Paper # 157_S

Designing & Evaluating Agile C2 Systems Based on Service Oriented Architectures*

Ashraf M. Abusharekh <aabushar@gmu.edu>
Lee W. Wagenhals <lwagenha@gmu.edu>
Alexander H. Levis <alevis@gmu.edu>

14th International Command and Control Research and Technology Symposium
Washington, DC
Jun 15-17, 2009

** This work was supported by the Office of Naval Research under grant N00014-06-1-0081*

Outline

- Introduction & Background
- SOA Environment
- SOA Federation Structure
- Architecting Process
  - Architecture Design
  - Analysis & Evaluation
  - Architecture Deployment
- Case Study
  - Airborne Theater Ballistic Missile Interceptor System (ATIS)
- Conclusions & Future Work

Introduction & Background (1)

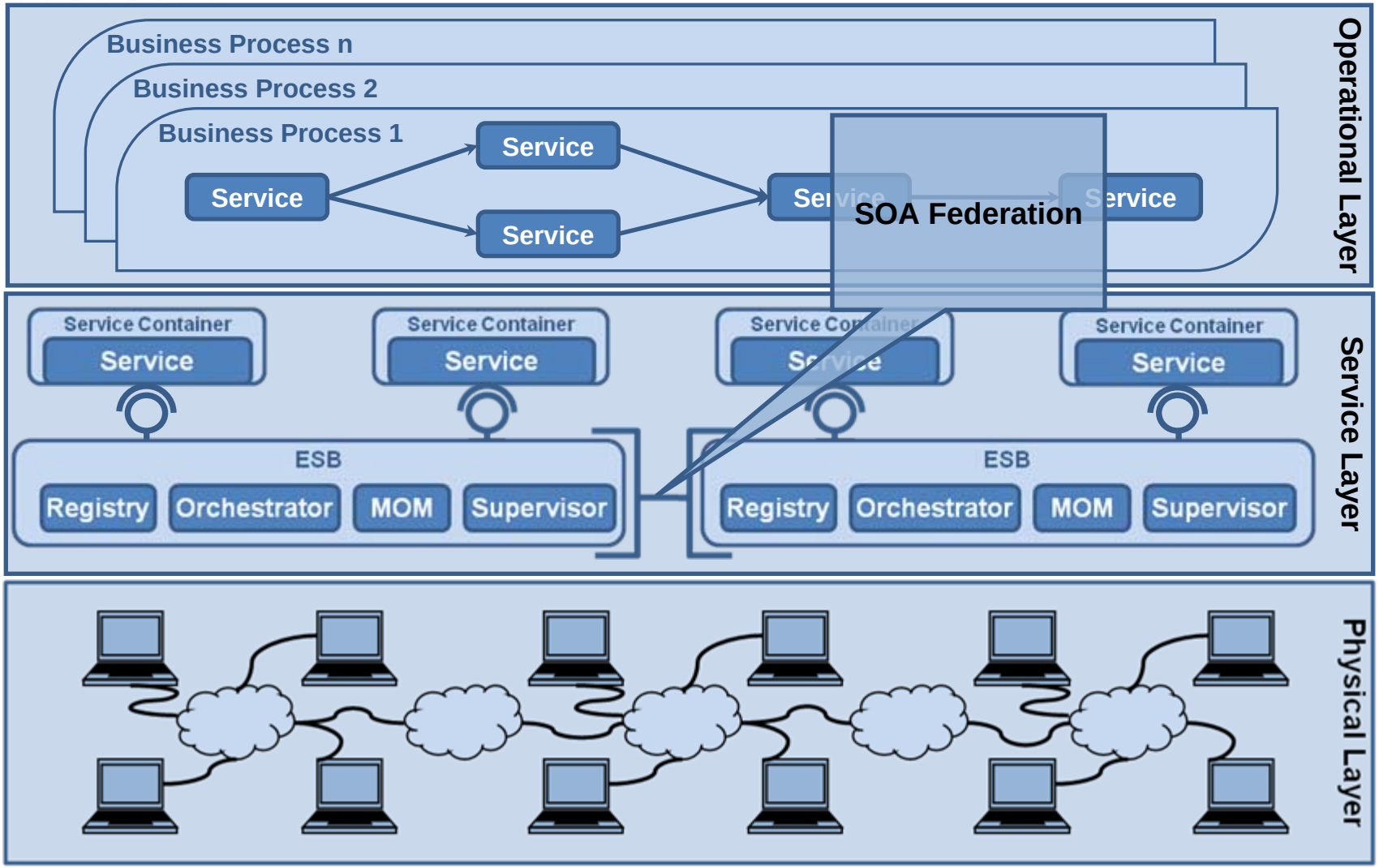
- **A key to Command and Control (C2) agility is EFFECTIVE information sharing.**
- **DoD defined a set of concepts, objectives and strategies to achieve Net-Centric Operations (NCO)**
  - **Concepts**
    - **Populate Net-Centric Environment (NCE).**
    - **Utilize the Net-Centric Environment.**
    - **Accommodate un-anticipated users.**
    - **Promote the use of Communities of Interest (COI).**
    - **Support shared infrastructure.**
  - **Strategies**
    - **Net-Centric Data Strategy.**
    - **Net-Centric Services Strategy.**
- **DoD views architectures as the mechanism for designing solutions to transform to NCO**
- **DoDAF v.1.5 is focused on data centricity and uses the *Service Oriented Architecture* (SOA) paradigm as a key enabler for implementing NCO.**

