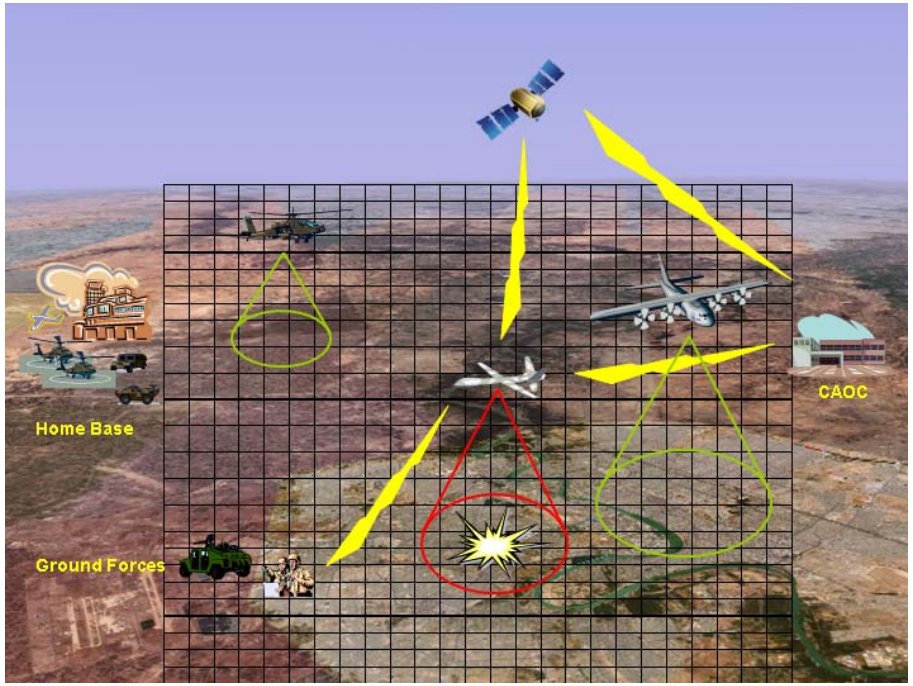
Air Force Institute of Technology

LINKING INTEROPERABILITY CHARACTERS AND MEASURES OF EFFECTIVENESS: A METHODOLOGY FOR EVALUATING ARCHITECTURES



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Disclaimer

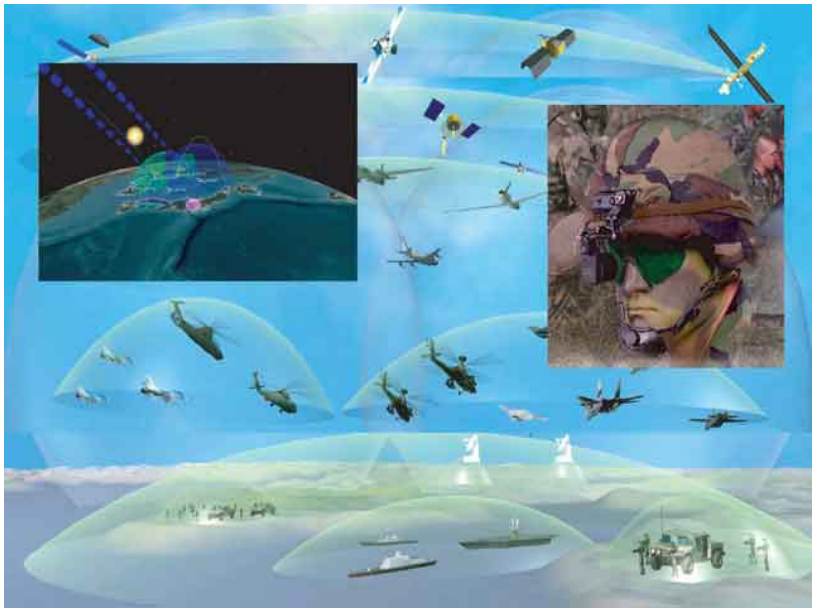
This is early on in a basic research effort ….

… but we think it has promise!

Problem Statement

Can changes in "*Interoperability*" of an ISR architecture be quantitatively linked to changes in mission effectiveness?

From good…..

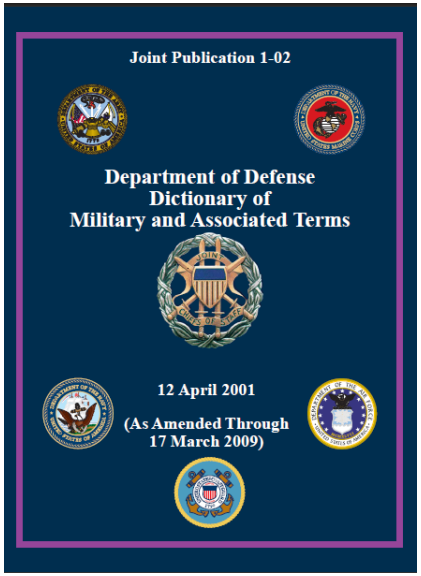


To better….?

Interoperability Defined

Joint doctrine defines interoperability as:

> "The ability to operate in synergy in the execution of assigned tasks." **JP 1-02, 2008**

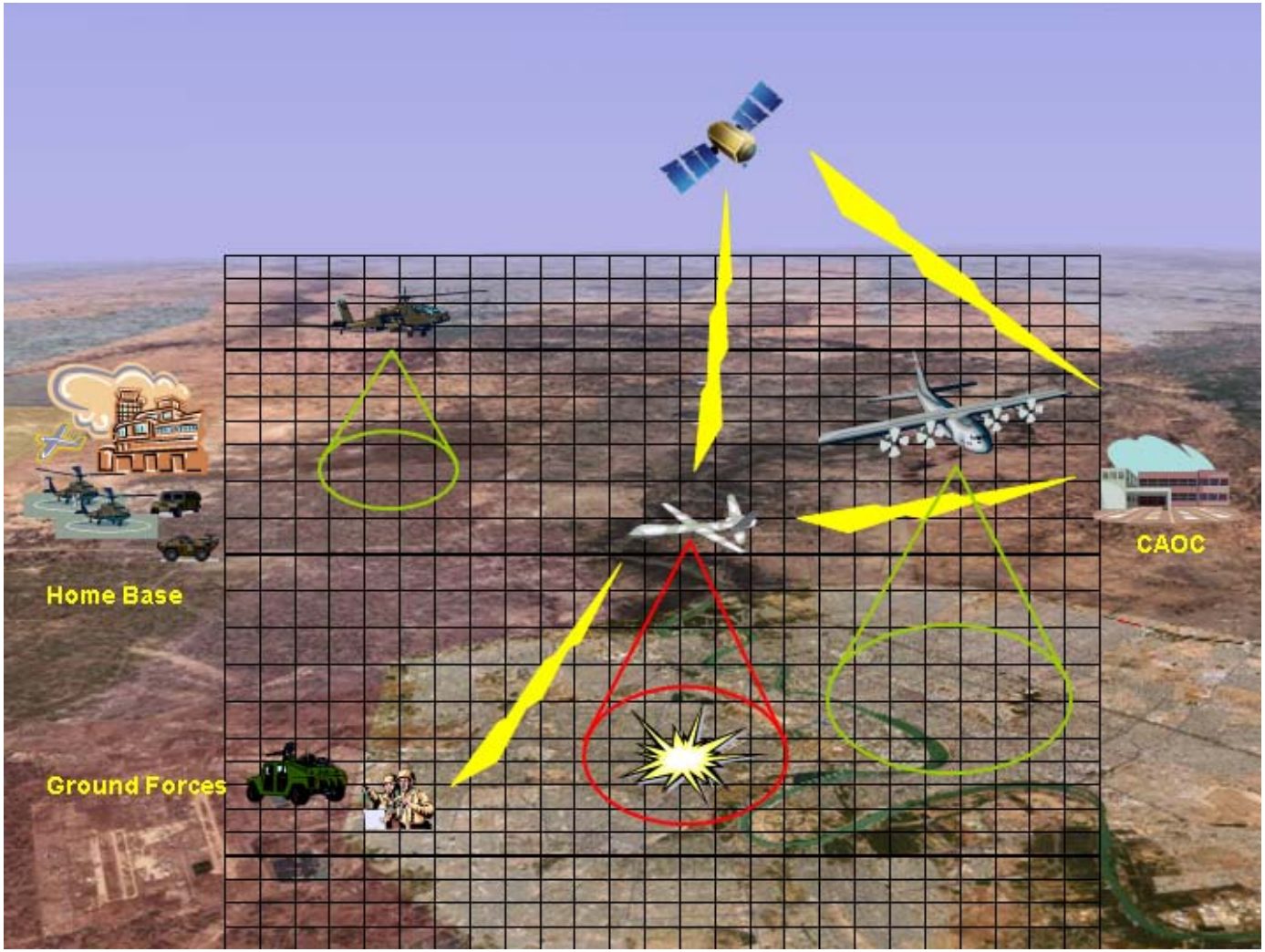


Layered Sensing Background

- Unconventional and evolving enemy tactics require better intelligence, situational awareness, tactics and technologies
- Must be robust, flexible, agile, timely, and effective
- Must be able to produce “tailored effects”

