26th annual INCOSE international symposium

Edinburgh, UK

July 18 - 21, 2016

The SoS-VEE Model

Mastering the Socio-Technical Aspects and Complexity of Systems of Systems Engineering (SoSE)

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- **Dr Judith Dahmann**: “The State of Systems of Systems Engineering Knowledge Sources ", INCOSE SoSWG Webinar, Oct 2015
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- **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
- **INCOSE**: Systems Engineering Handbook, Third & Fourth Edition

AGENDA

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- **Problem Statement**
  - Complex System of System Environments
  - Acquisition Challenges in SoS Environments
- **Background**
  - System of Systems Engineering Overview
- **Offered Solution**
  - SoS-VEE Model
- **Conclusion & Summary**

PROBLEM STATEMENT

COMPLEX SYSTEM OF SYSTEMS ENVIRONMENTS

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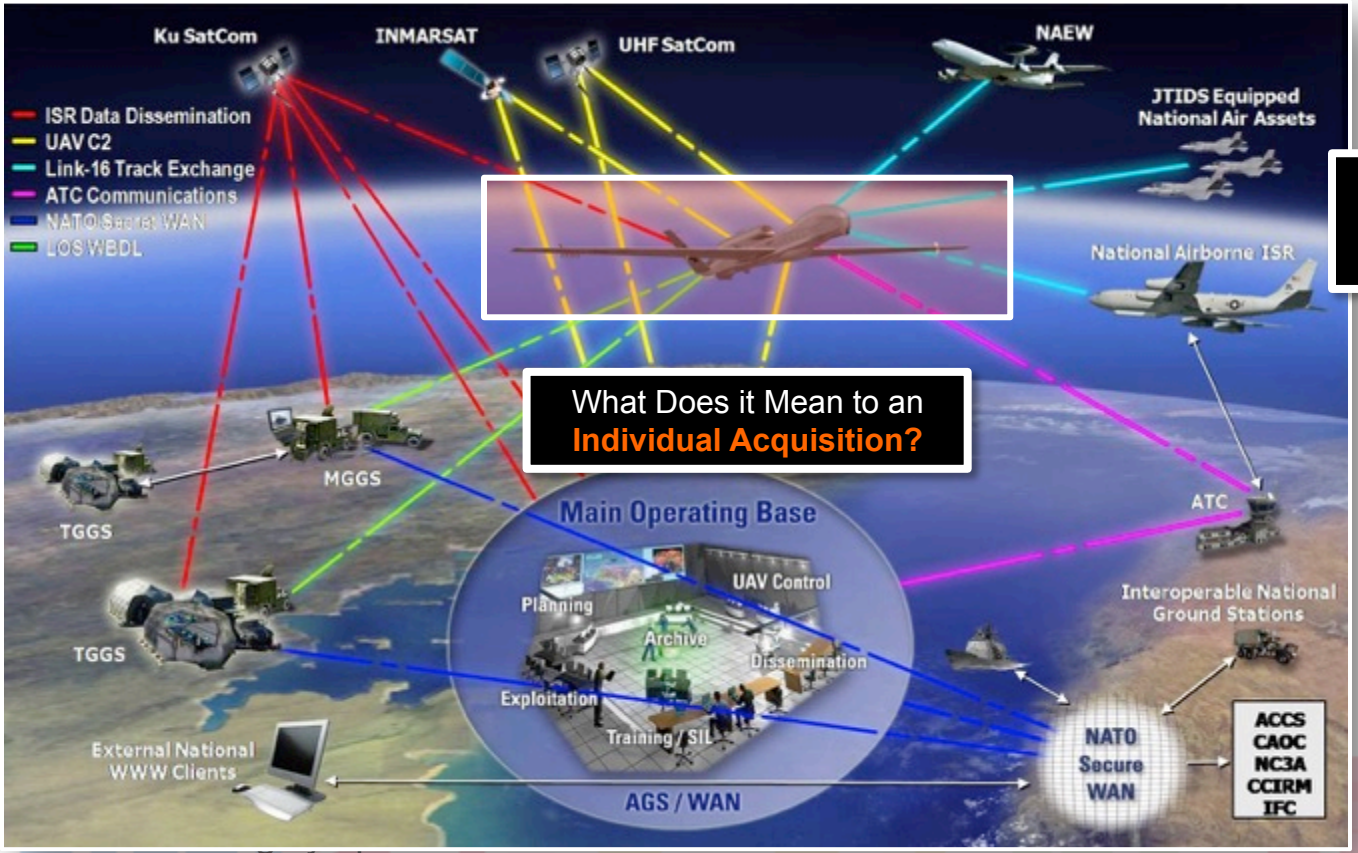

Example: NATO Alliance Ground Surveillance (AGS) System

Source: http://nagsma.nato.int/images1/AGS2_large.jpg

PROBLEM STATEMENT

ACQUISITION CHALLENGES IN SOS ENVIRONMENTS

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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.

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.

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.

Source:
http://archive.defensenews.com/article/20130514/DEFREG01/305140015

European Authorities
will not certify Euro Hawk

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

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

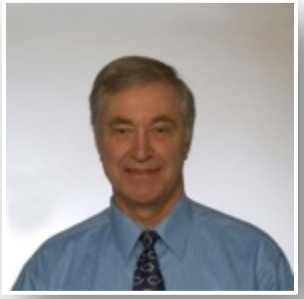
PROBLEM STATEMENT

ACQUISITION CHALLENGES IN SOS ENVIRONMENTS (CONT'D)

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

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

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UNDESIRABLE OUTCOMES

RESULTS OF STOVEPIPING OR SILO ENGINEERING

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

PROGRESS

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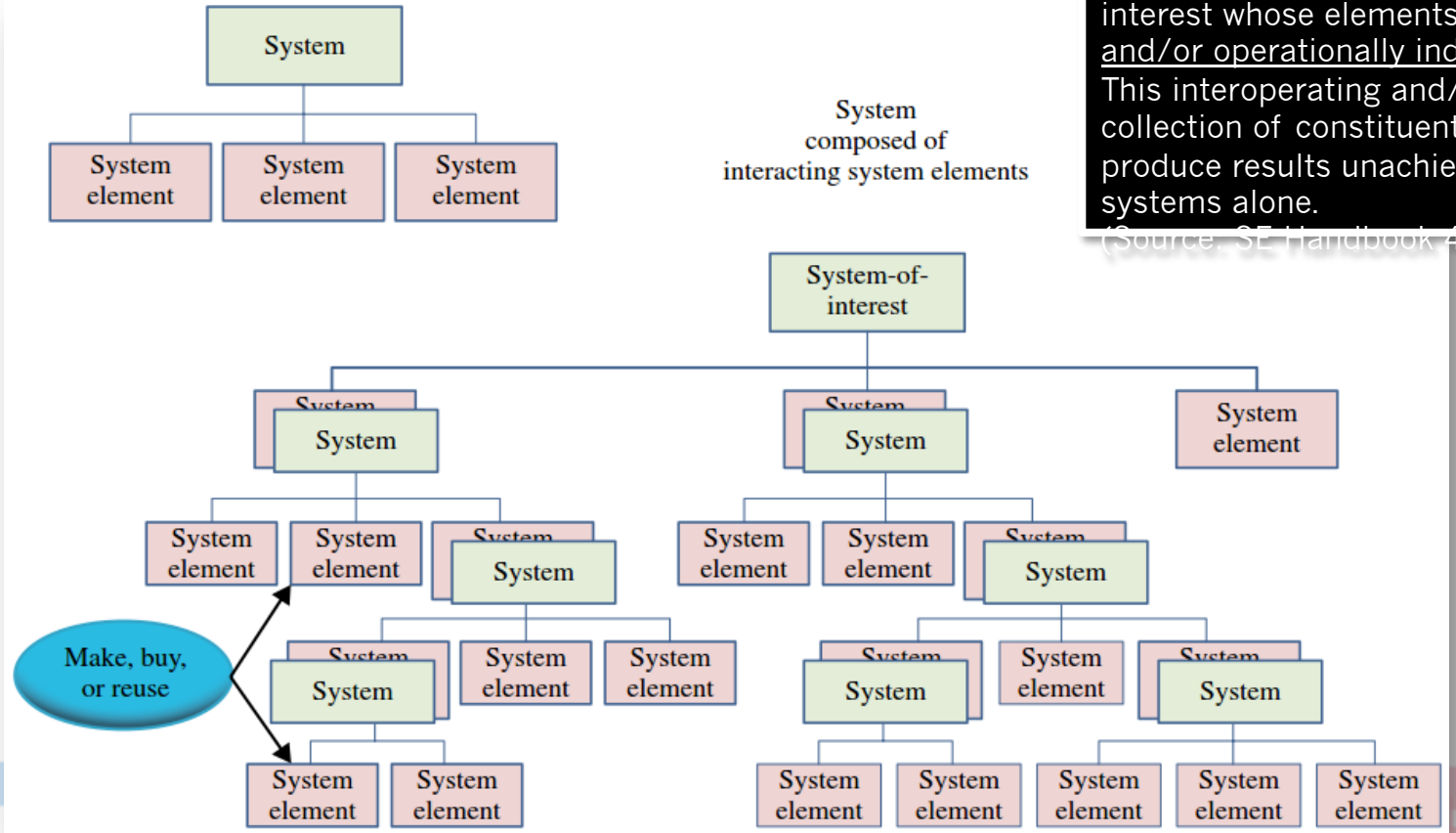
SYSTEM OF SYSTEMS ENGINEERING

HIERARCHY WITHIN A SYSTEM

"Systems-of-Systems" (SoS): Is a system of interest whose elements are managerially and/or operationally independent systems. This interoperating and/or integrated collection of constituent systems usually produce results unachievable by the individual systems alone.
(Source: SE Handbook 4.0)



SYSTEM OF SYSTEMS ENGINEERING

HIERARCHY WITHIN A SYSTEM (CONT'D)

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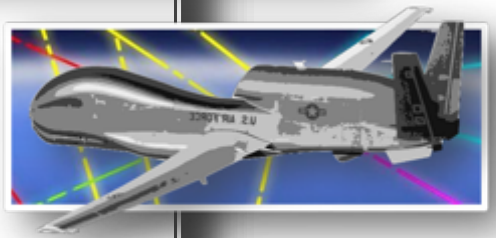
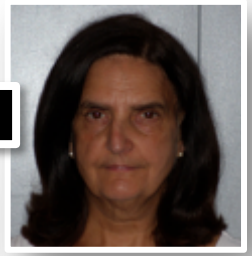
- Air Traffic Managem.
  - Civil Air Traffic Ctrl.
  - NATO AGS System
    - Ku SatCom
    - UAV
      - Radar System
      - Power Plant



SYSTEM OF SYSTEMS ENGINEERING

MAIER SOS CHARACTERIZATION

Judith Dahmann



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SEBoK: SoS Types

Source: "The State of Systems of Systems Engineering Knowledge Sources ", INCOSE SoSWG Webinar, Oct 2015