Introduction & Background (2)

- **DoDAF v.1.5: All View (AV), Operational View (OV), Systems & Services View and Technical View**
- **How to construct an Event Driven Service Oriented Architecture compliant to DoDAF v1.5 ?**
- **The architecture (SOA) should:**
  - **Net-Centric Concepts**
    - **Populate NCE with new capabilities**
    - **Utilize existing NCE capabilities**
    - **Accommodate un-anticipated users**
    - **Promote the use of COI**
    - **Support shared infrastructure**

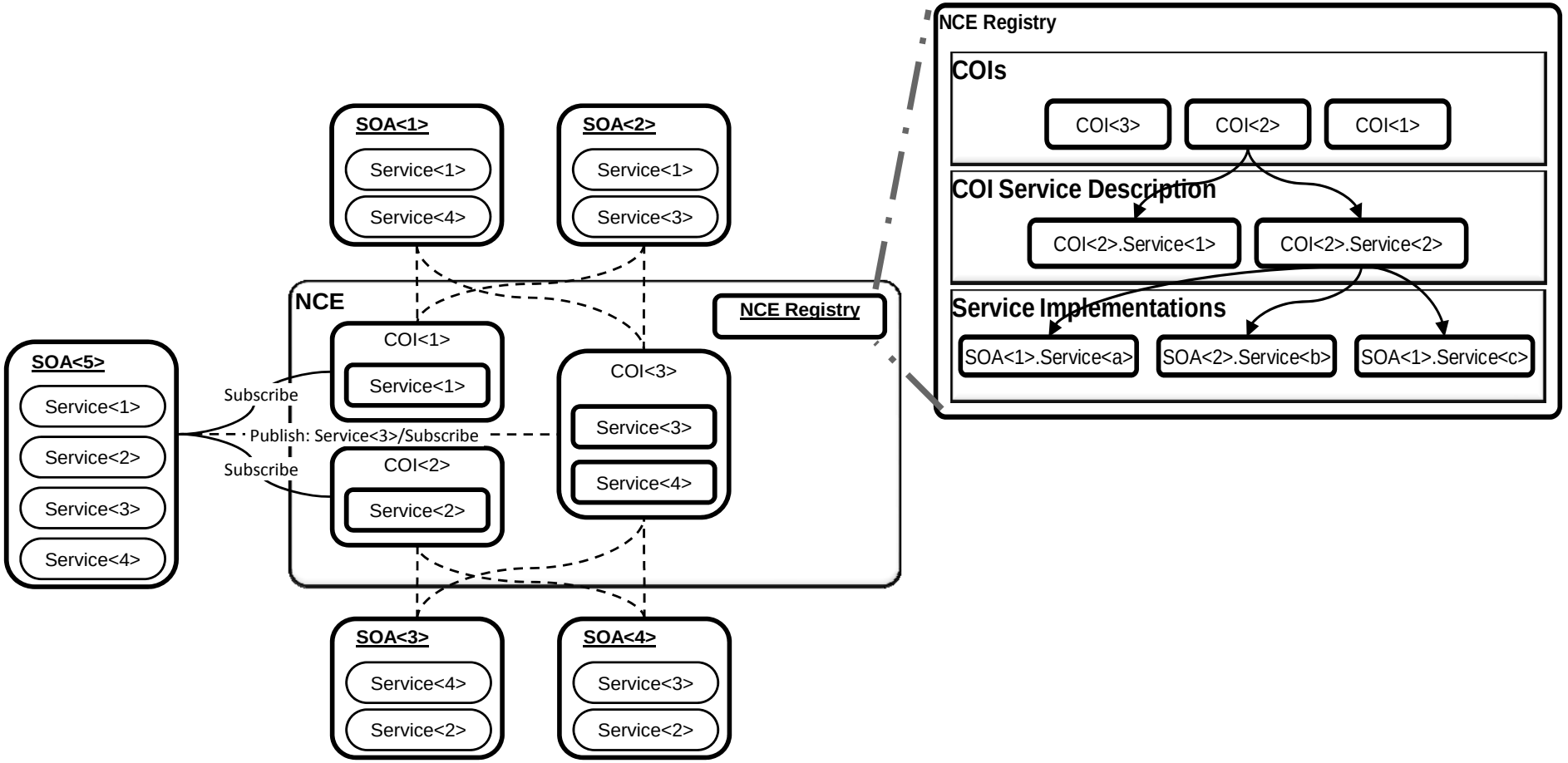
    SOA Federation
  - **Net-Centric Data Strategy**
    - **Make data visible, accessible, understandable, and trusted**
  - **Net-Centric Services Strategy**
    - **Provide and consume services from the NCE, govern these services and their infrastructure, and monitor and manage them**

