Air Force Institute Of Technology

Modeling and Measuring Network Centric Warfare (NCW) with the System Effectiveness Analysis Simulation (SEAS)

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Overview

- Defining NCW
- Problem Statement
- Modeling NCW with SEAS
  - SEAS
  - Kosovo Scenario
  - Measures of Effectiveness
- Analysis
- Conclusions

Defining NCW

Network Centric Warfare

The conduct of military operations through the utilization of networked information systems, which supply the warfighter with the right information at the right time in the right form to the right person being put to the right use, in order to achieve desired effects across the Physical, Information, and Cognitive Domains of warfare.

Problem Statement

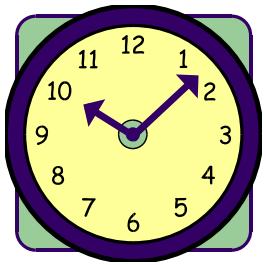
Simulation and Analysis Facility (SIMAF) Task

- ***Use the Systems Effectiveness Analysis Simulation (SEAS) to conduct Network-Centric Warfare (NCW) modeling***
  - ***Develop an NCW scenario***
  - ***Propose and validate or refute selected measures of effectiveness applied to NCW operations***

(from Air Force Institute of Technology
RESEARCH PROPOSAL, 15 February 2005)

The SEAS Simulated Environment

SEAS is a time step simulation

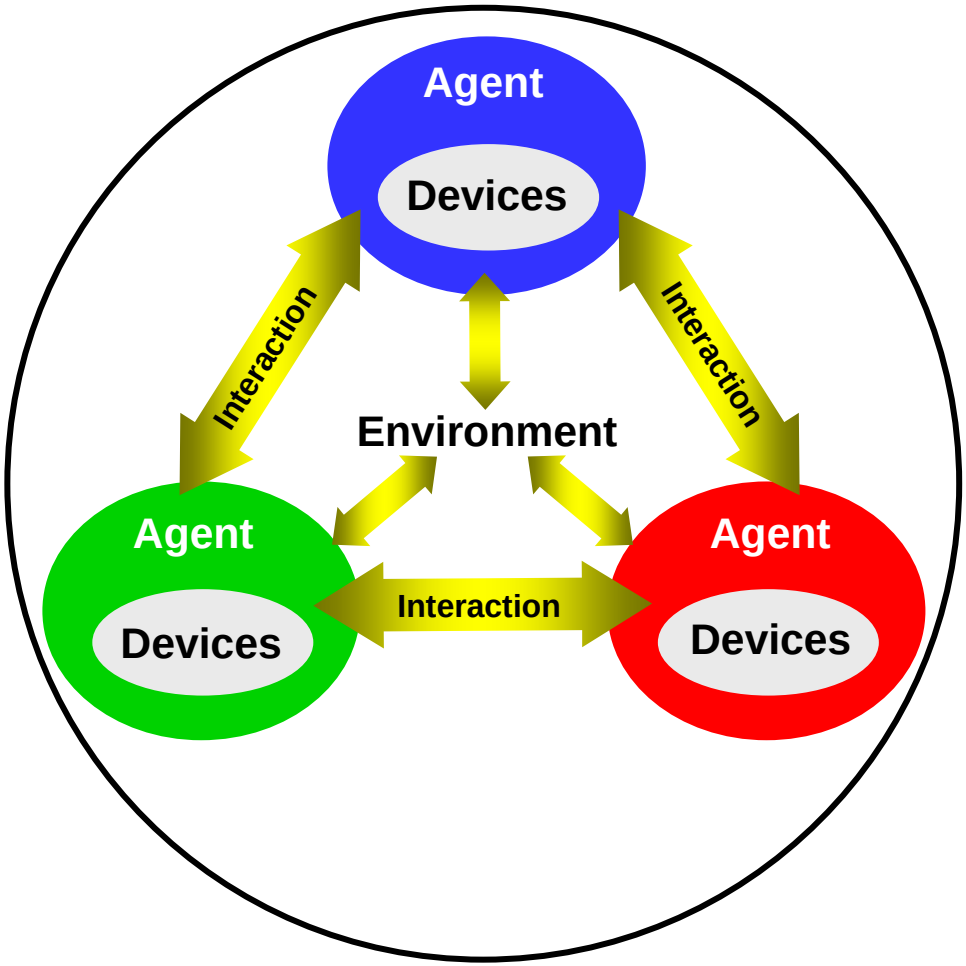


Δt = Is Analyst Defined Default is 1 minute

Agents execute parallel threads of user defined tactical programming language (TPL) that controls their behavior

SEAS Modeling Constructs

Agents, Devices, Environment



Agents Interact

- Units
- Platforms (vehicles, planes, sats)