“Layered Sensing provides military and homeland security decision makers at all levels with timely, actionable, trusted, and relevant information necessary for situational awareness to ensure their decisions achieve the desired military/humanitarian effects. Layered Sensing is characterized by the appropriate sensor or combination of sensors/platforms, infrastructure and exploitation capabilities to generate that situation awareness and directly support delivery of “tailored effects”. (AFRL White Paper, 2008)

Layered Sensing OV-1: Interoperability



Sensor Packages

Gotcha – ISR pallet on cargo aircraft

Lair/Nitestare - C-12 Huron

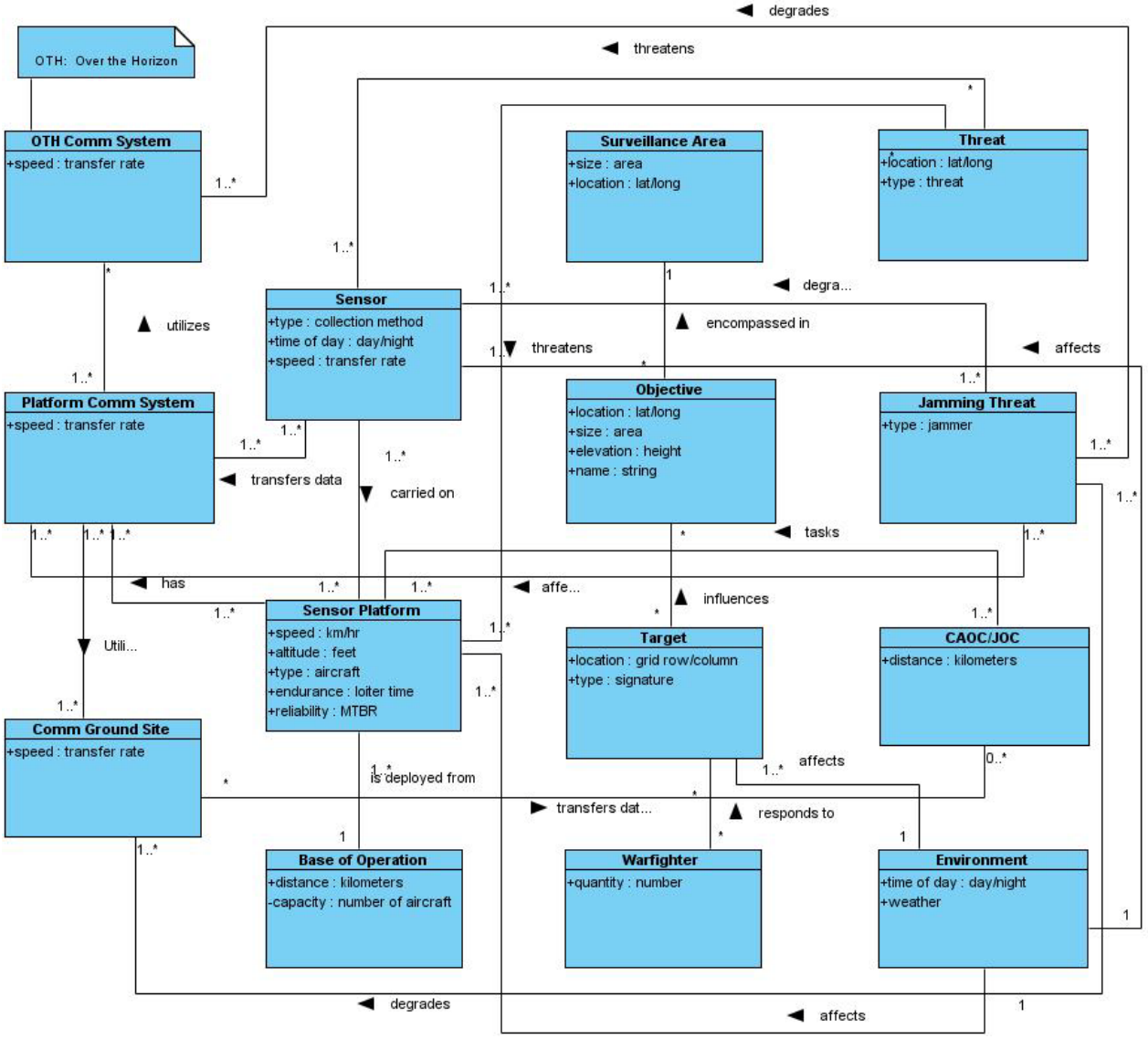
Argus-IS - A-160

“Generic” - MQ-X Pred-like

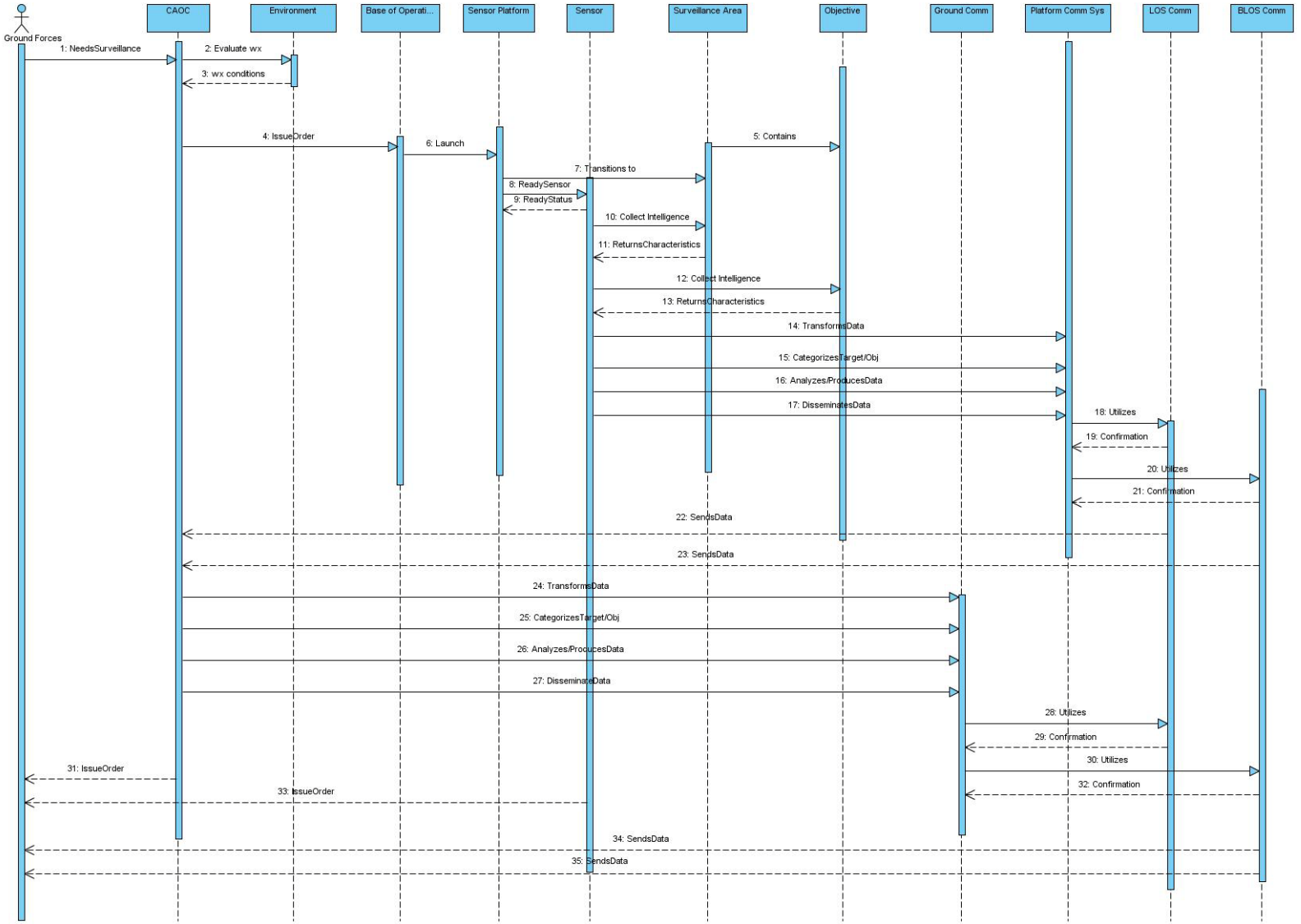
Attributes and MOEs

Attribute (LS WhitePaper)	Measure of Effectiveness (MOE)
Persistent Coverage	Percentage of time mission is covered by sensor (MOE 1)
Wide Area Coverage	Percentage of Area of Responsibility covered by sensors (MOE 2)
Timeliness	Time for information to pass from sensor to decision node (MOE 3)
Robust, Agile, Adaptable	Layered sensing mission failure rate (MOE 4)
	Average time taken to begin mission coverage (MOE 5)
Spectrum Dominance and Control	Percentage of time mission covered by at least two platforms (MOE 6)