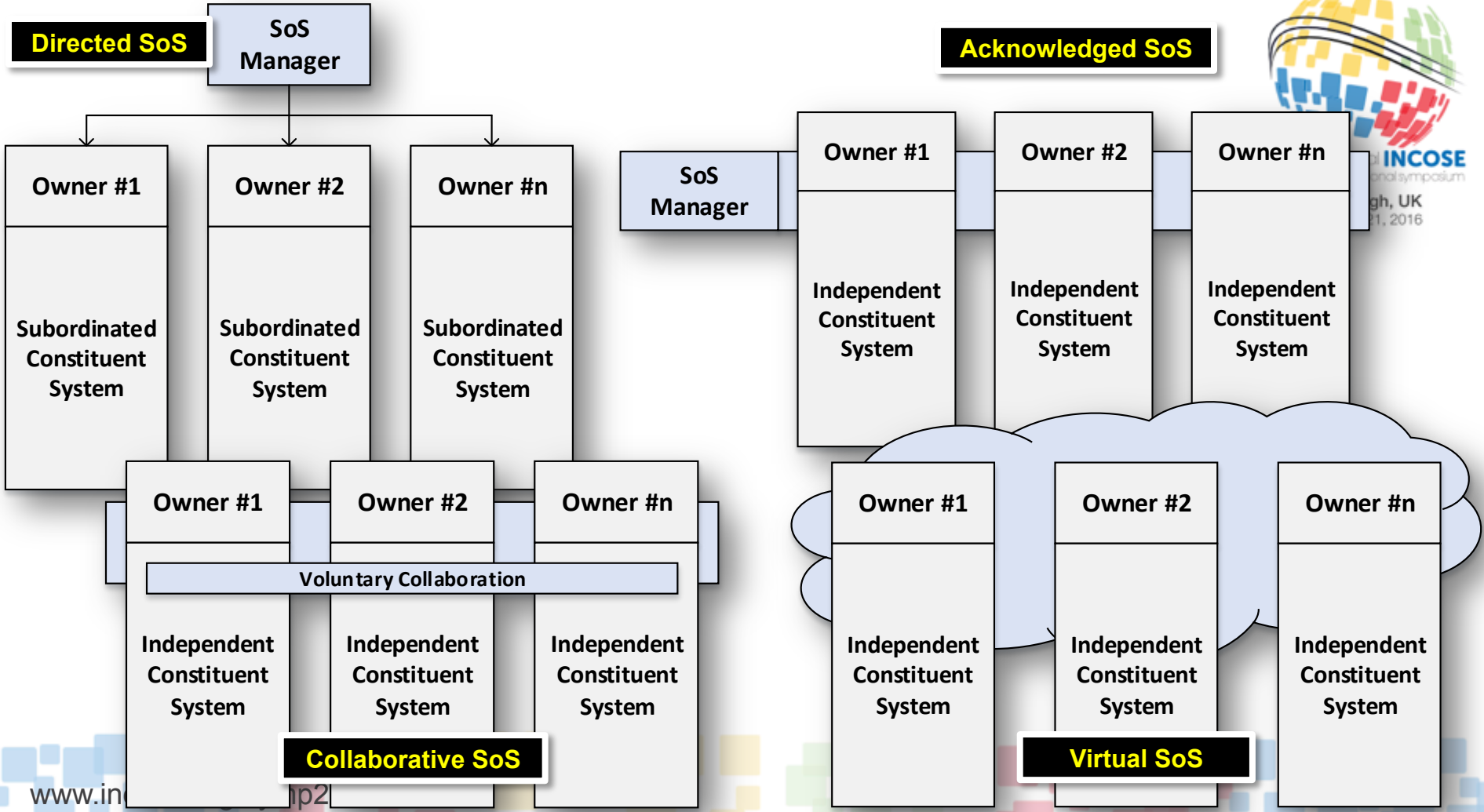
- **Directed**
  - The SoS is created and managed to fulfill specific purposes and the constituent systems are subordinated to the SoS.
  - The component systems maintain an ability to operate independently; however, their normal operational mode is subordinated to the central managed purpose;
- **Acknowledged**
  - The SoS has recognized objectives, a designated manager, and resources for the SoS; however, the constituent systems retain their independent ownership, objectives, funding, and development and sustainment approaches.
  - Changes in the systems are based on cooperative agreements between the SoS and the system;
- **Collaborative**
  - The component systems interact more or less voluntarily to fulfill agreed upon central purposes.
  - The central players collectively decide how to provide or deny service, thereby providing some means of enforcing and maintaining standards; and
- **Virtual**
  - The SoS lacks a central management authority and a centrally agreed upon purpose for the SoS.
  - Large-scale behavior emerges—and may be desirable—but this type of SoS must rely on relatively invisible mechanisms to maintain it.

Directed SoS:
- Created to Fulfill Specific Purpose
- Dedicated SoS Manager
- Subordinated Constituent Systems

Acknowledged SoS:
- Recognized SoS Objectives
- Designated SoS Manager & Resources
- Independent Constituent Systems

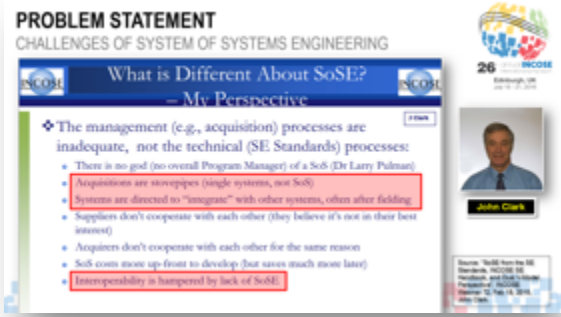
Collaborative SoS:
- Agreed Upon Central Purpose
- Voluntary Interaction
- Independent Constituent Systems

Virtual SoS:
- Lacks Central Management
- Lacks Agreed Upon Purpose
- Large Scale Emergent Behavior


Directed SoS
SoS Manager
Owner #1
Owner #2
Owner #n
Subordinated Constituent System
Subordinated Constituent System
Subordinated Constituent System
Owner #1
Owner #2
Owner #n
Voluntary Collaboration
Independent Constituent System
Independent Constituent System
Independent Constituent System
Collaborative SoS
Acknowledged SoS
SoS Manager
Owner #1
Owner #2
Owner #n
Independent Constituent System
Independent Constituent System
Independent Constituent System
Owner #1
Owner #2
Owner #n
Independent Constituent System
Independent Constituent System
Independent Constituent System
Virtual SoS

SYSTEM OF SYSTEMS ENGINEERING

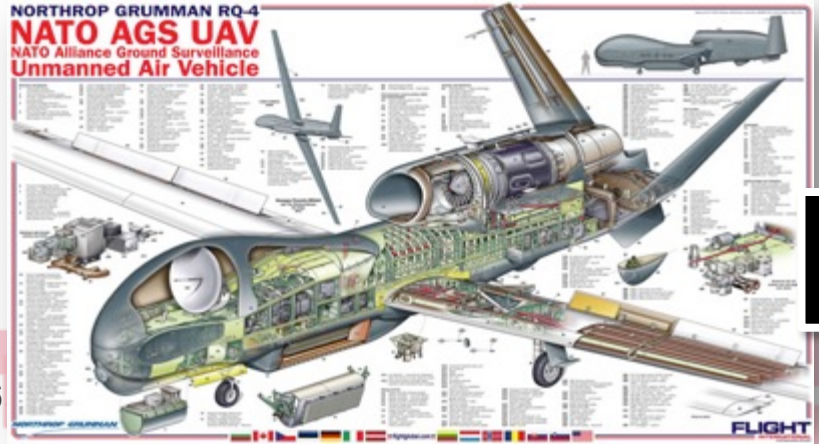
TRADITIONAL ACQUISITION



System Boundary

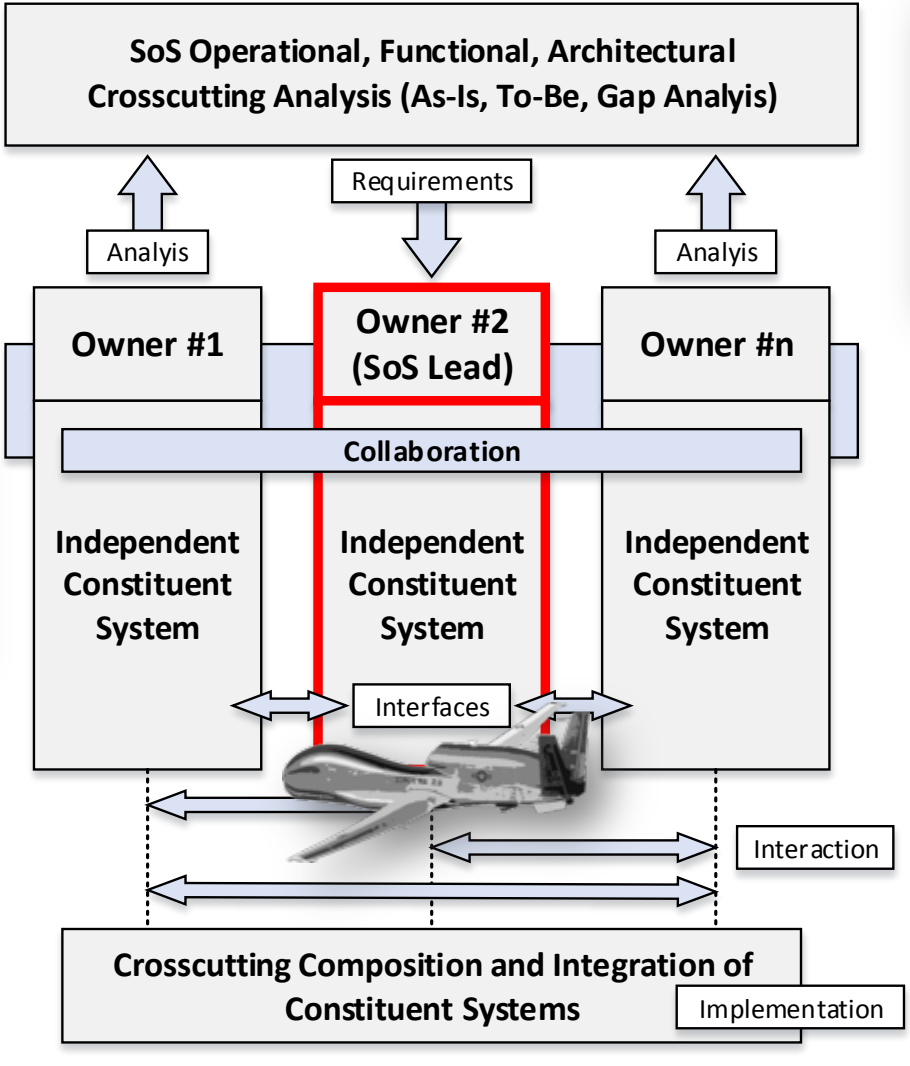
Stovepiped Acquisition

Independent Constituent System



Focus on Constituent System Engineering

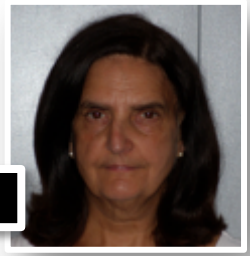
ENGINEERING CONSTITUENT SYSTEMS WITHIN CONTEXT



Focus on System of Systems Engineering

SYSTEM OF SYSTEMS ENGINEERING

SYSTEM OF SYSTEMS ENGINEERING (SoSE)



Judith Dahmann

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SEBoK: Comparing Systems and SoS

	SE	SoS SE
		Management/Oversight
System	Physical engineering	Socio-technical management and engineering
Stakeholder Involvement	Clear set of stakeholders	Multiple levels of stakeholders with mixed and possi
Governance	Aligned management and funding	Added levels of complexity due to management and systems; SoS does not have control over all constitu
		Operational Focus (Goals)
Operational Focus	Designed and developed to meet common objectives	Called upon to meet new SoS objectives using syste may not align with the SoS objectives
		Implementation
Acquisition/ Development	Aligned to established acquisition and development processes	Cross multiple system lifecycles across asynchronou efforts, involving legacy systems, developmental sys
Process	Well-established	Learning and Adaptation
Test and Evaluation	Test and evaluation of the system is possible	Testing is more challenging due to systems' asynchr complexity of all the parts
		Engineering and Design Considerations
Boundaries and Interfaces	Focuses on boundaries and interfaces	Focus on identifying systems contributing to SoS ob data, control and functionality across the SoS while OR focus on interactions between systems. Difficult
Performance and Behavior	Performance of the system to meet performance objectives	Performance across the SoS that satisfies SoS use needs of the systems
Metrics	Well defined (e.g., INCOSE handbook)	Difficult to define, agree, and quantify

SEBoK: Socio-Technical Aspects of SoS

- SoSE often entails more than simply integrating physical systems but also incorporates integration of the people and processes associated with the constituent systems
- SoSE needs to consider both
  - The operating processes of the consti… hese will affect the SoS as well as
  - The development processes of the constituent systems including their current state of development (e.g., in development, fielded, evolving) and how this affects their ability to change to meet SoS needs.
- Finally, many SoS are in effect socio-technical systems composed of interdependent resources, including people, processes, information, and technology expanding the concerns for SoSE beyond the technical.

