting the U.S. and its allies, and help oppressed nations around the world in a complex environment of ever-changing threats and conditions. The Weapon Systems Acquisition Reform Act (WSARA) of 2009 defines Systems Engineering as a key player in helping effect improvements in defense acquisition and program execution, to achieve more effective and affordable military systems. Better Buying Power provided guidance on increasing efficiencies to "do more, without more." Systems Engineering is the "umbrella" engineering function that serves as the key integrating function for these initiatives.

Improve the Acquisition of Military Equipment

CONCEPTUAL MBSE MBSE DURING CONCEPTUAL DESIGN



CONCEPTUAL MBSE USING SYSML TO CREATE USE CASE & SEQUENCE DIAGRAM



APPLICATION TO NATO AGS SYSTEM OPERATIONAL CONCEPT (STAKEHOLDER REQS.)

Scenario X.Y - UAV Operation **Users / Actors (Stakeholders)**

Background
The NATO-owned and -operated AGS core capability will enable the Alliance to persistent surveillance over wide areas from high-altitude long-endurance (HALE) aircraft, operating at considerable stand-off distances and in any weather or light condition. Using advanced radar sensors, these systems will continuously detect and track moving objects throughout observed areas and will provide radar imagery of areas of interest and stationary objects. (Source: http://www.nato.int/cps/en/nat/olive/topics_4892.htm)

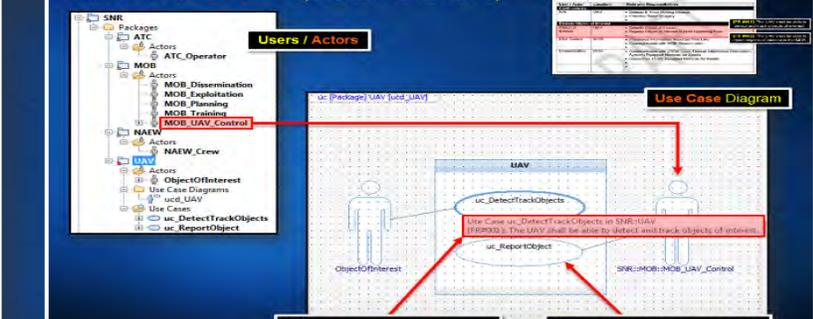
Scenario X.Y-Z: Detect and Track Moving Object **Why**

Scenario Description ...

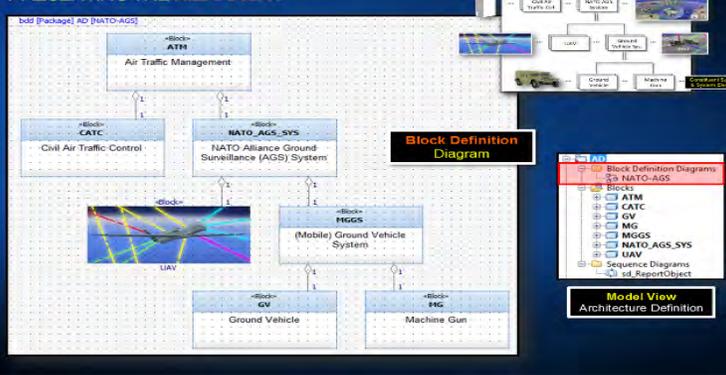
User / Actor	Location	Role and Responsibilities	When
Continuously	UAV	<ul style="list-style-type: none"> Detects & Track Moving Objects Provides Radar Imagery 	
Object of Interest	UAV	<ul style="list-style-type: none"> Detects Object of Interest Reports Object of Interest to Main Operating Base 	
UAV Control	MOB	<ul style="list-style-type: none"> Processes Information Reported from UAV Communicates with MOB Dissemination ... 	
Dissemination	MOB	<ul style="list-style-type: none"> Communicates with JTIDS (Joint Tactical Information Distribution System) Equipped National Air Assets Dispatches JTIDS Equipped National Air Assets 	