Layered Sensing Object Diagram

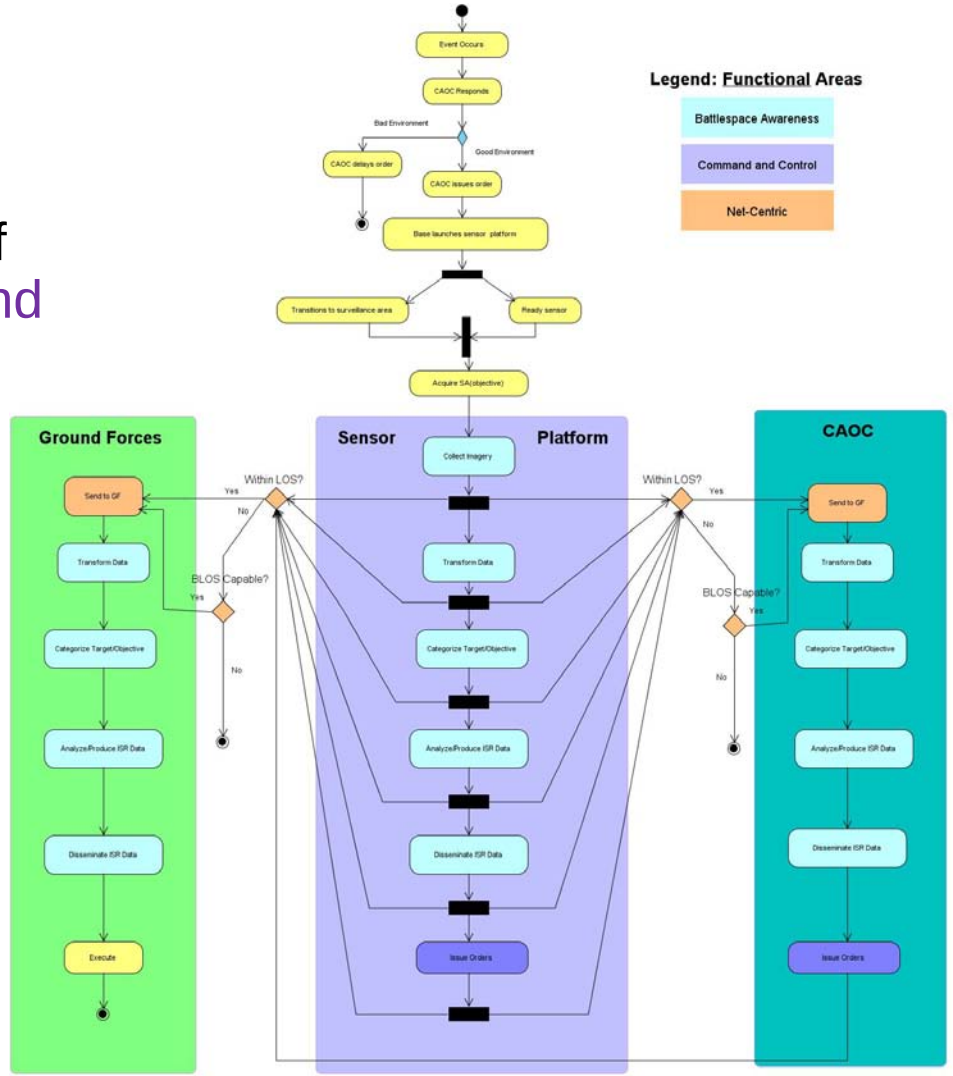


Layered Sensing System Sequence Diagram

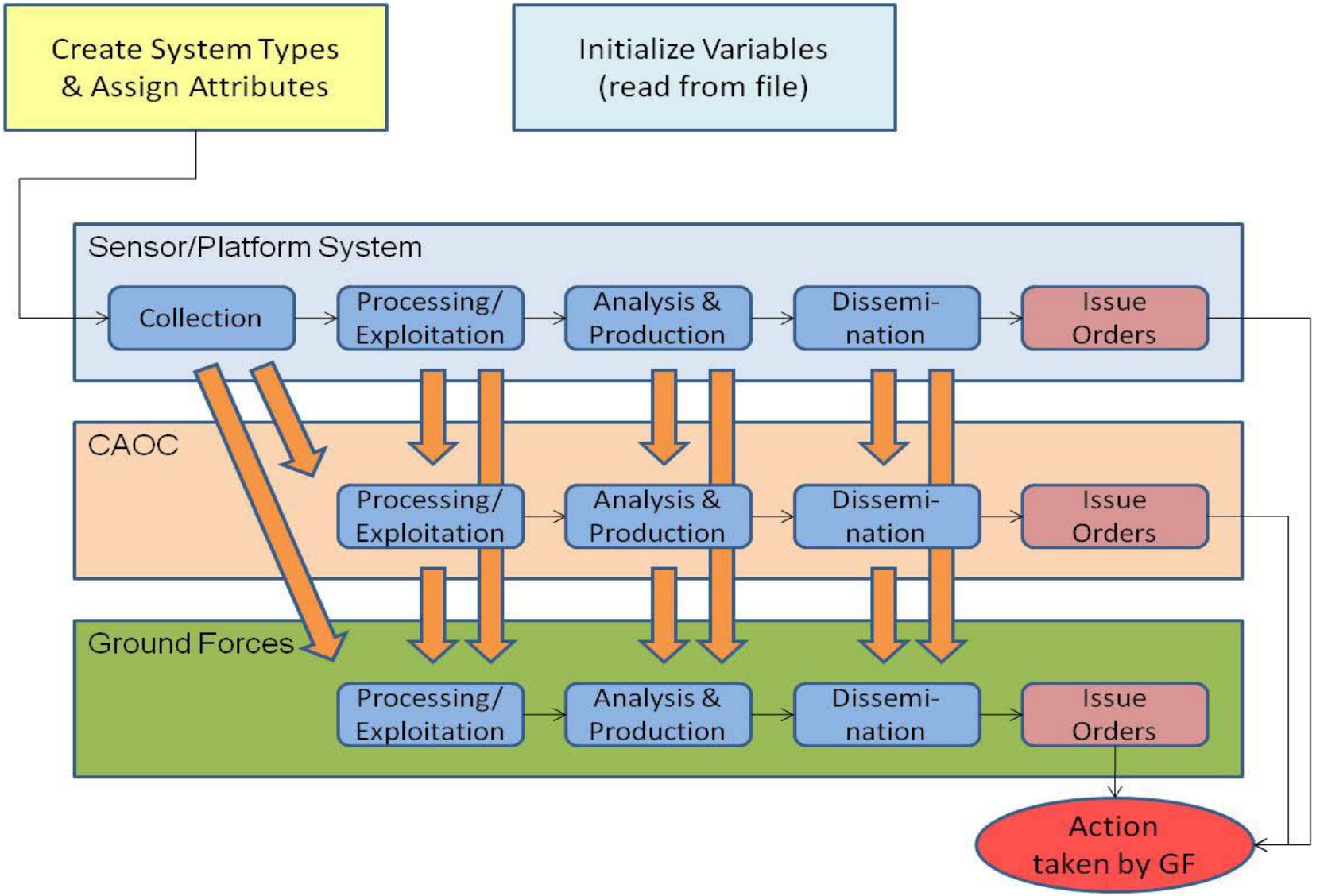


Operational Activity Model (OV-5)

- Models Use Case scenario previously described
- Organized into functional areas of Battlespace Awareness, Command and Control and Net-Centricity
- “Actions” within the activity model represent interoperability characters derived from the DoD 2009 Joint Capability Areas (JCA)