Socio-Technical Aspects

Integration of People & Processes

Integration of Physical Systems

SoS Operational, Functional, Architectural Crosscutting Analysis (As-Is, To-Be, Gap Analyis)

Requirements

Analyis

Analyis

Owner #1

Owner #2 (SoS Lead)

Owner #n

Collaboration

Independent Constituent System

Independent Constituent System

Independent Constituent System

Interfaces

Interaction

Crosscutting Composition and Integration of Constituent Systems

Implementation

PROGRESS

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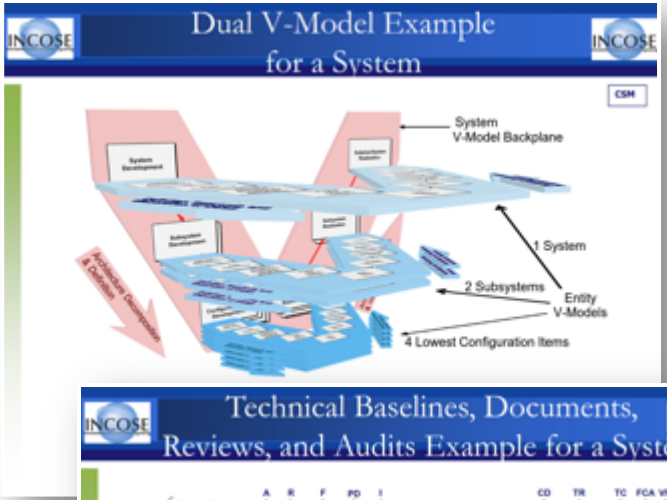
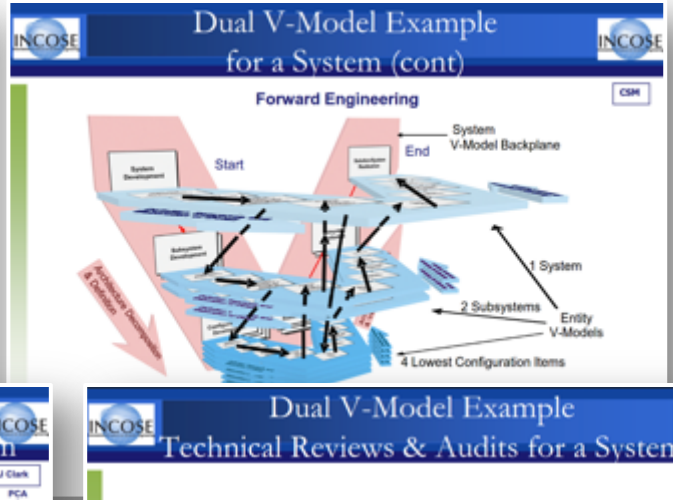
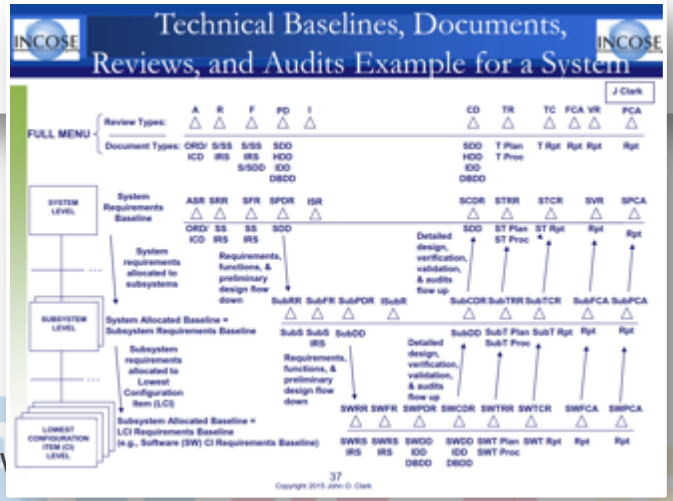
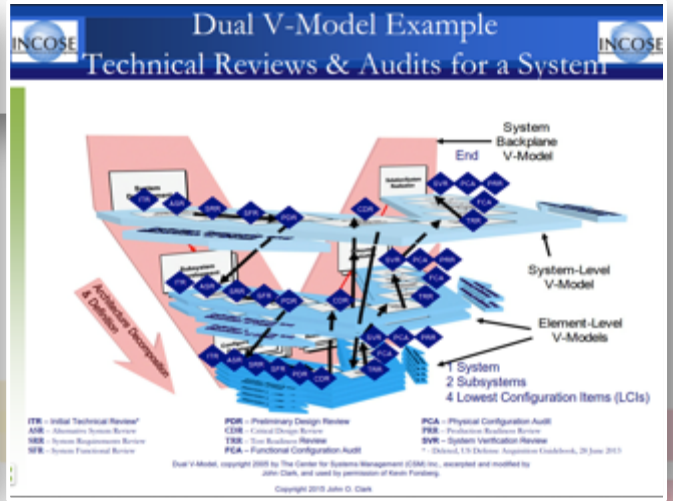
SoS-VEE Model: SIMPLE, MODULAR & SCALABLE

BENCHMARK: DUAL-VEE MODEL





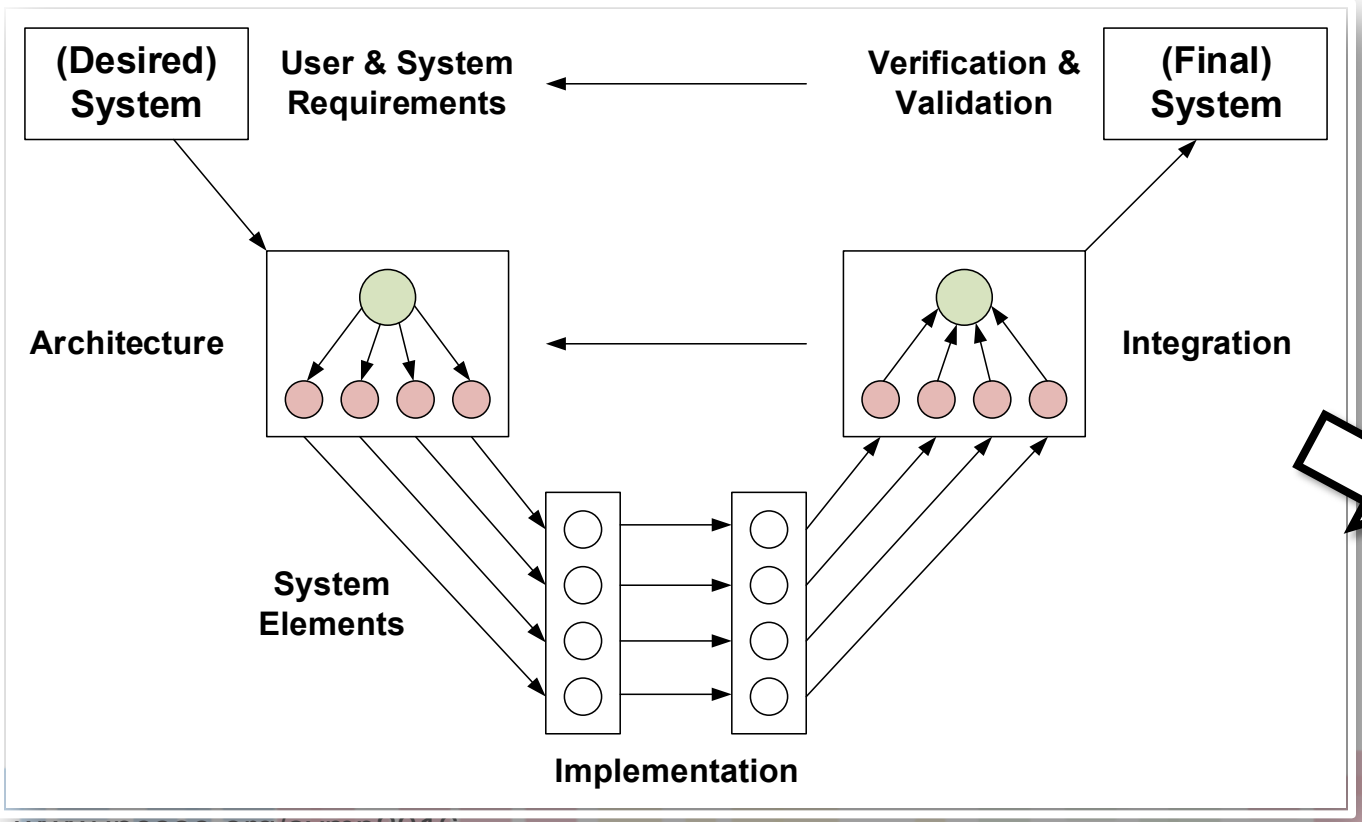




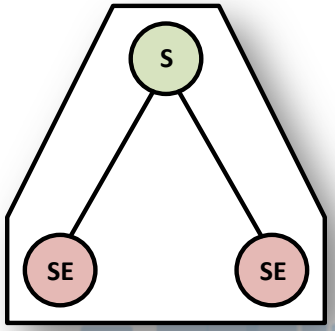
Source: "SoSE from the SE Standards, INCOSE SE Handbook, and Dual V-Model Perspective", INCOSE Webinar 72, Feb 18, 2015, John Clark

SoS-VEE Model

CREATING THE MAIN BUILDING BLOCK



Main Building Block



SoS-VEE Model

CREATING THE MAIN BUILDING BLOCK (CONT'D)

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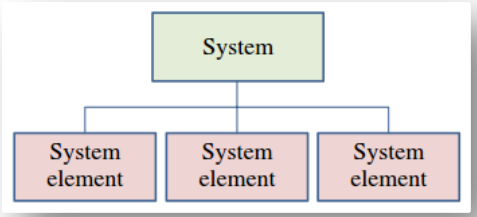
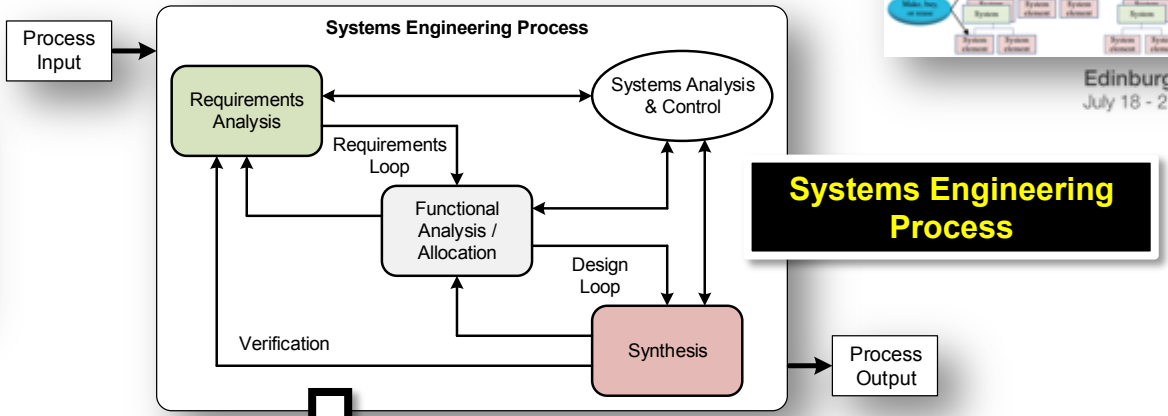
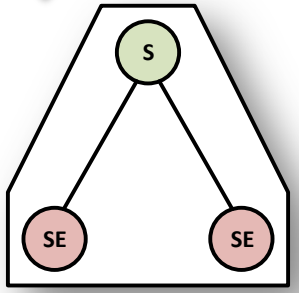