SOA Federation Environment



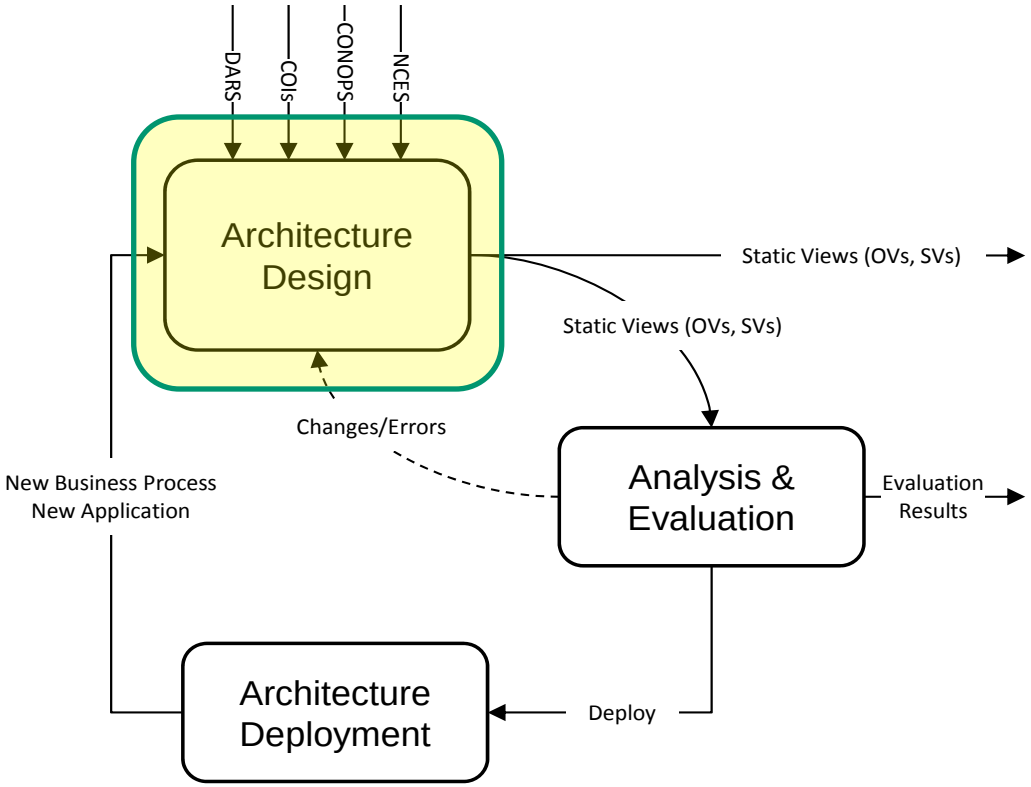
SOA Federation Structure

- ***The concept of Communities of Interest (COI) will be used to enable dynamic federation with pre-defined or un-anticipated users***