System Interoperability



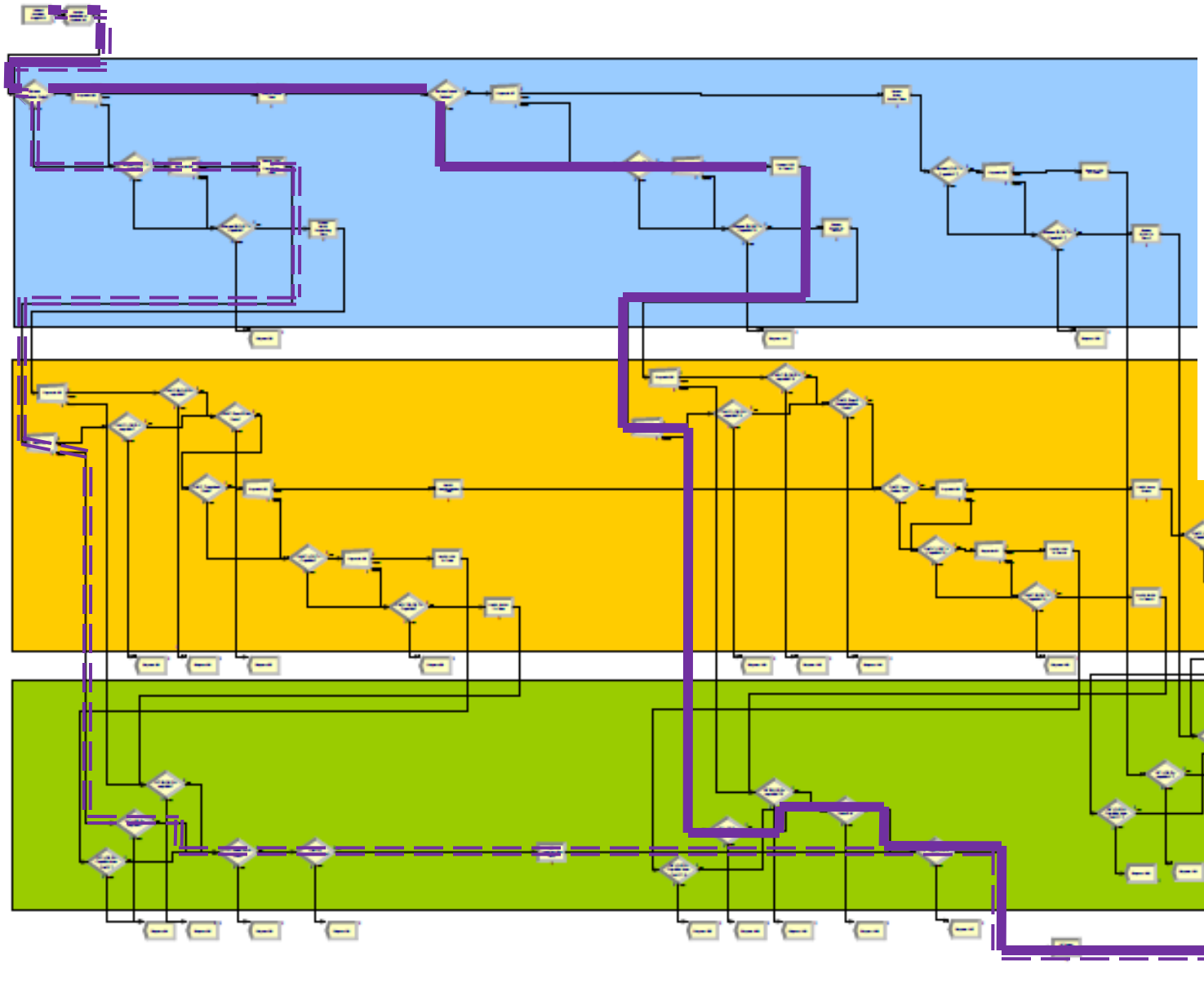
Interoperability Matrix (Transmit)

	transmit / can actively do						
	BLUE SYSTEMS					BLUE PLAYERS	
	LAIR	ARGUS-IS	GOTCHA	NITE STARE	generic	CAOC	GF
Battlespace Awareness	1	1	1	1	1	1	1
Intelligence, Surveillance and Reconnaissance	1	1	1	1	1	1	1
Collection	1	1	1	1	1	0	0
Imagery Collection	1	1	1	1	1	0	0
Electro-Optical Imagery Collection	1	1	0	1	1	0	0
Panchromatic Collection	1	1	0	0	1	0	0
Infrared Collection	0	0	0	1	1	0	0
RADAR Imagery Collection	0	0	1	0	1	0	0
Processing / Exploitation	1	1	1	1	1	1	1
Data Transformation	1	1	1	1	1	1	0
Objective / Target Categorization	1	1	1	1	1	1	1
Analysis and Production	1	0	1	1	0	1	1
Intelligence, Surveillance and Reconnaissance Dissemination	1	0	1	1	0	1	1
Command and Control	1	0	1	1	0	1	1
Direct	1	0	1	1	0	1	1
Task	1	0	1	1	0	1	1
Synchronize Operations	0	0	0	0	0	0	0
Issue Plans	0	0	0	0	0	0	0
Issue Orders	1	0	1	1	0	1	1
Net-Centric	1	1	1	1	1	1	1
Information Transport (IT)	1	1	1	1	1	1	1
Wireless Transmission	1	1	1	1	1	1	1
Line of Sight	1	1	1	1	1	1	1
Beyond Line of Sight	0	0	0	0	1	1	0

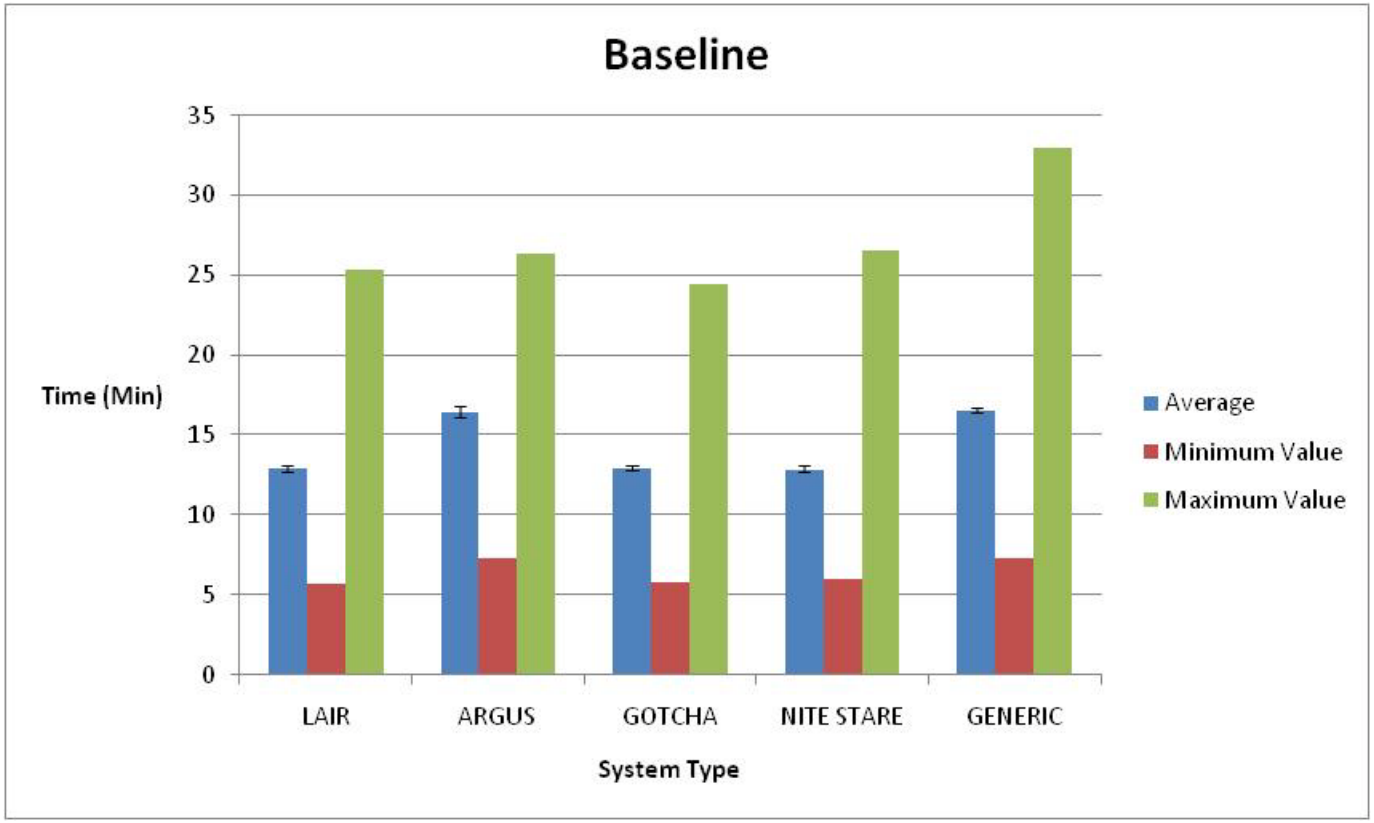
Interoperability Matrix (Receive)

	receive / can understand or work with						
	BLUE SYSTEMS					BLUE PLAYERS	
	LAIR	ARGUS-IS	GOTCHA	NITE STARE	generic	CAOC	GF
Battlespace Awareness	1	1	1	1	1	1	1
Intelligence, Surveillance and Reconnaissance	1	1	1	1	1	1	1
Collection	1	1	1	1	1	1	1
Imagery Collection	1	1	1	1	1	1	1
Electro-Optical Imagery Collection	1	1	0	1	1	1	1
Panchromatic Collection	1	1	0	0	1	1	1
Infrared Collection	0	0	0	1	1	1	1
RADAR Imagery Collection	0	0	1	0	1	0	0
Processing / Exploitation	0	0	0	0	0	1	1
Data Transformation	0	0	0	0	0	1	1
Objective / Target Categorization	0	0	0	0	0	1	1
Analysis and Production	0	0	0	0	0	1	1
Intelligence, Surveillance and Reconnaissance Dissemination	0	0	0	0	0	1	1
Command and Control	1	1	1	1	1	0	1
Direct	1	1	1	1	1	0	1
Task	1	1	1	1	1	0	1
Synchronize Operations	0	0	0	0	0	0	0
Issue Plans	0	0	0	0	0	0	0
Issue Orders	1	1	1	1	1	0	1
Net-Centric	1	1	1	1	1	1	1
Information Transport (IT)	1	1	1	1	1	1	1
Wireless Transmission	1	1	1	1	1	1	1
Line of Sight	1	1	1	1	1	1	1
Beyond Line of Sight	0	0	0	0	1	1	0