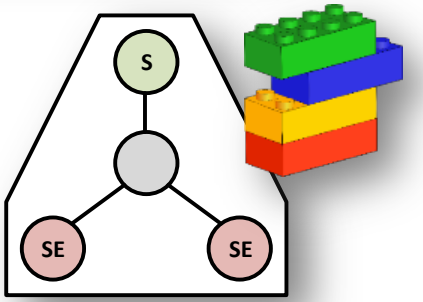
Systems Engineering Process

System

System Element



- Stakeholder Needs & Requirements (SNR)
- System Requirements
- Architecture Definition Process (AD)



SoS-VEE Model

ITERATION AND RECURSION PRINICPLES

Garry Roedler

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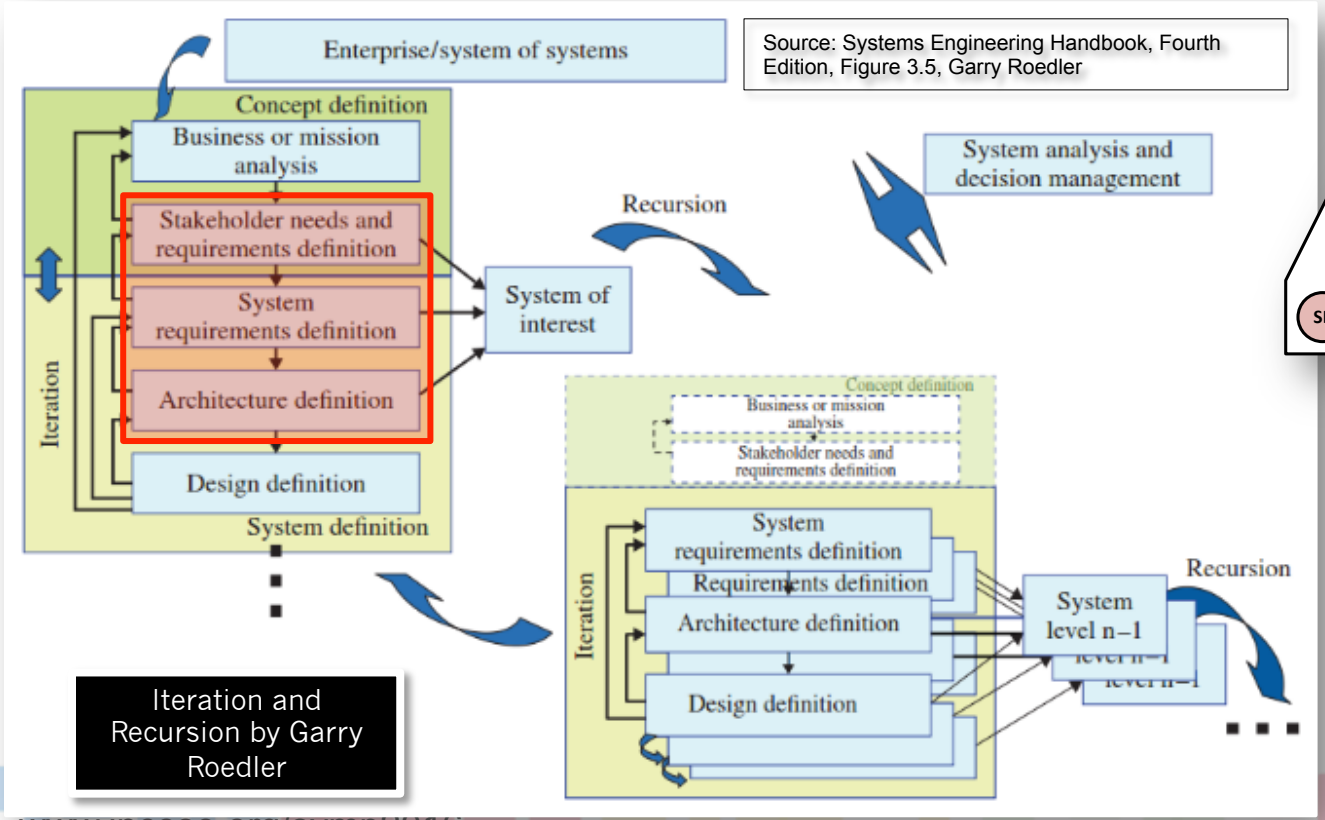
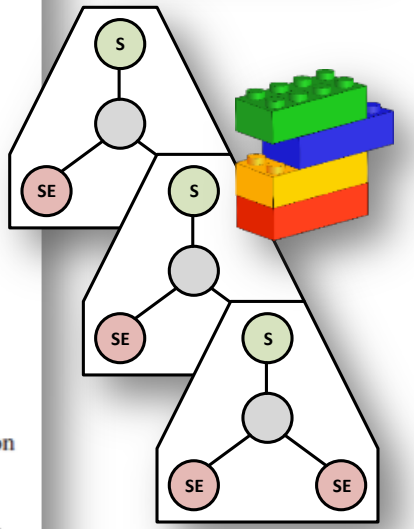


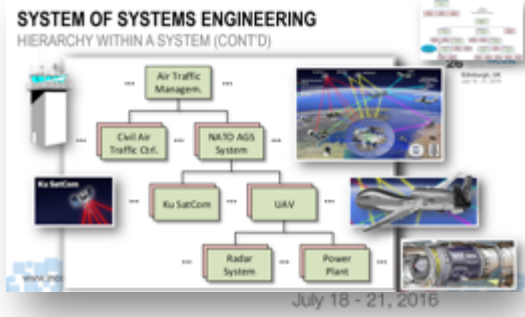
Iteration and Recursion by Garry Roedler