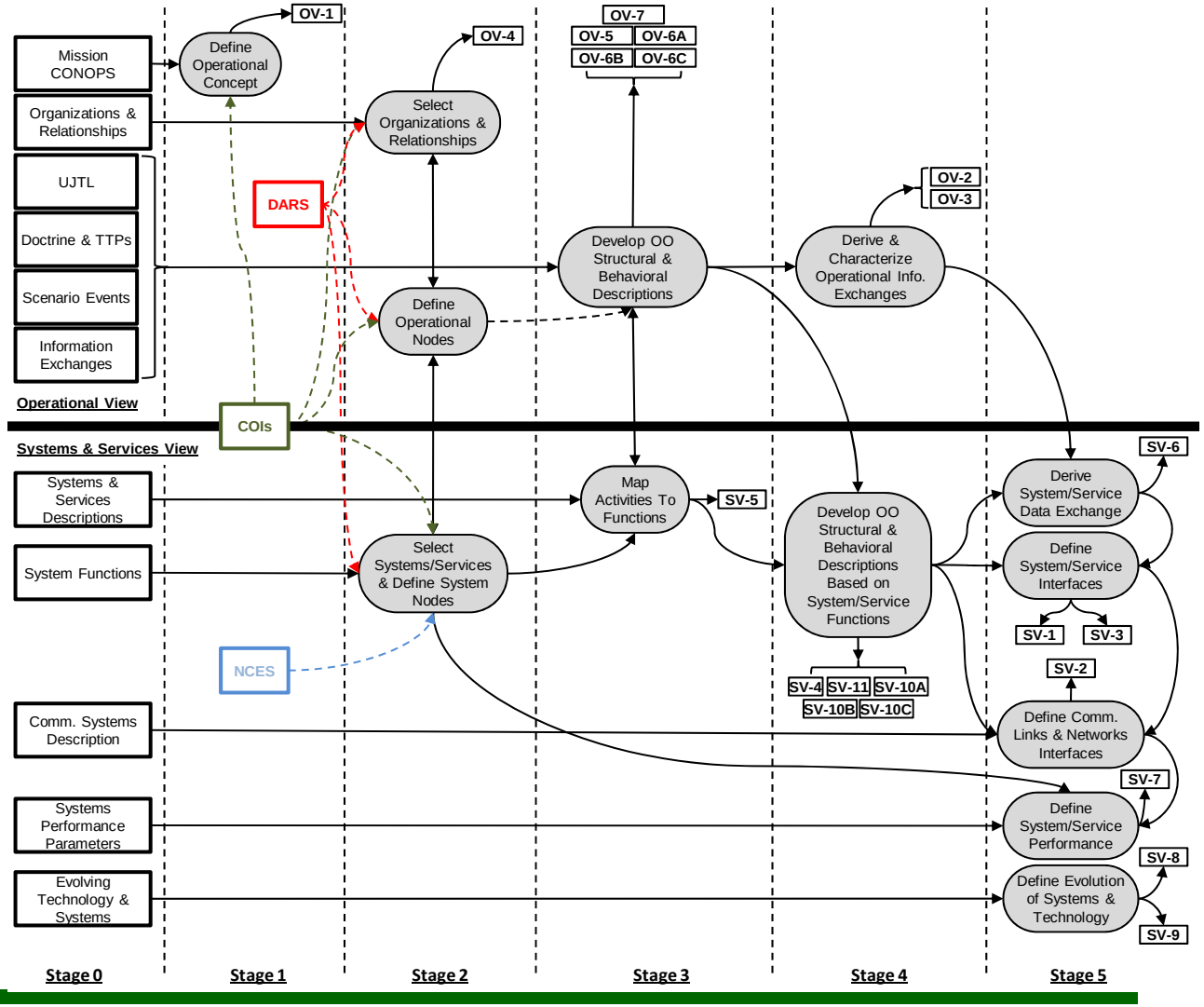
Architecting Process

- **Architecture Design phase: Produce DoDAF v.1.5 products**
- **Analysis & Evaluation phase:**
  - **Synthesize the executable model (EM).**
  - **Use it to evaluate and verify the architecture.**
  - **Reflect corrections or changes back in the DoDAF products**
  - **Compute Measures of Performance and Measures of Effectiveness of the architecture.**
- **Architecture Deployment phase: new processes will trigger the design process again**