System Interoperability

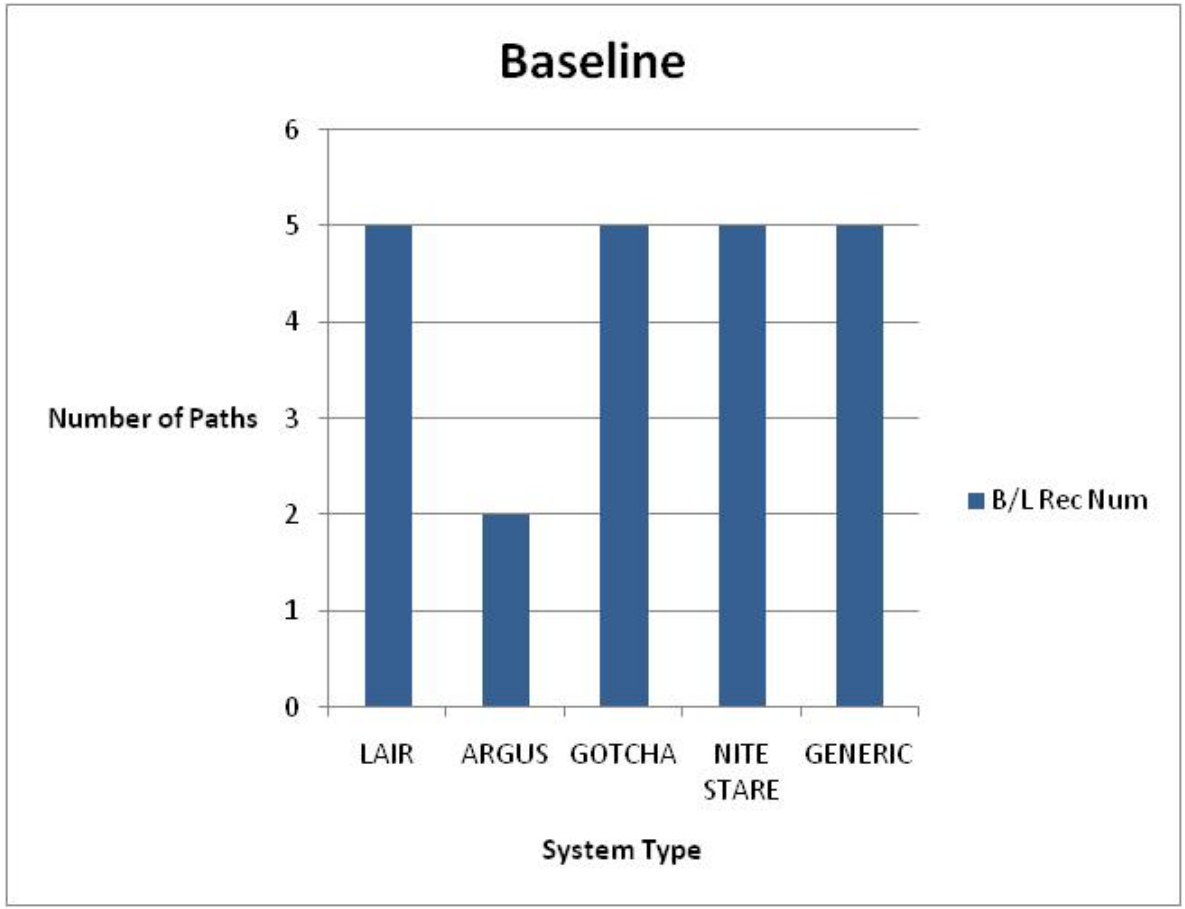


System Interoperability



Time for Data to Pass from Sensor to Ground Forces

System Interoperability



Number of Process Paths Data Can Follow from Sensor to Ground Forces

System Interoperability

Experimental setup

- IE 2: Ground forces receive BLOS comms
- Measure interoperability*
- Calculate MOE
- Compare results … look for correlation

* Used binary system similarity, T. Ford, INCOSE Systems Engineering, 2008.

System Interoperability

Experiment 2

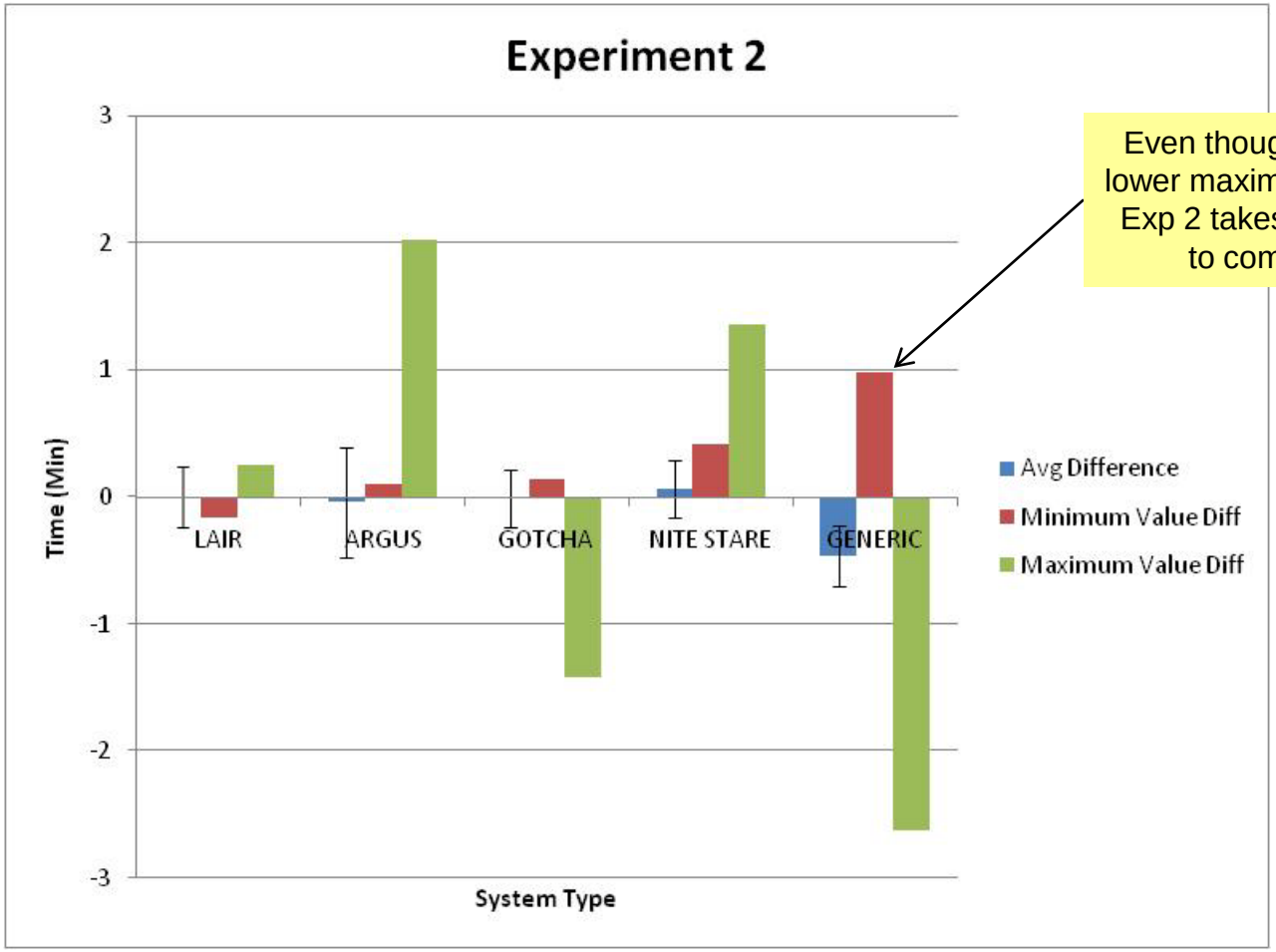
	LAIR	ARGUS-IS	GOTCHA	NITE STARE	generic	CAOC	GF
LAIR	0	7/12	1/2	13/24	7/12	5/8	19/24
ARGUS-IS	5/12	0	1/3	3/8	5/12	13/24	13/24
GOTCHA	1/2	1/2	0	1/2	13/24	13/24	17/24
NITE STARE	13/24	13/24	1/2	0	7/12	5/8	19/24
generic	5/12	5/12	3/8	5/12	0	5/8	5/8
CAOC	5/12	5/12	5/12	5/12	11/24	0	2/3
GF	5/12	5/12	5/12	5/12	11/24	11/24	0
average interoperability measure:		0.5089					