Operating Scenarios (Stakeholder Language)

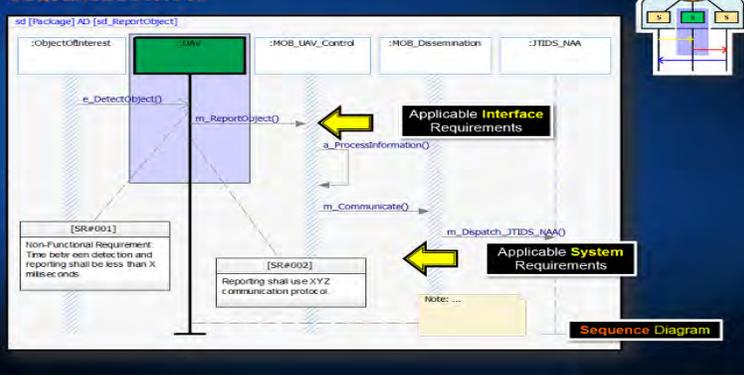
APPLICATION TO NATO AGS SYSTEM IDENTIFYING USE CASES (SYSTEM FUNCTIONS)



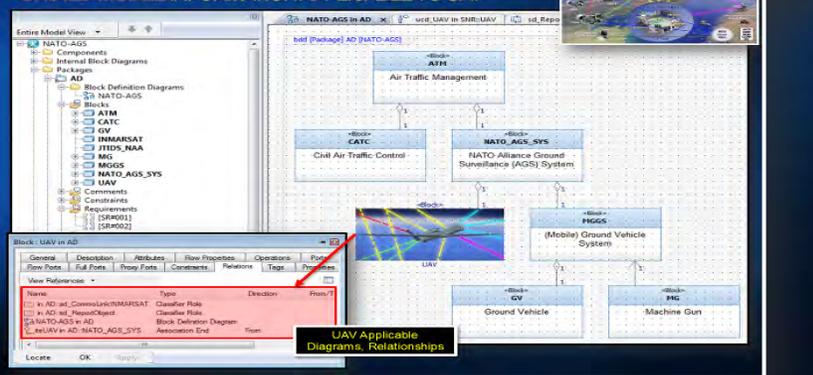
APPLICATION TO NATO AGS SYSTEM PRESENTING THE HIERARCHY