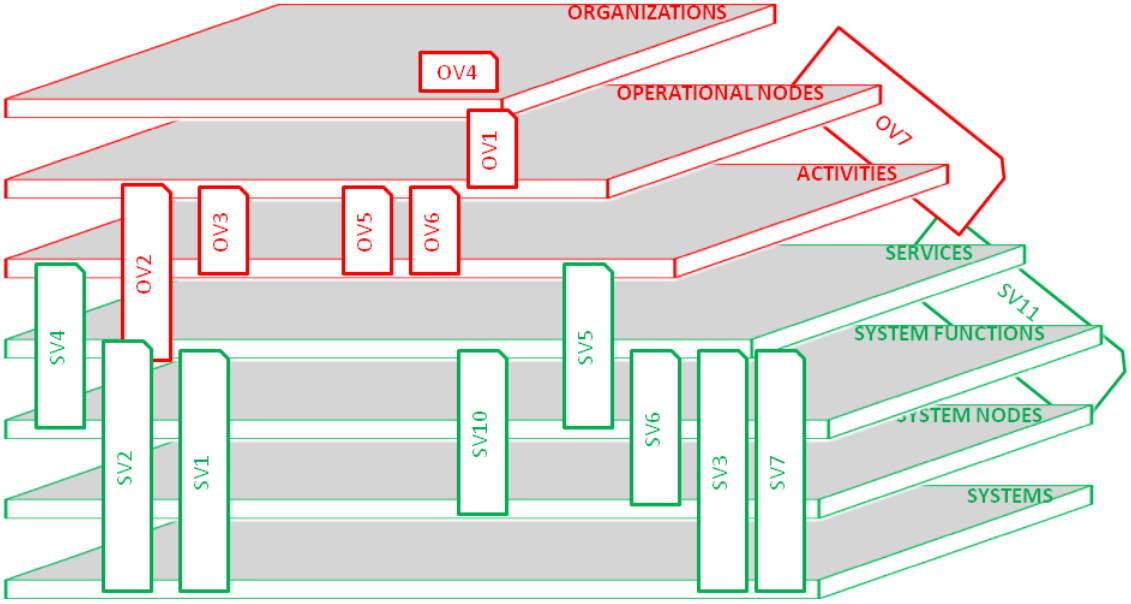
Architecture Design

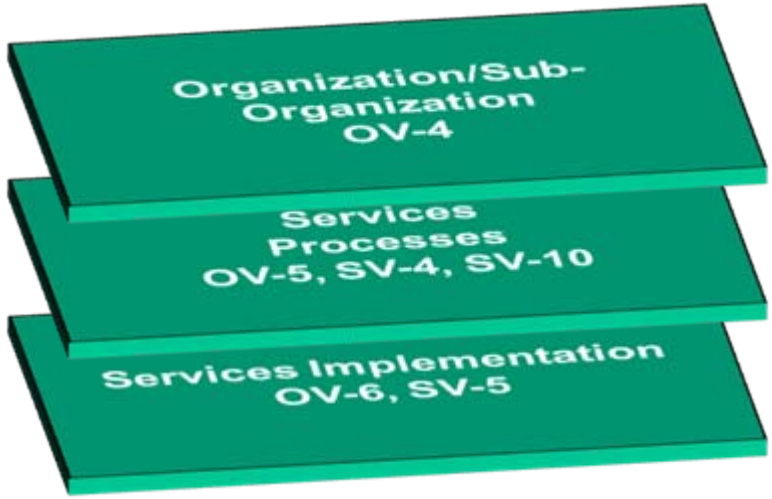
- **Based on the OO approach introduced by Wagenhals et. al**
- **Additional sources of information needed:**
  1) **Information about existing COIs and the services they expose**
  2) **Information about architectures of systems implementing capabilities that might be leveraged by the new architecture**
  3) **Access to existing Net-Centric Enterprise Services (NCES) currently available through the Net-Centric Environment**