Interoperability Measurement

Interoperability Measurement Difference

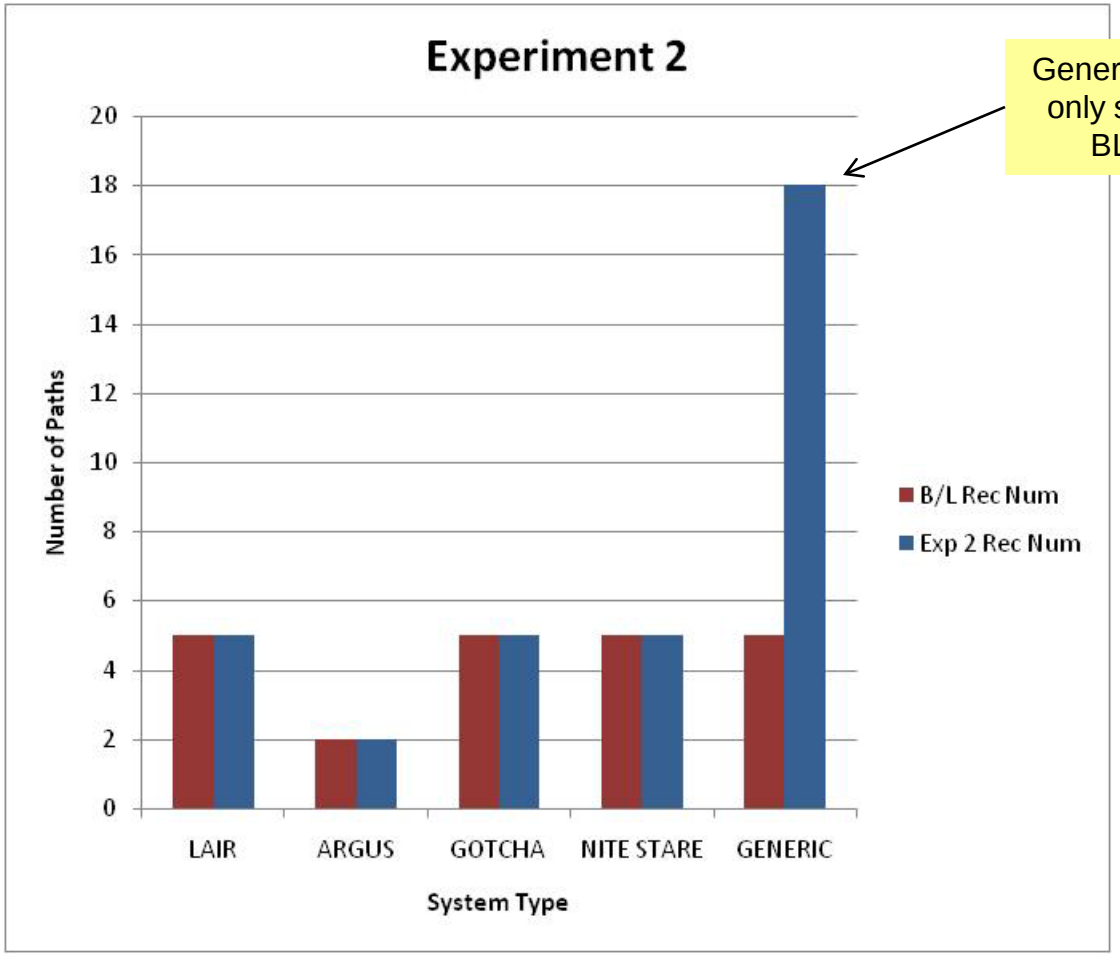
	LAIR	ARGUS-IS	GOTCHA	NITE STARE	generic	CAOC	GF
LAIR	0	0	0	0	0	0	0
ARGUS-IS	0	0	0	0	0	0	0
GOTCHA	0	0	0	0	0	0	0
NITE STARE	0	0	0	0	0	0	0
generic	0	0	0	0	0	0	1/24
CAOC	0	0	0	0	0	0	1/24
GF	0	0	0	0	1/24	1/24	0
avg interop measure difference:		0.0039					

System Interoperability



Time for Data to Pass from Sensor to Ground Forces

System Interoperability



Number of Process Paths Data Can Follow from Sensor to Ground Forces

System Interoperability

Experimental trial goals

- IE 3: Argus receives BLOS comms

System Interoperability

Experiment 3

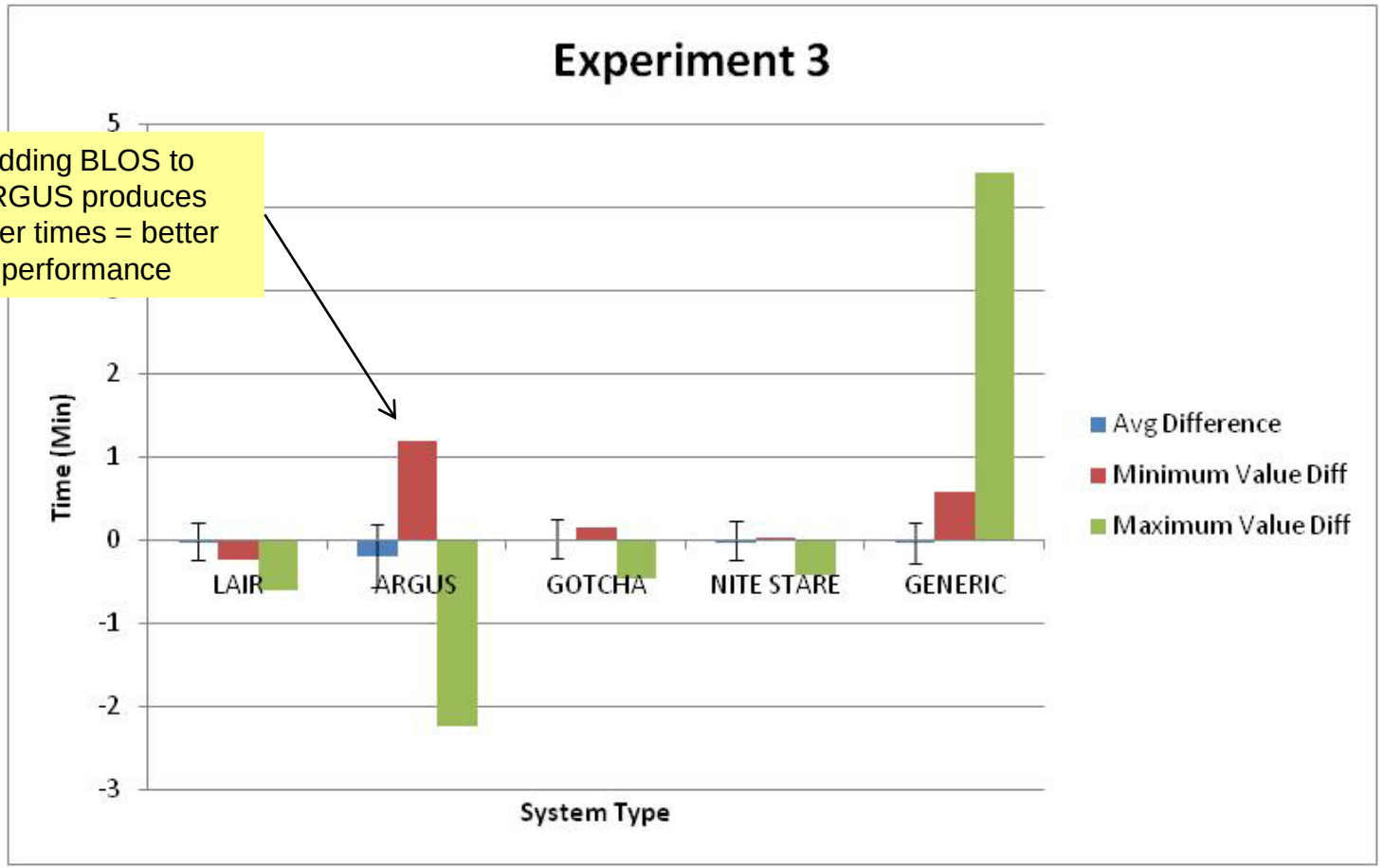
	LAIR	ARGUS-IS	GOTCHA	NITE STARE	generic	CAOC	GF
LAIR	0	7/12	1/2	13/24	7/12	5/8	19/24
ARGUS-IS	5/12	0	1/3	3/8	11/24	7/12	13/24
GOTCHA	1/2	1/2	0	1/2	13/24	13/24	17/24
NITE STARE	13/24	13/24	1/2	0	7/12	5/8	19/24
generic	5/12	11/24	3/8	5/12	0	5/8	7/12
CAOC	5/12	11/24	5/12	5/12	11/24	0	5/8
GF	5/12	5/12	5/12	5/12	5/12	5/12	0
average interoperability measure:		0.5089					