APPLICATION TO NATO AGS SYSTEM SEQUENCE DIAGRAM

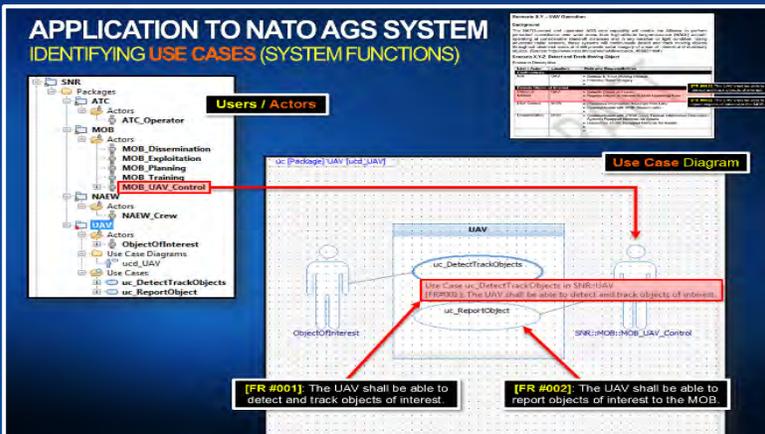


APPLICATION TO NATO AGS SYSTEM UNIFIED MODEL INFORMATION APPLICABLE TO UAV



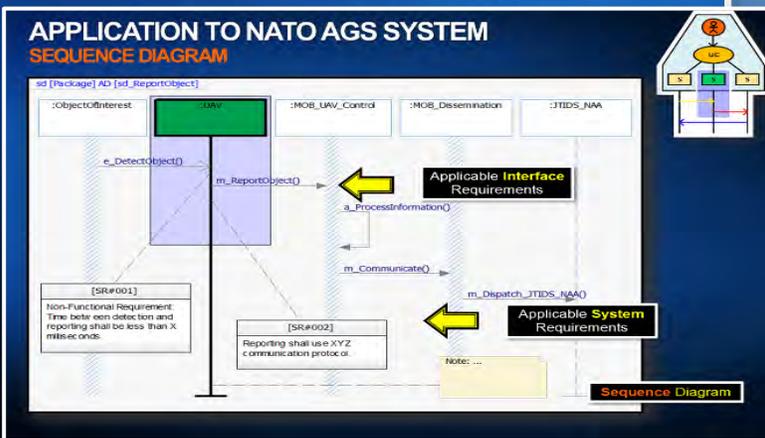
CONCEPTUAL MBSE

WHAT DOES IT MEAN TO YOU

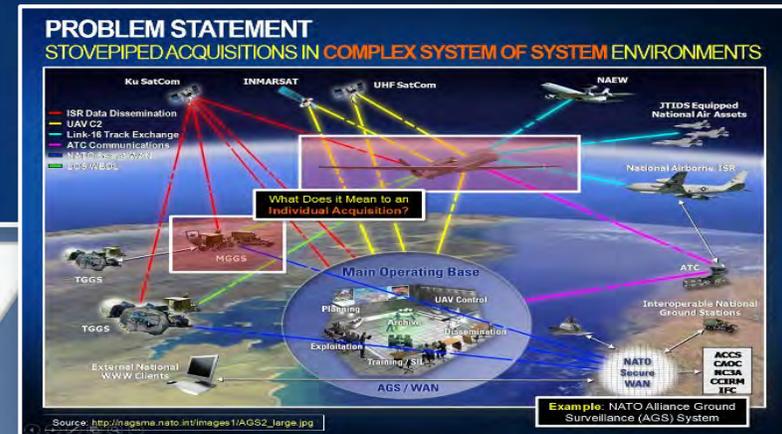
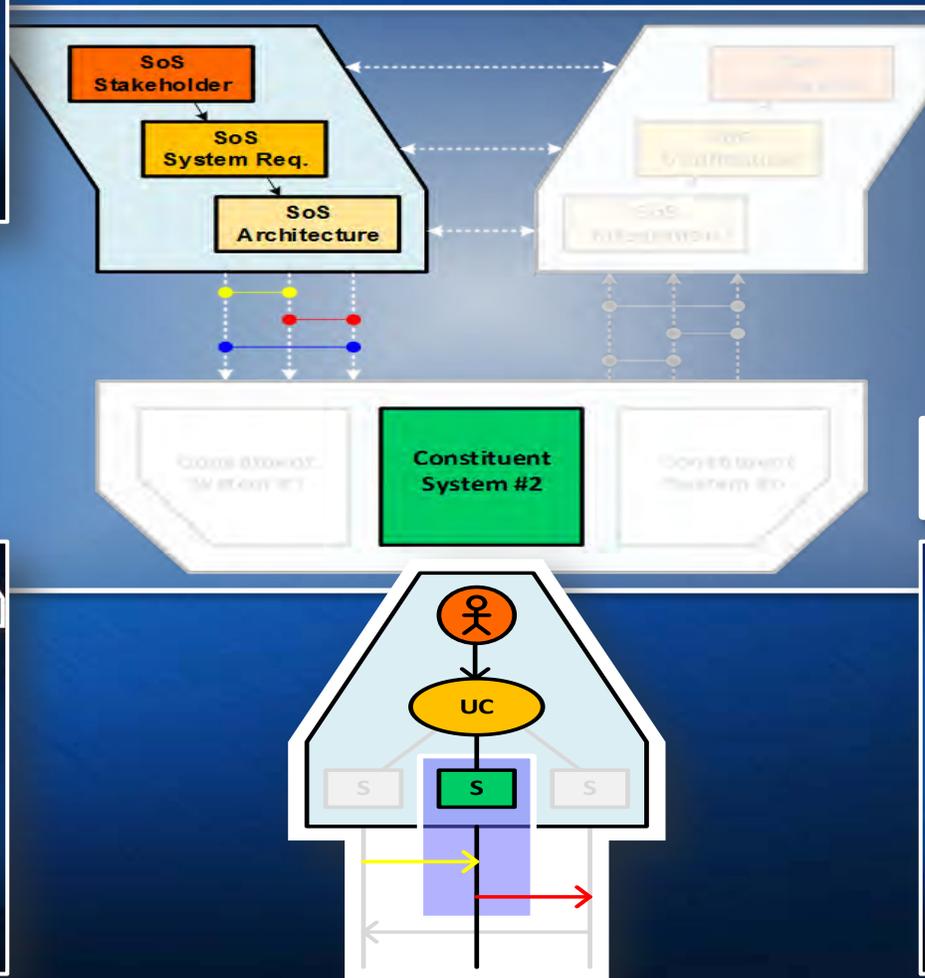