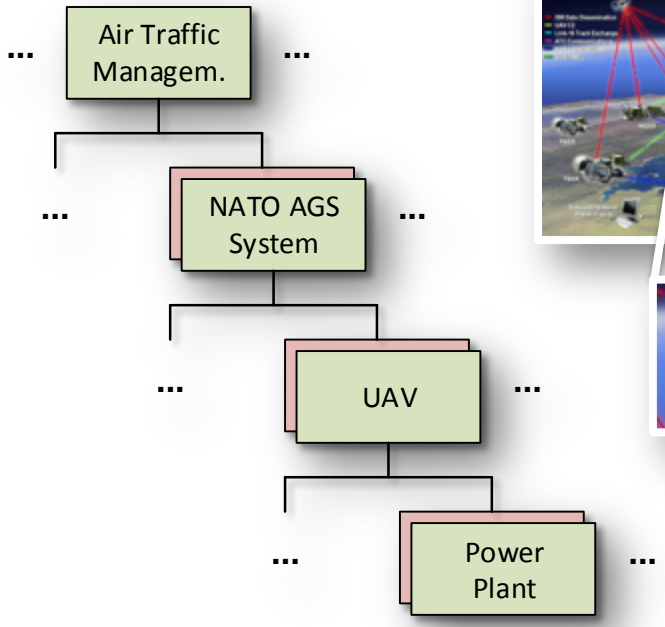


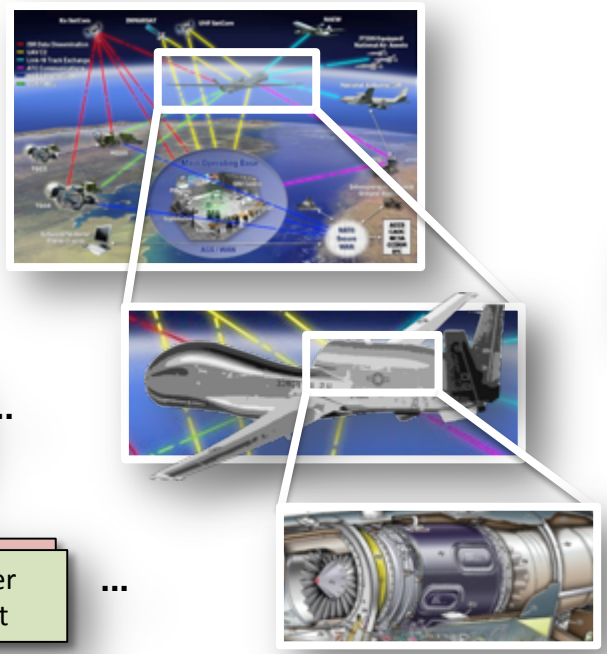
Apply to SoS-VEE Model

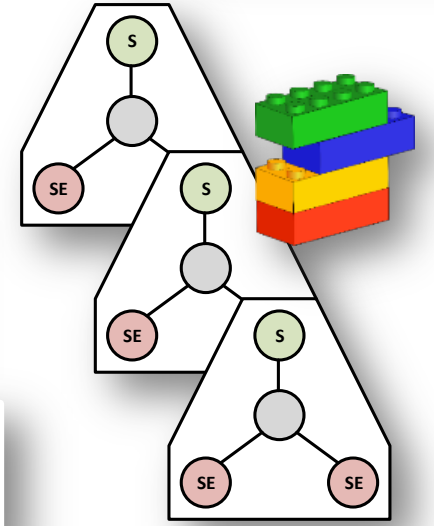
SoS-VEE Model

APPLIED SYSTEM HIERARCHY, ITERATION & RECURSION



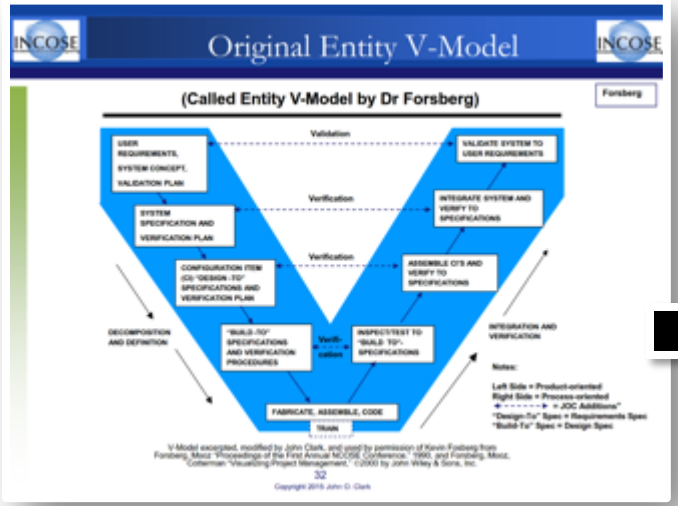




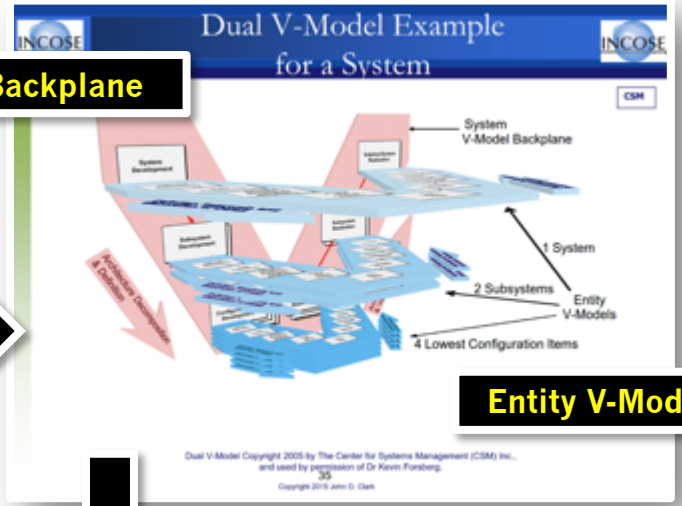


SoS-VEE Model

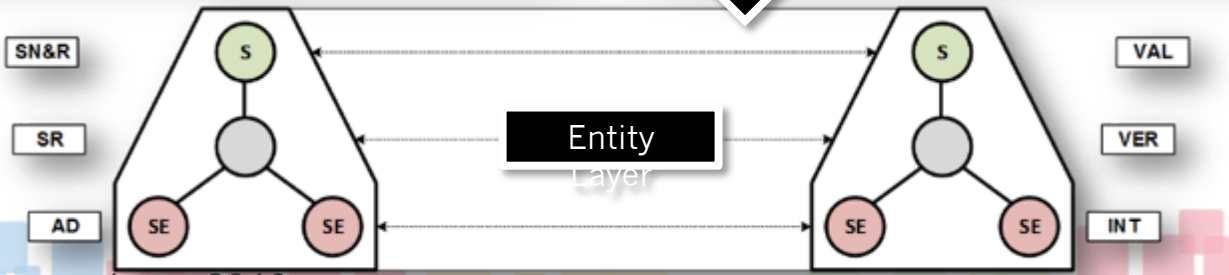
CREATING THE ENTITY LAYER



Backplane



Entity V-Model



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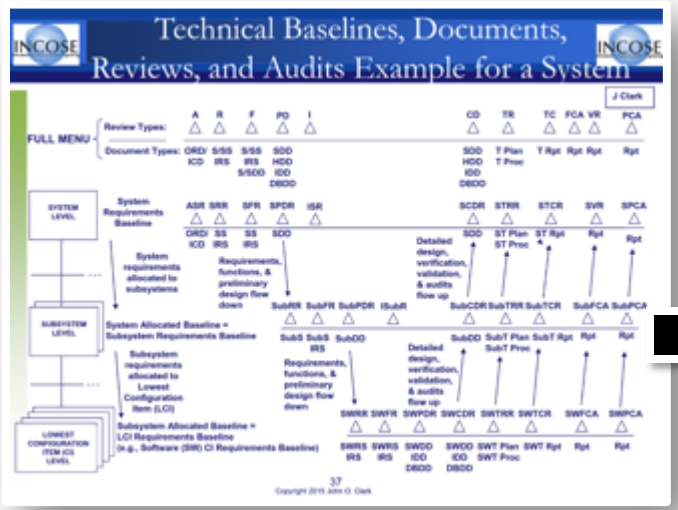
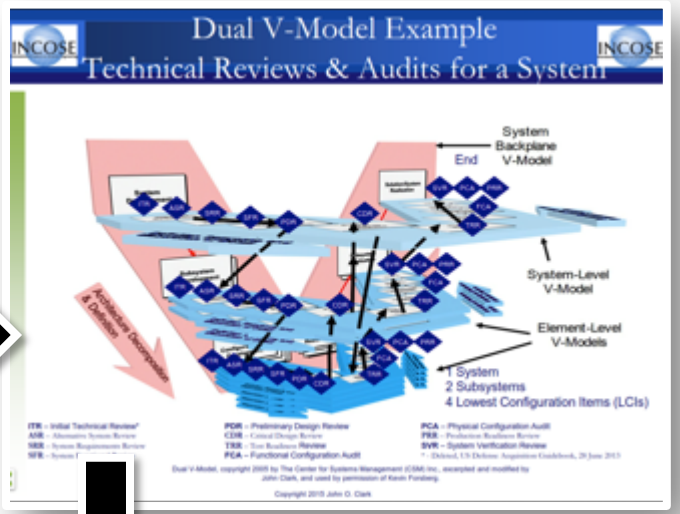
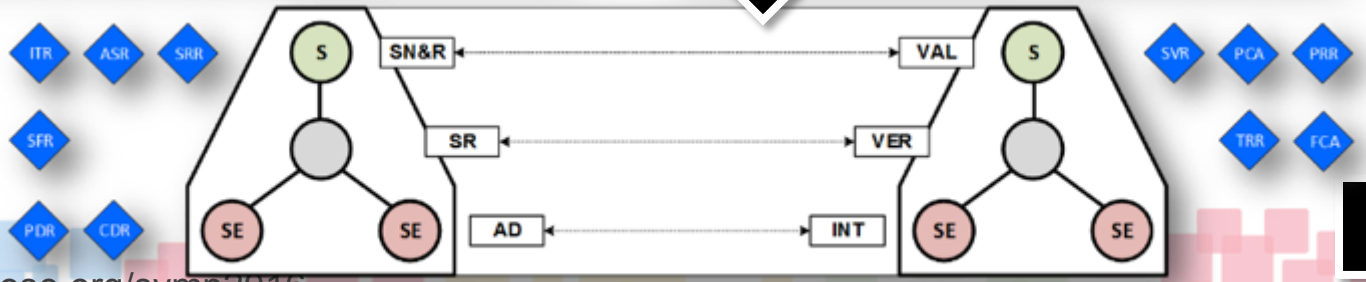
SoS-VEE Model