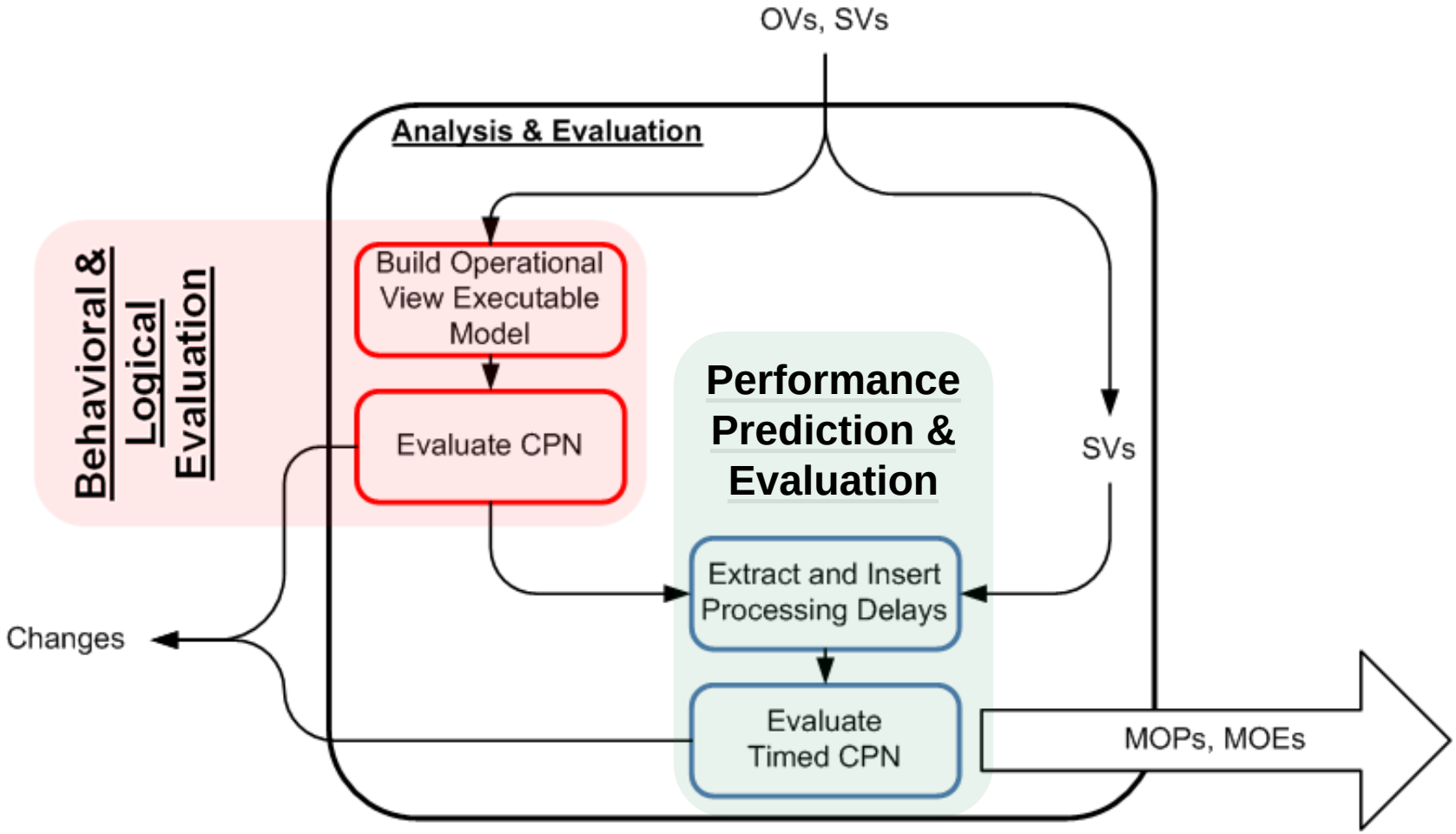
Analysis & Evaluation (1)

- A dynamic model of the business services and processes is built using CPN Tools
- Scenarios are defined to evaluate the logical and behavioral aspects of the architecture
- Formal analysis of system properties (Reachability, Boundedness, Liveness, etc…) is conducted
- State Space analysis to detect errors and unwanted behavior is carried out
- Corrections and changes are reflected back to the architecture description





Analysis & Evaluation (2)