Interoperability Measurement

Interoperability Measurement Difference

	LAIR	ARGUS-IS	GOTCHA	NITE STARE	generic	CAOC	GF
LAIR	0	0	0	0	0	0	0
ARGUS-IS	0	0	0	0	1/24	1/24	0
GOTCHA	0	0	0	0	0	0	0
NITE STARE	0	0	0	0	0	0	0
generic	0	1/24	0	0	0	0	0
CAOC	0	1/24	0	0	0	0	0
GF	0	0	0	0	0	0	0
avg interop measure difference:		0.0039					

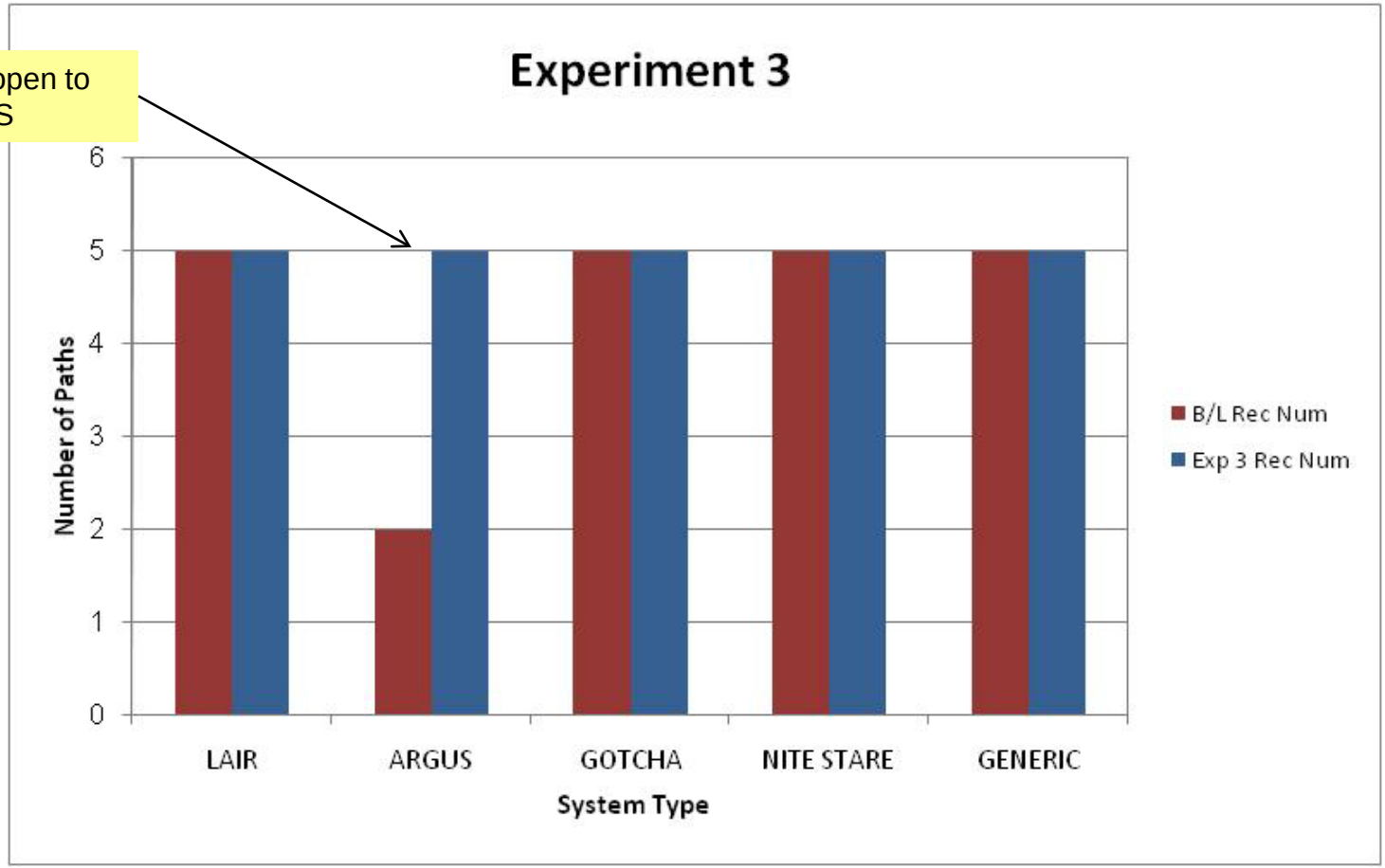
System Interoperability



Time for Data to Pass from Sensor to Ground Forces

System Interoperability

More paths open to ARGUS



Number of Process Paths Data Can Follow from Sensor to Ground Forces

System Interoperability

Experimental trial goals

- IE 4: CAOC located within LOS of the AOR

System Interoperability

Experiment 4

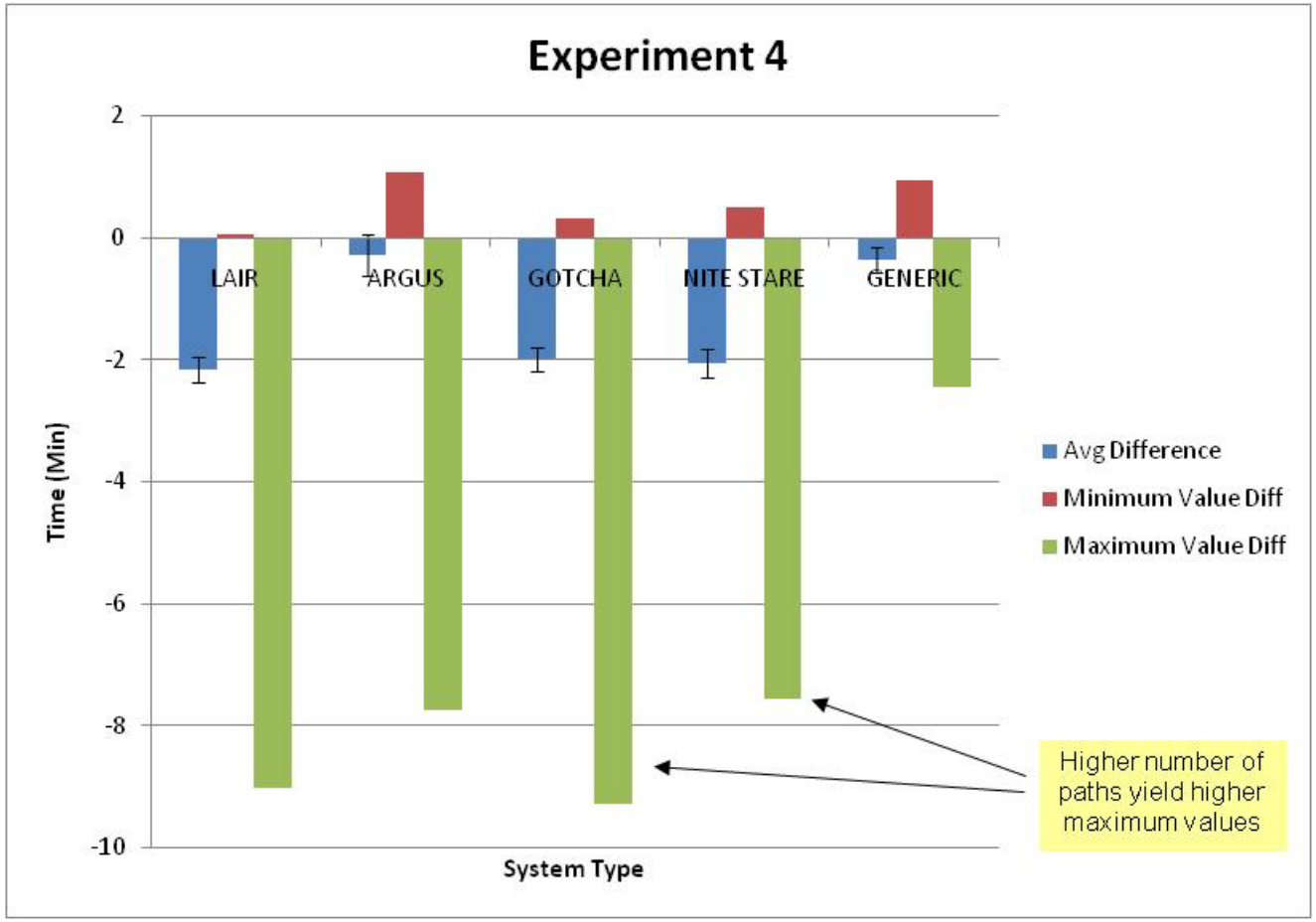
	LAIR	ARGUS-IS	GOTCHA	NITE STARE	generic	CAOC	GF
LAIR	0	7/12	1/2	13/24	7/12	5/8	19/24
ARGUS-IS	5/12	0	1/3	3/8	5/12	13/24	13/24
GOTCHA	1/2	1/2	0	1/2	13/24	13/24	17/24
NITE STARE	13/24	13/24	1/2	0	7/12	5/8	19/24
generic	5/12	5/12	3/8	5/12	0	5/8	7/12
CAOC	5/12	5/12	5/12	5/12	11/24	0	5/8
GF	5/12	5/12	5/12	5/12	5/12	5/12	0
average interoperability measure:		0.5050					