ASSIGN **REVIEW & AUDIT MILESONES**



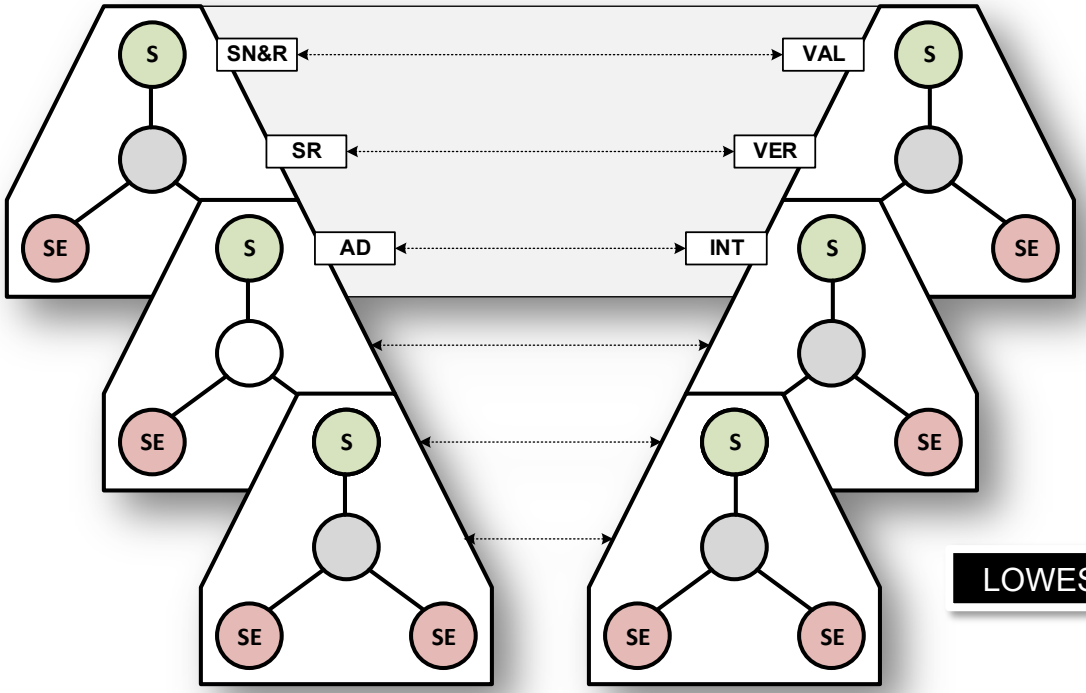




Review & Audit Milestones

SoS-VEE Model

BUILDING THE SYSTEM HIERARCHY



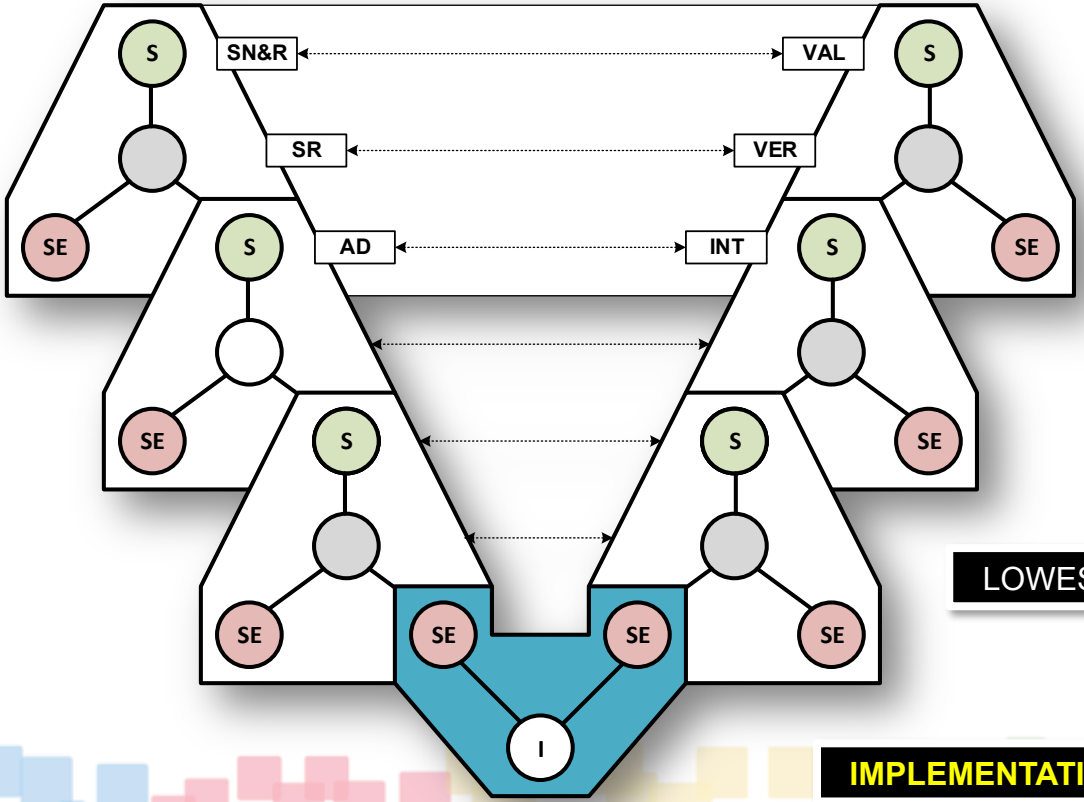
SYSTEM

SUBSYSTEM

LOWEST CONFIGURATION ITEM

SoS-VEE Model

IMPLEMENTATION OF SYSTEM ELEMENTS



SYSTEM

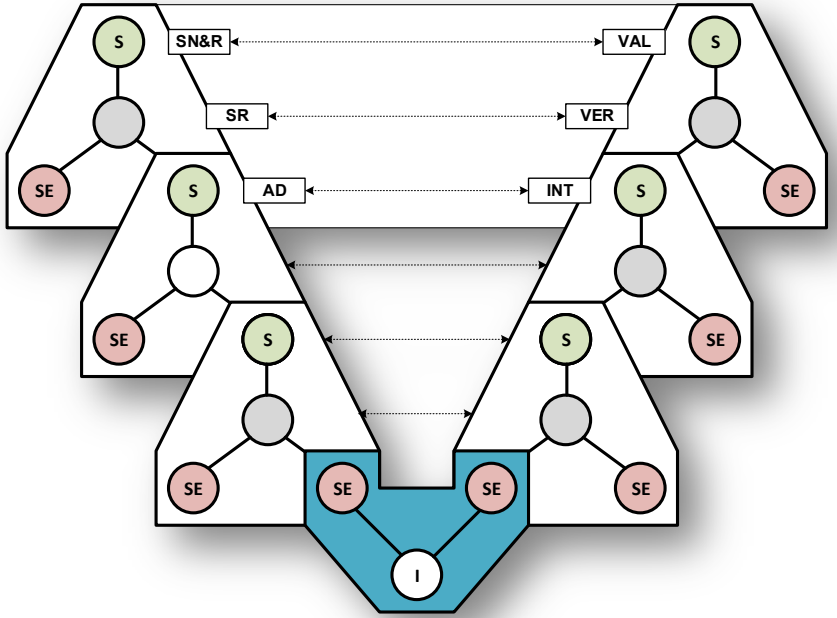
SUBSYSTEM

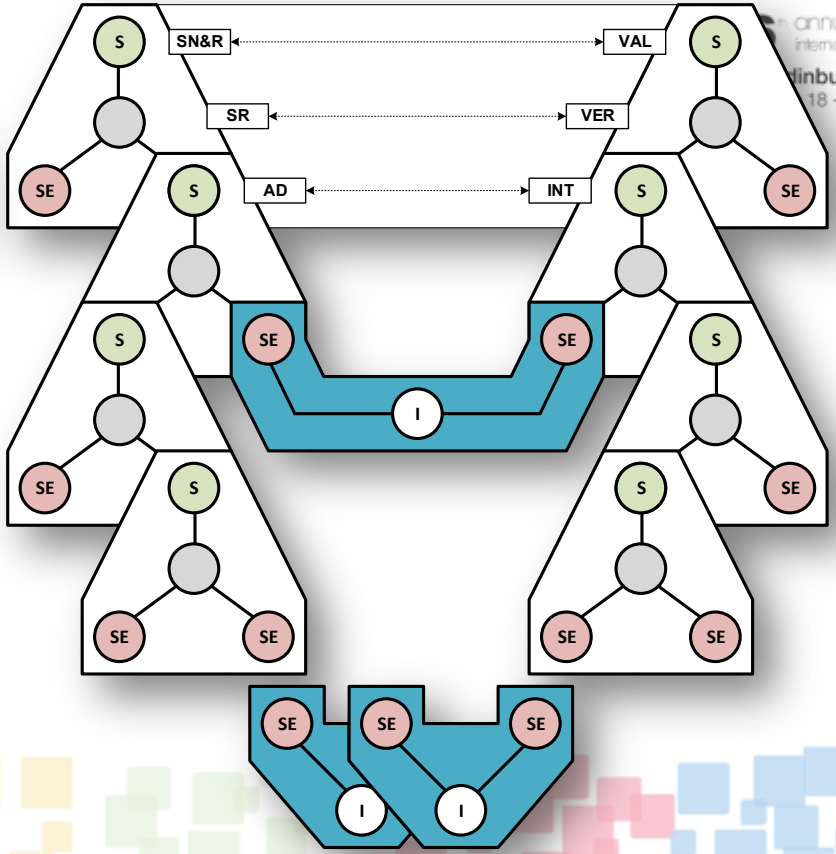
LOWEST CONFIGURATION ITEM

IMPLEMENTATION

SoS-VEE Model

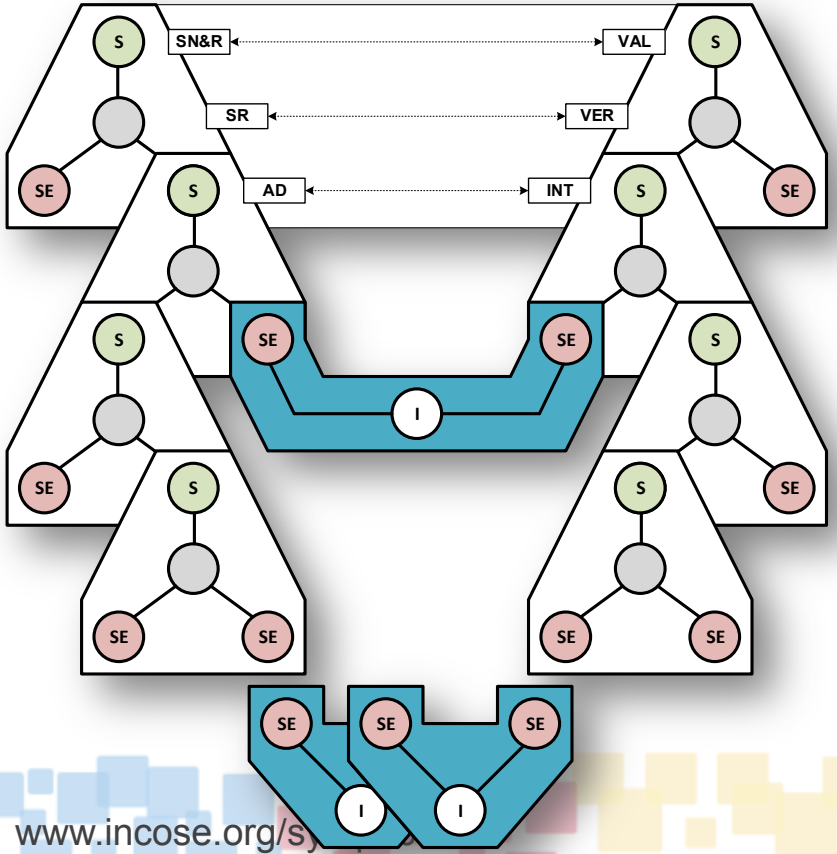
IMPLEMENTATION AT ANY LEVEL

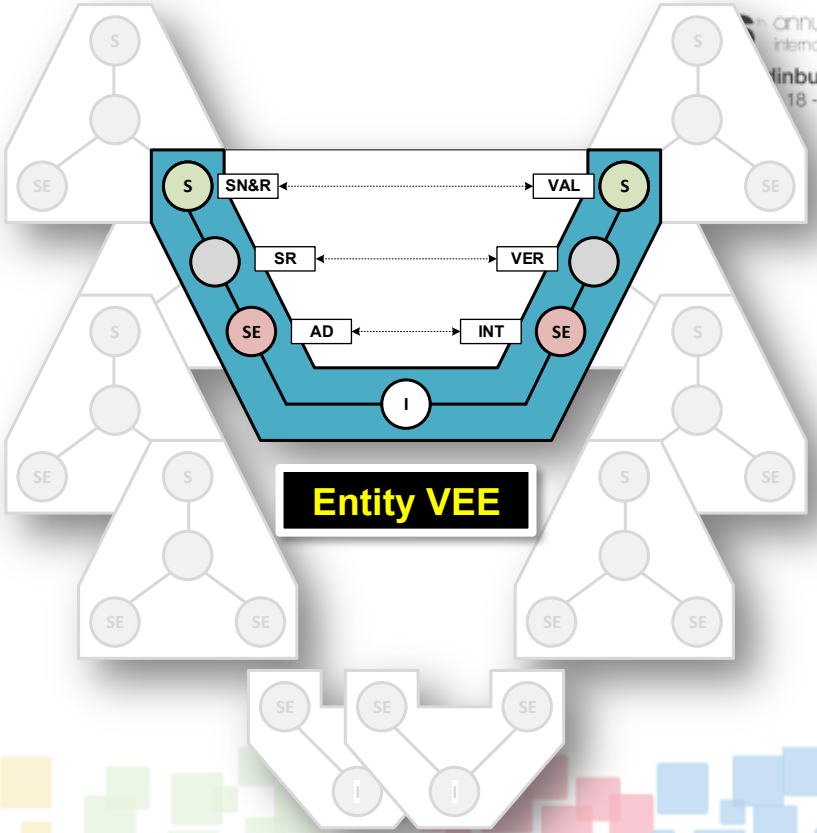




SoS-VEE Model

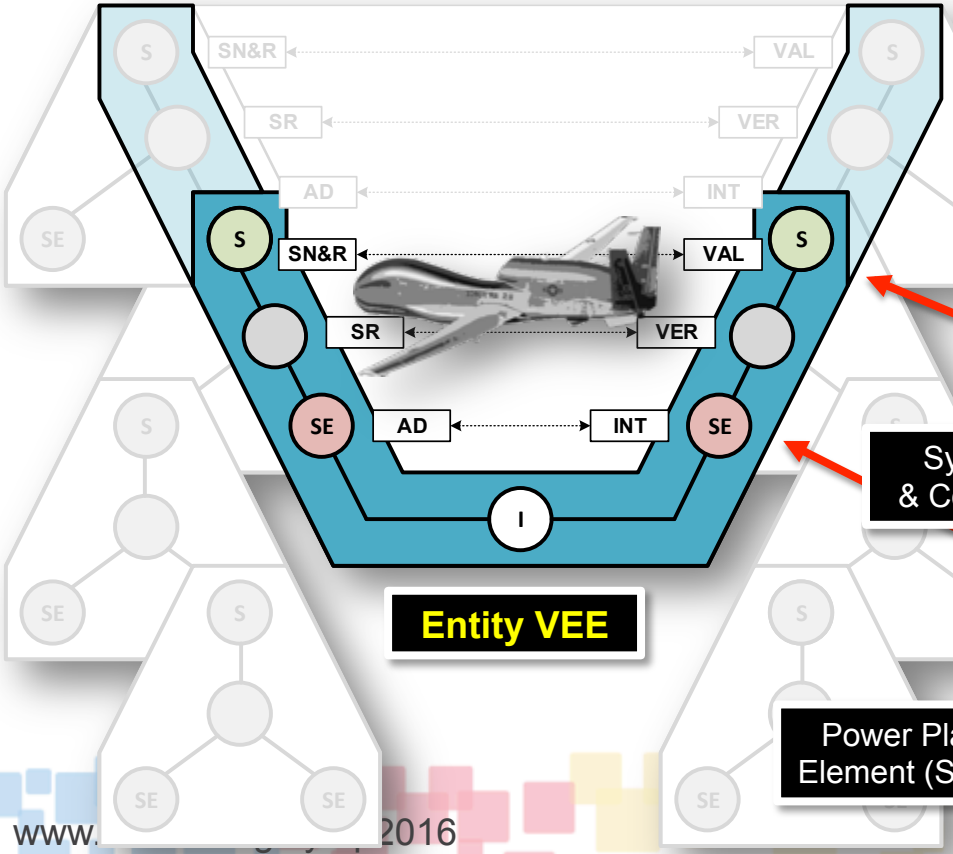
ENTITY VEE





SoS-VEE Model

APPLICATION TO NATO AGS SoS



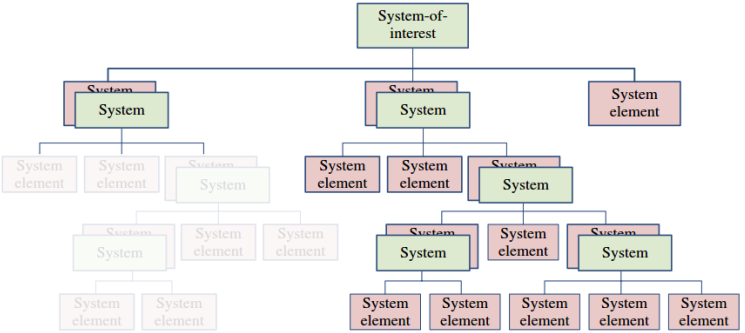
System of Systems