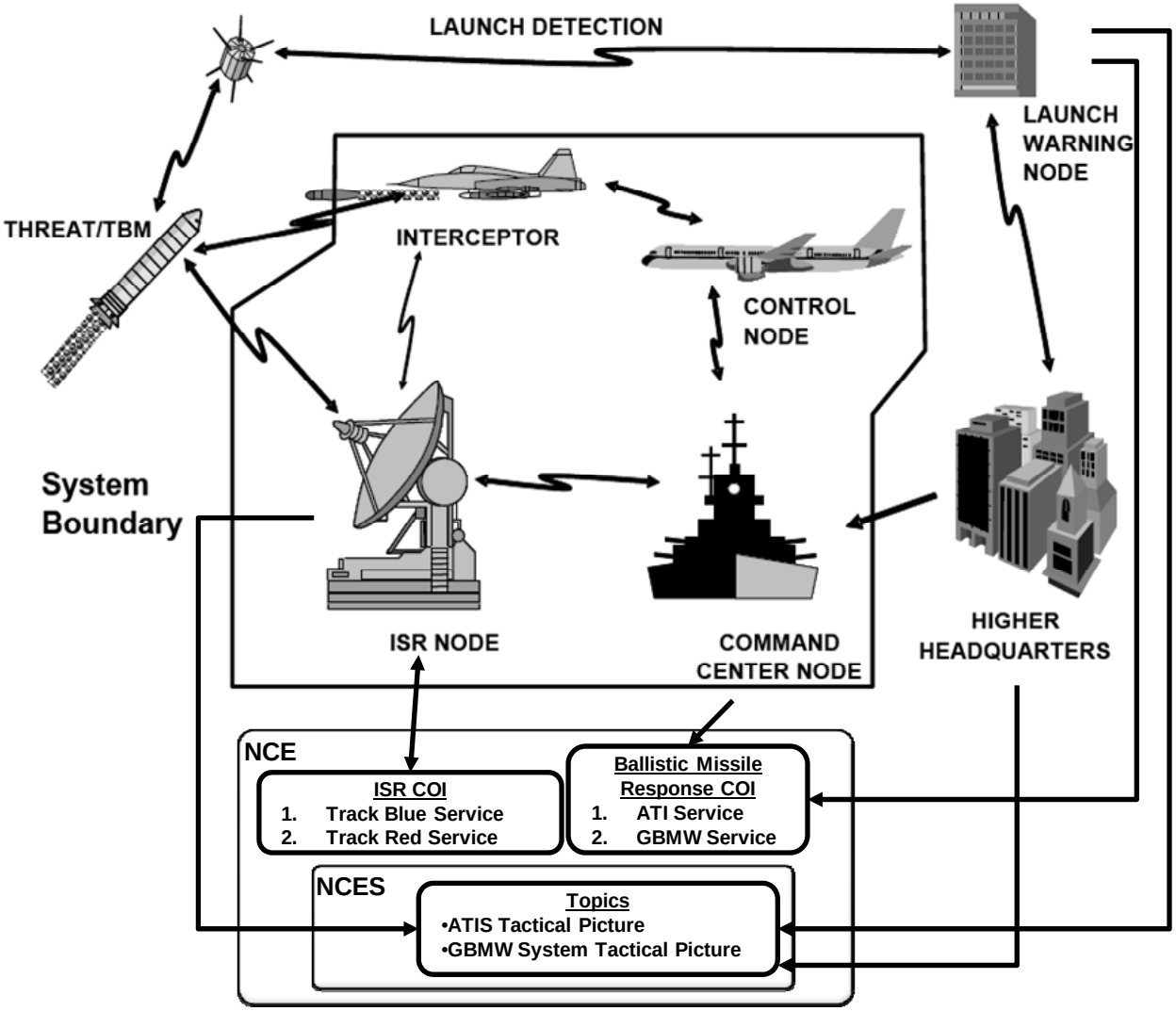


Architecture Deployment

- **Deployment phase: the architecture is instantiated and deployed to accomplish its missions and business objectives**
- **New business processes or changes to existing ones as a result of a SOA instance being deployed should trigger an architecture review**
- **This requires maintaining and calibrating the executable model of the architecture after deployment to support such exploration**

Case Study: Airborne Theater Ballistic Missile Interceptor System (ATIS)

- **Operational Concept graphic (OV-1): shows main operational nodes and Net-Centric Environment (NCE) support**



Case Study (2)

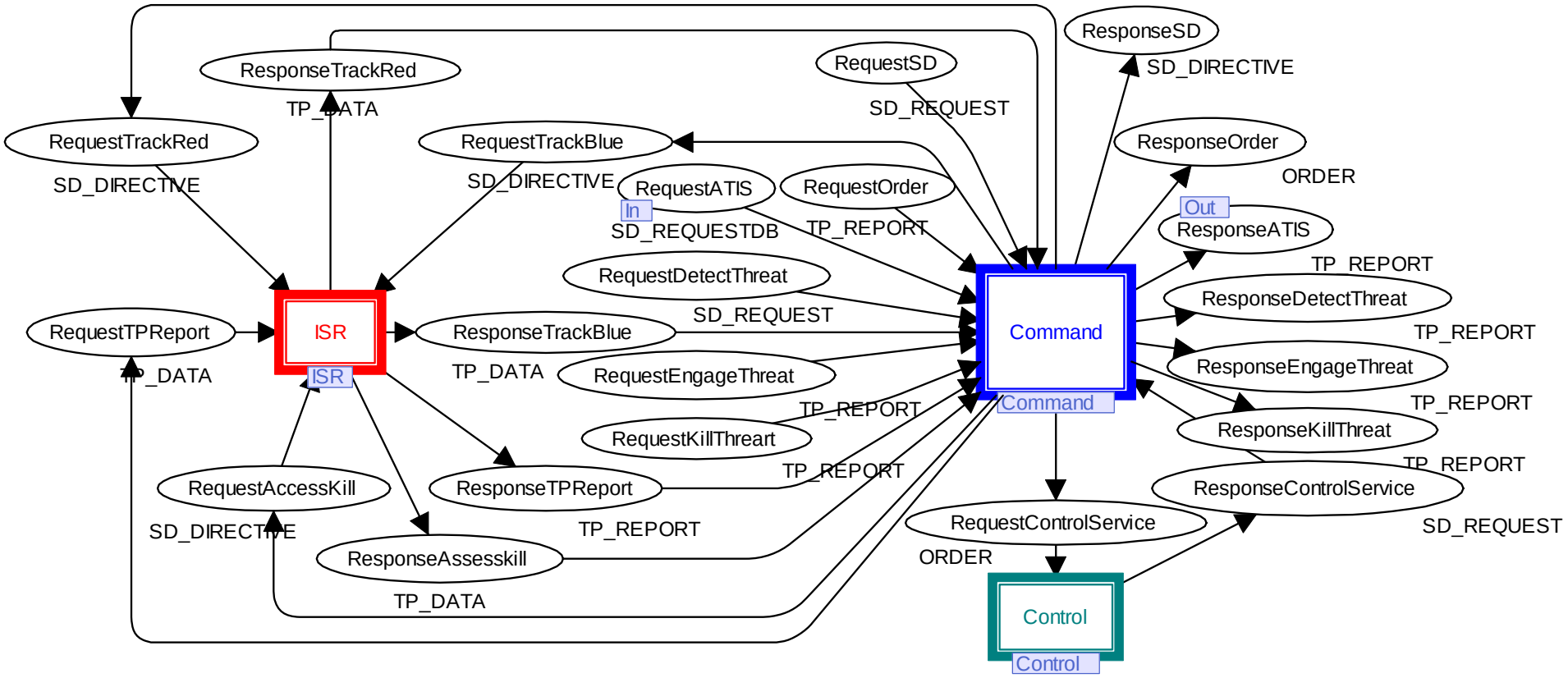
- ***Main objectives***
  - ***Determine if the operational concept can be made to work.***
  - ***Assess the impact of evolving this system into a federated SOA,***
  - ***Determine how to make its business services or their composition* (business processes) accessible by anticipated and un-anticipated users***
- **Assumptions:**
  - **Two COIs:**
    - **Ballistic Missile Response COI**
    - **Intelligence, Surveillance, and Reconnaissance (ISR) COI**
  - **A Global Ballistic Missile Warning (GBMW) Service is deployed and is published through the Ballistic Missile Response COI**
  - **Net-Centric Enterprise Services (NCES) and capabilities are available and accessible. *"e.g. Discovery, Messaging, Mediation Services"***