Interoperability Measurement

Interoperability Measurement Difference

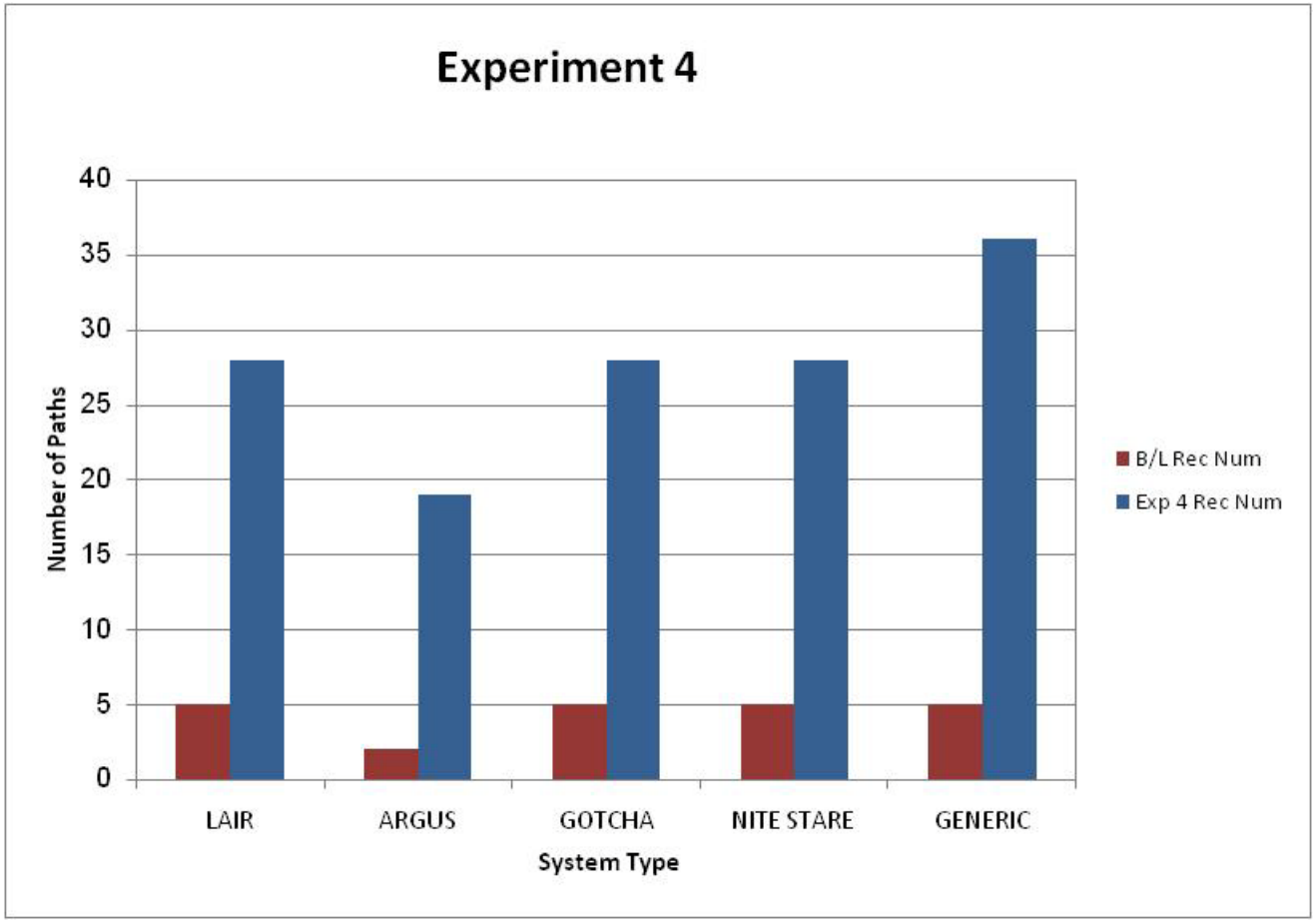
	LAIR	ARGUS-IS	GOTCHA	NITE STARE	generic	CAOC	GF
LAIR	0	0	0	0	0	0	0
ARGUS-IS	0	0	0	0	0	0	0
GOTCHA	0	0	0	0	0	0	0
NITE STARE	0	0	0	0	0	0	0
generic	0	0	0	0	0	0	0
CAOC	0	0	0	0	0	0	0
GF	0	0	0	0	0	0	0
avg interop measure difference:		0.0000					

System Interoperability



Time for Data to Pass from Sensor to Ground Forces

System Interoperability



Number of Process Paths Data Can Follow from Sensor to Ground Forces

Research Conclusions

- Changes in architecture related to collaborative interoperability can be quantitatively linked to changes in mission effectiveness
  - In some cases, interoperability measurement is an insufficient indicator of effectiveness changes (e.g., process paths is probably a better indicator for this example)
- Successful linking of interoperability measurements and MOE calculations is critically dependent on character selection and MOE determination
- Not all MOEs are directly linked to interoperability
- A method to quantitatively compare architectures was demonstrated for layered sensing

Research Recommendations

- Interoperability Measurements
  - Analyze utility of additional interoperability character complexity levels
  - Explore non-Boolean character state representation
- Discrete event simulations and MOE calculations
  - Consider modeling additional scenarios (use cases)
  - Incorporate decision logic into process path selection

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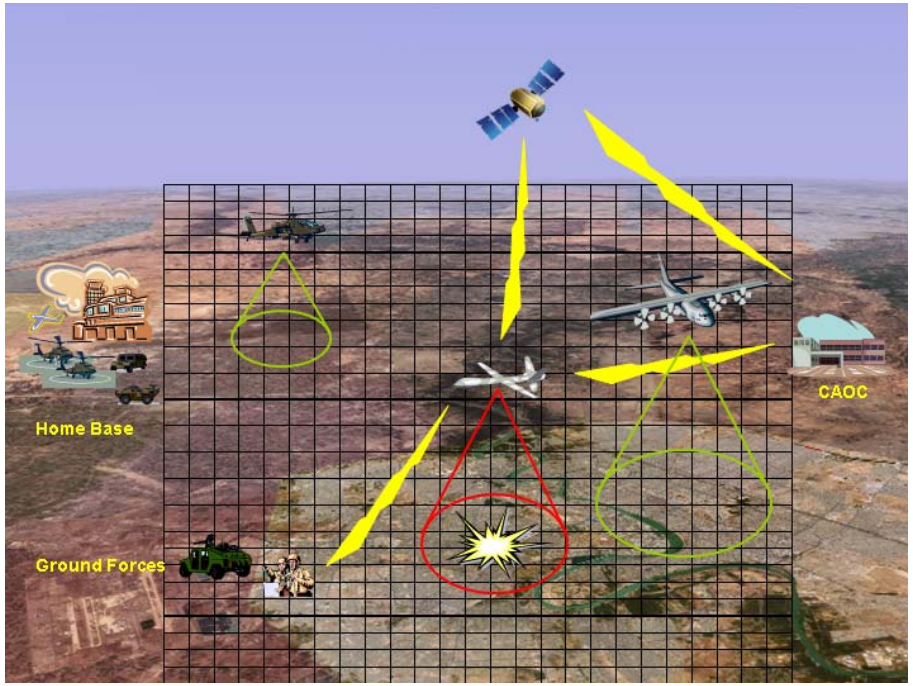

Final Questions?