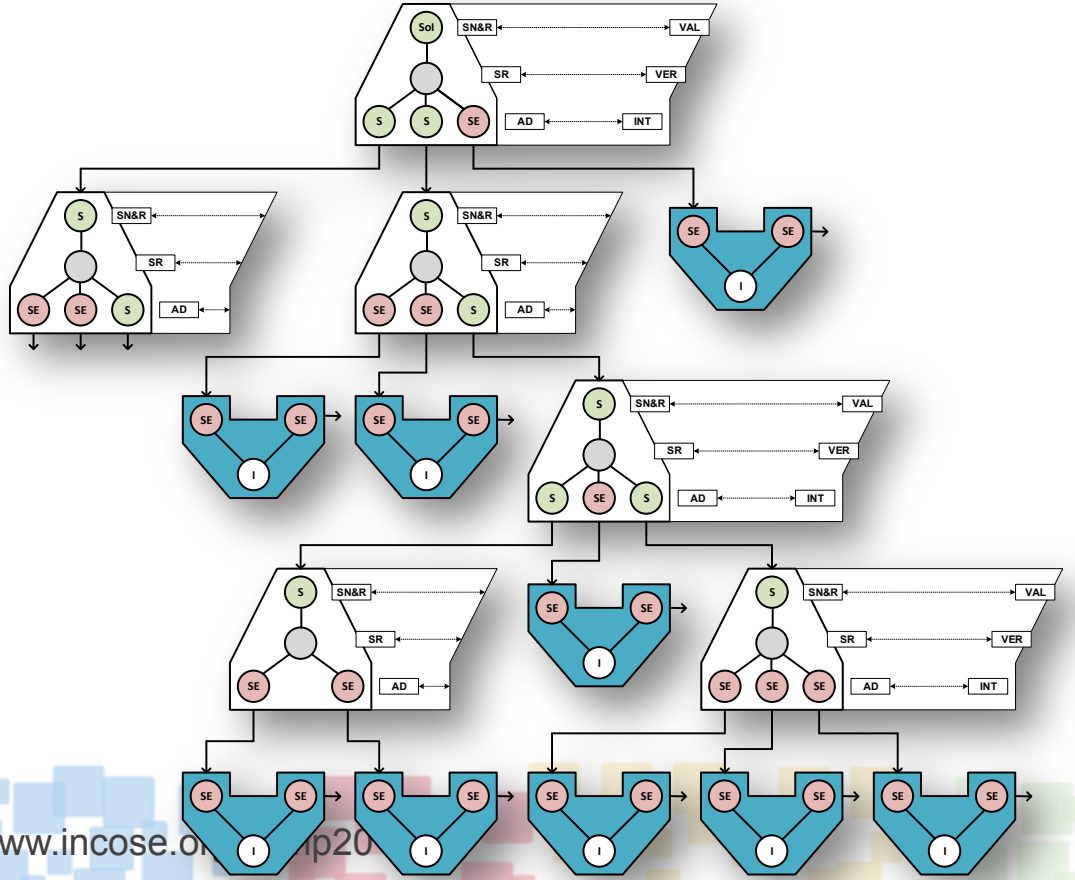
System of Interest & Constituent System

Power Plant as a System Element (SE) of the UAV CS

SoS-VEE Model

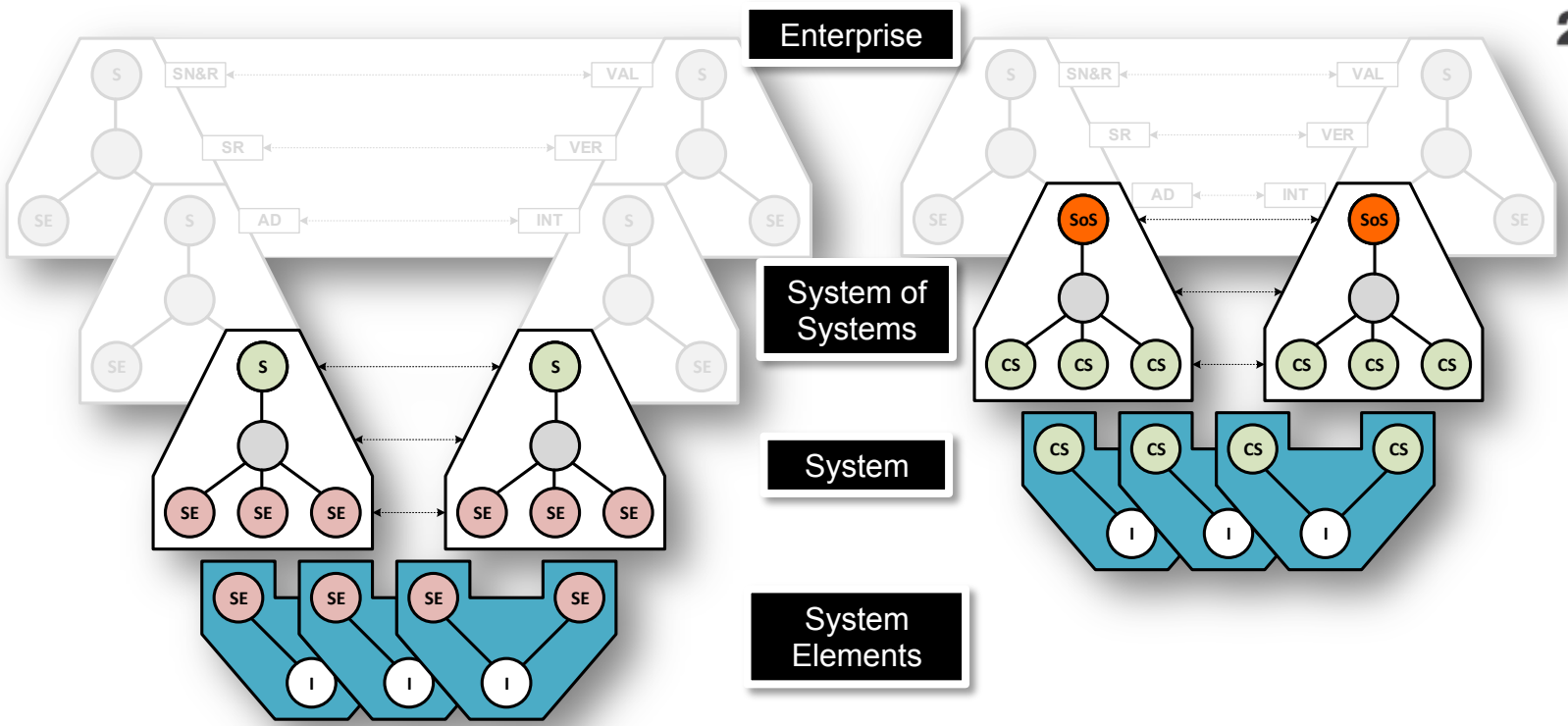
COMPLEX SYSTEM OF SYSTEMS HIERARCHIES





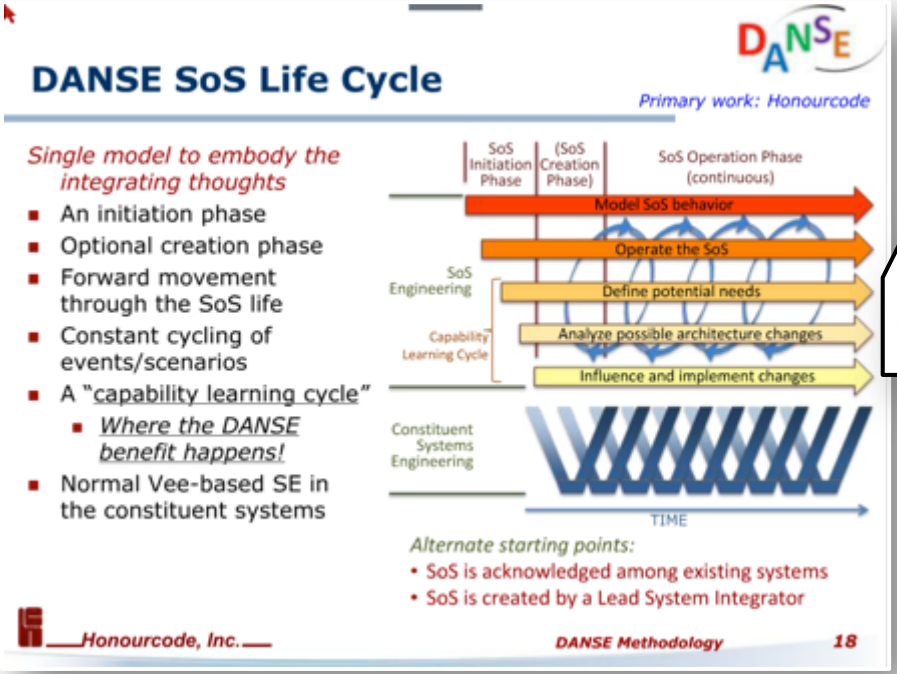
SoS-VEE Model

SHAPING THE GENERAL FORM DEPICTION OF THE MODEL

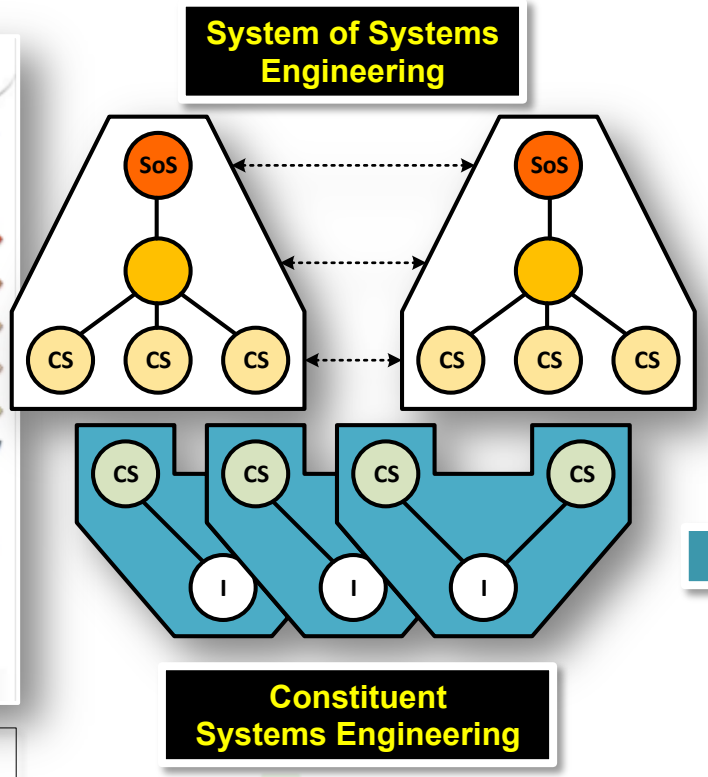


SoS-VEE Model

ALIGNMENT WITH DANSE SoS LIFE-CYCLE



Source: "DANSE – Final Report on SoS Methodology and Tools", INCOSE SoS WG Series, June 26, 2015, Eric Honour



Operation

Needs

Architecture

VEE Based SE

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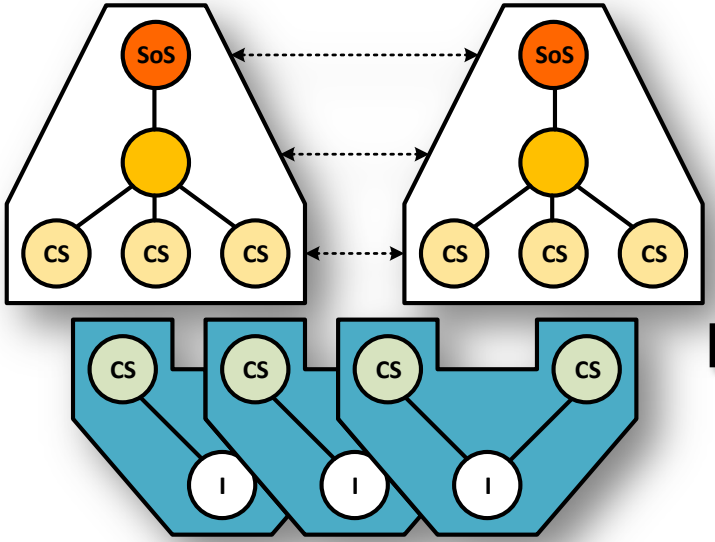
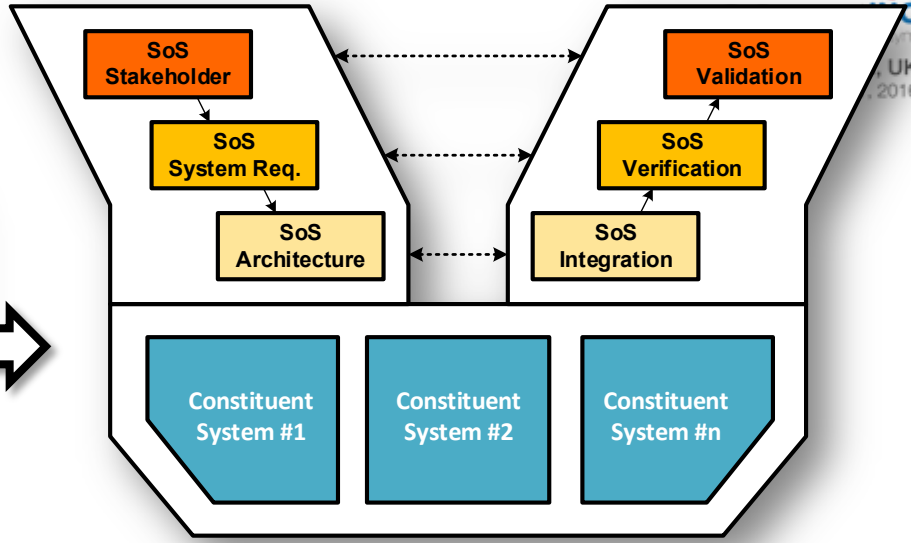
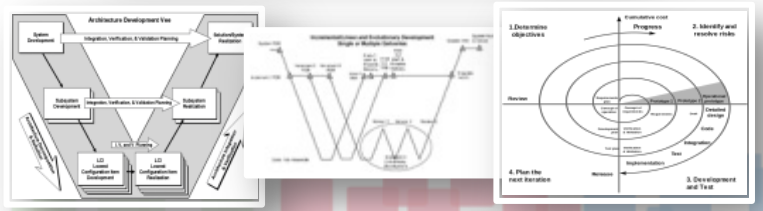
SoS-VEE Model