Improved Acquisition
(Stakeholder & Functional Reqs.)

Improved Interoperability
(Identified Interfaces)

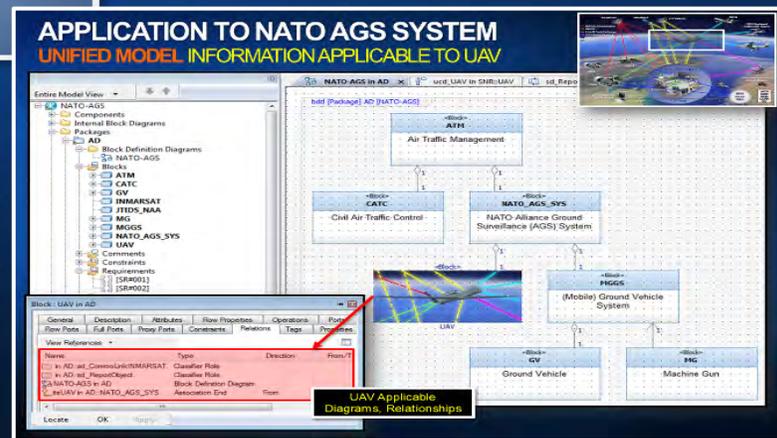


Increased Effectiveness of System Acquisitions

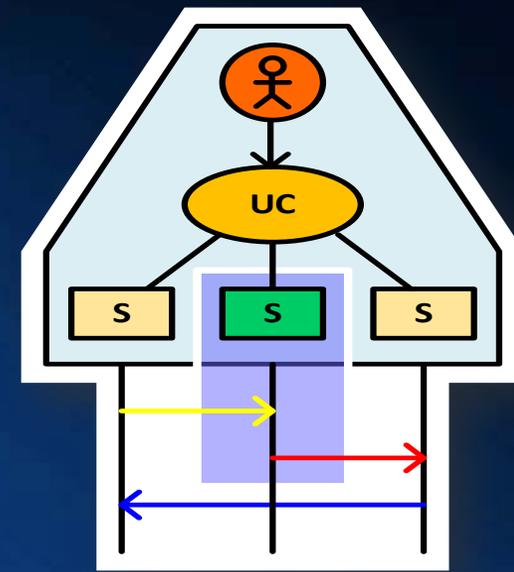


Improved Performance (Integration, V&V of SoS)

Unified Model, Improved Communication, Configuration Mgmt.



CONCEPTUAL MBSE QUESTIONS & ANSWERS



**Thank You for Your
Attention!**

Oliver Hoehne, PMP, CSEP, CSM

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Cell: (862) 371-7314