**** Business processes are composed of multiple business services***

ATIS Business Services & Processes

Services	System Node	Business Process Name	External Anticipated User	External Un-anticipated User
EngageOrder	ATIS Command	-	-	-
DetectThreat		DetectThreatBP	-	-
EngageThreat		EngageThreatBP	-	-
KillThreat		KillThreatBP	-	-
SD		-	-	-
ATIService		ATISBP	GBMWS	BMR COI
TrackRed	ATIS Radar	-	-	ISR COI
TrackBlue		-	-	ISR COI
AssessKill		-	-	-
TPReport		-	-	-
Control	ATIS Control	-	-	-

ATIS CPN Top Page



ATIS Scenario Profile

Input Variables (Parameters)		
Name	**Description**	**Values**
Number of TBMs	Total number of TBMs launched by adversary (fixed).	10
TBM Inter-arrival	Time interval between TBM arrivals.	0, 25,50,75,100 (seconds)
Number of Interceptors	Total number of ATIS Interceptors.	3, 4, 5

Output Variables (Measures of Performance – MOPs)		
Name	**Description**	**Requirement**
Average Response Time	The average time between the ATIS detecting the TBM until the TBM is engaged.	<= 400 seconds
Number of Leakers	Total number of TBMs not destroyed within 400 seconds of being detected by ATIS.	<=2

Results

- 3 interceptors can handle the 10 threats (with a max of four leakers) if they arrive at a rate slower than 1 in 25 seconds
- 4 interceptors can handle the 10 threats (with a max of two leakers) if they arrive at a rate slower than 1 in 25 seconds
- 5 interceptors can handle the 10 threat with no leakers

Number of Interceptors	TBM Inter-arrival	Average Response Time	Number of Leakers
3	0	347.1	4
	25	270.1	1
	50	180.6	0
	75	159	0
	100	159	0
4	0	283.9	2
	25	212.9	0
	50	159	0
	75	159	0
	100	159	0
5	0	245.5	0
	25	180	0
	50	159	0
	75	159	0
	100	159	0

MOE = 93%

Conclusion & Future Work

- **A formal dynamic model of federated SOAs suitable for analysis and evaluation**
  - **Dynamically federate with NCE systems through COI registries and by utilizing the NCES to share enterprise-level information**
- **An approach for constructing an event driven SOA compliant to DoDAF v1.5**
- **Behavioral and Logical evaluation of business service and processes , and baseline performance measures of SOA using Colored Petri Nets**

- **Future work**
  - **Extend the analysis and evaluation to capture SOA infrastructure**

QUESTIONS?