ENABLING INDIVIDUAL CONSTITUENT SYSTEM DEV. LIFE-CYCLES

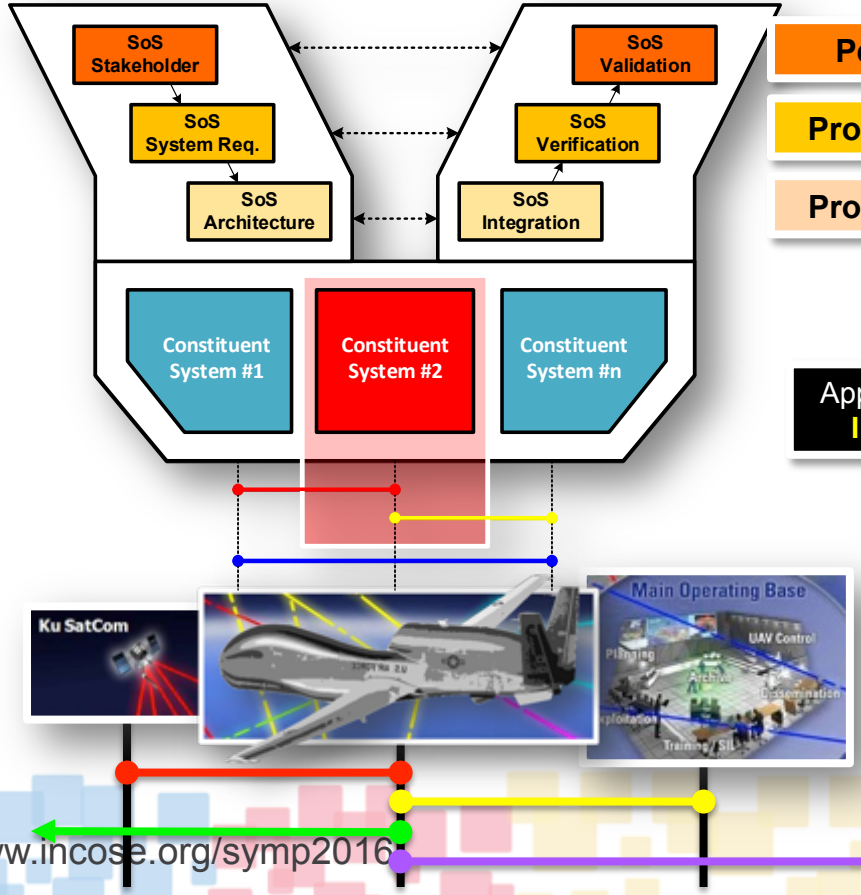






SoS-VEE Model

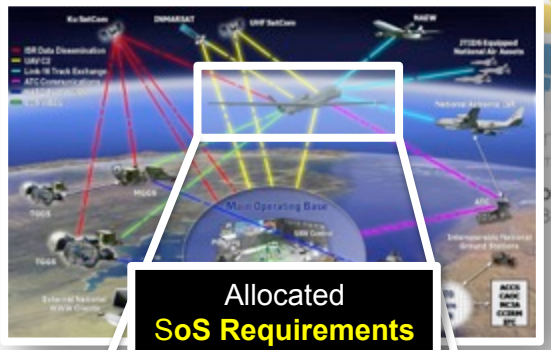
INTEGRATION OF SOCIA-TECHNICAL ASPECTS



People

Processes

Product(s)



Allocated SoS Requirements

Applicable SoS Interfaces

Air Traffic Control (ATC)

Integration of People & Processes

SoS Operational, Functional, Architectural Crosscutting Analysis (As-Is, To-Be, Gap Analyis)

Requirements

Analyis

Analyis

Owner #1

Owner #2 (SoS Lead)

Owner #n

Integration of Physical Systems

Collaboration

Independent Constituent System

Independent Constituent System

Independent Constituent System

Interfaces

Interaction

Crosscutting Composition and Integration of Constituent Systems

Implementation

People

Processes

Product(s)

SoS Stakeholder

SoS System Req.

SoS Architecture

SoS Validation

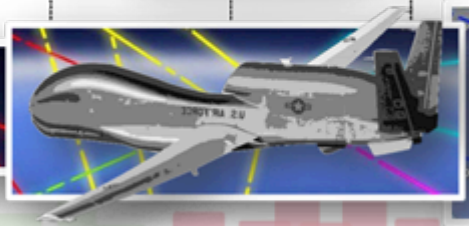
SoS Verification

SoS Integration

Constituent System #1

Constituent System #2

Constituent System #n



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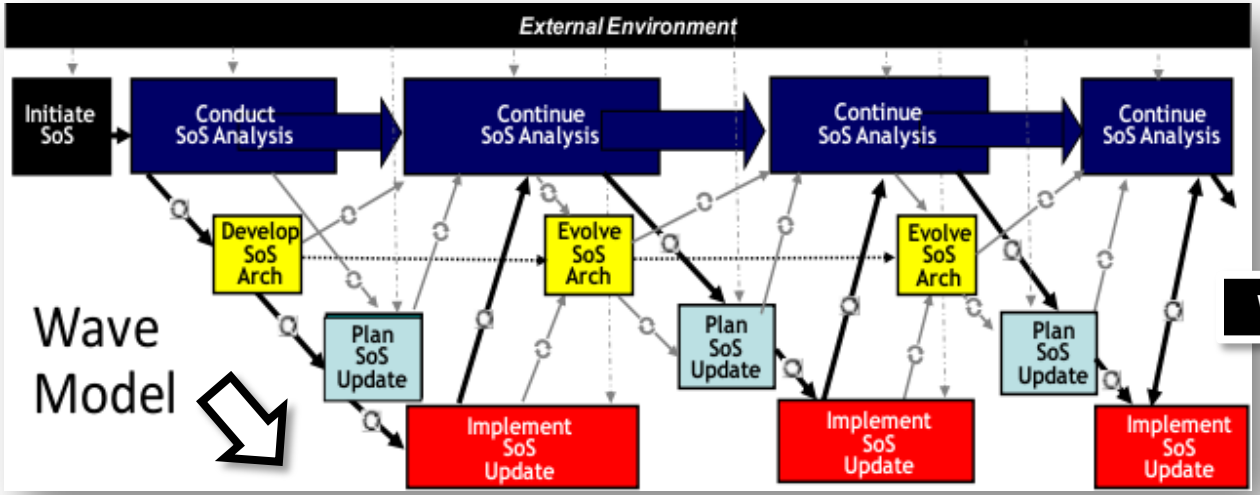
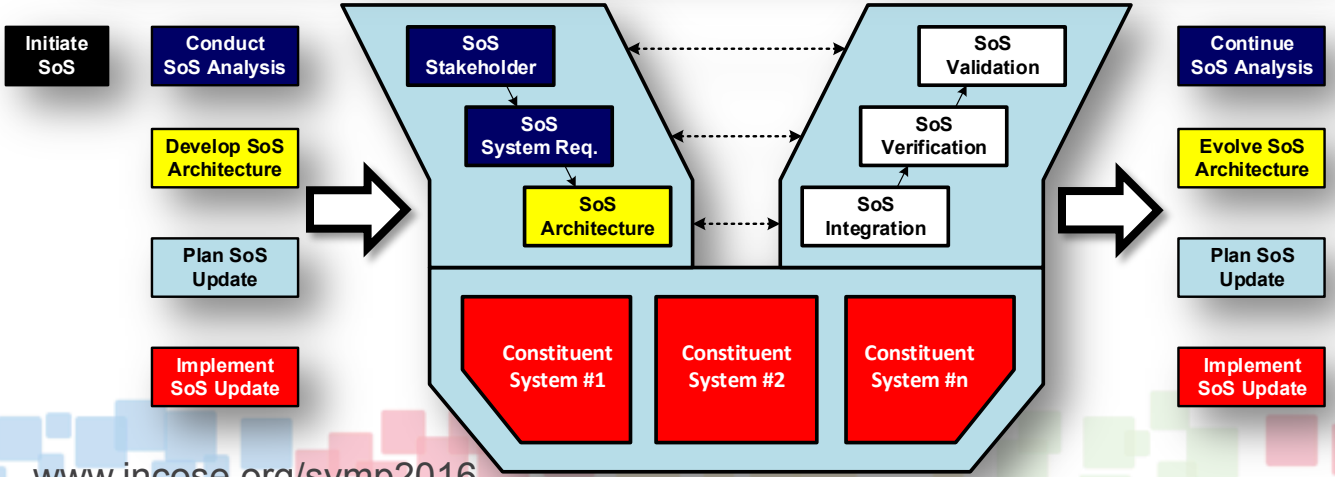


Wave Model



Process behind each Wave

SoS-VEE Model

CONLUSIONS & SUMMARY

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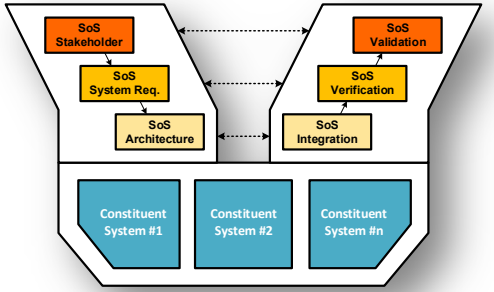
- Failure to consider SoSE (context) early and throughout the acquisition can result in significant risk to the effectiveness and fielding of systems
- **The SoS-VEE Model:**
  - Offers a simple, modular, and scalable engineering tool
  - Focuses on early SoSE activities (stakeholder needs, system requirements, architecture)
  - Addresses the socio-technical aspects of integrating people, processes, and products associated with the constituent system(s)
  - Based on VEE model principles
  - Focuses on SoSE behavior, defines Constituent System requirements & interfaces
  - Aligns with governing SE and SoSE principles (SE process, system hierarchy, iteration, recursion, recursion, DANSE SoS Life Cycle, Wave Model, etc.)

IMAGINE WHAT COULD HAVE BEEN …

Source: http://www.luftwaffe.de/portal/a/luftwaffe/!ut/p/c4/NYq5DsIwEAX_aNcJUojoOBSgCR0QuiWxIku-tFmTho_HLngjTTMPX5jx9DEziQmeLD5xGM3uvYJdQTQ5qFWtok0LJFrwUf6ThjF4LcWivZjsmUkCQwwstpTEnAuYCQdVnQ6qUf9V3_Zy787H7aa59t0No3P7HzlRsZQ!/

SoS-VEE Model
QUESTIONS & ANSWERS



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