Through ***Devices***

- Weapons
- Sensors
- Comm

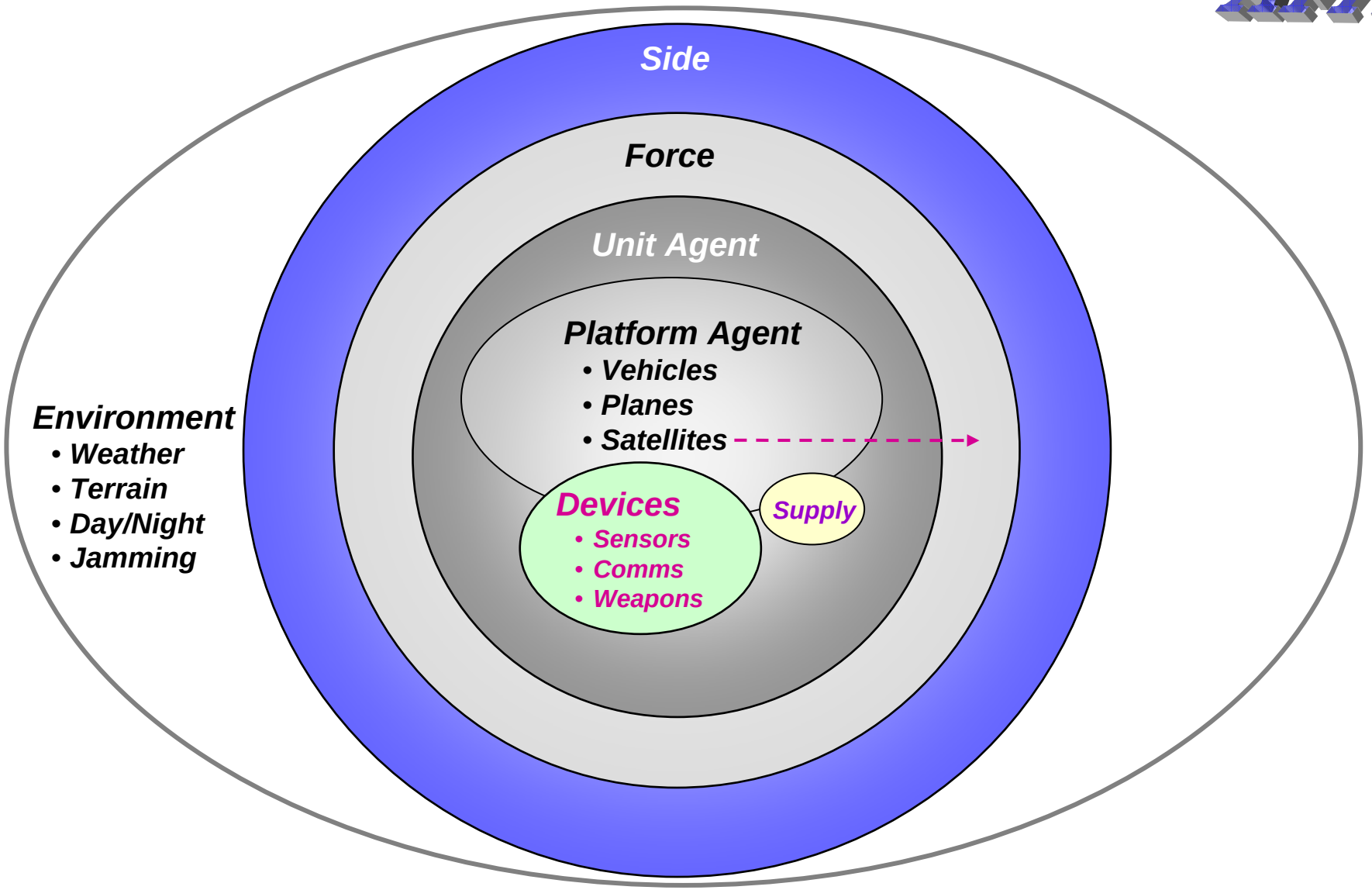
With each other and the ***Environment***

- Events
- Locations
- Terrain
- Weather
- Jamming
- Day/Night

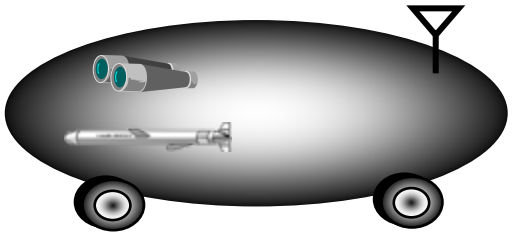
To Emerge Combat Outcomes

Reference: SPARTA, Inc. SEAS Training Course: Slide 12

SEAS Object Hierarchy



What a SEAS Agent Might Say



I am a SEAS agent.

- I can ***move*** around my environment.
- I can ***sense*** things in my environment.
- I can ***talk*** to other agents in my environment.
- When I ***use up resources*** I can get more.
- I can ***kill*** other agents.

I will do what I am told by my superiors unless my local programming over rides those orders. You can program me to be compliant or truculent, an observer, a killer, or even a leader/controller of other agents.

When I see an enemy or someone tells me about an enemy I remember and forward predict his position until the information for that target is too old. Its important for me to keep track of enemy positions because I might be ordered to 1) do nothing, 2) move toward them, 3) move away from them, 4) tell others about them, 5) kill them or some combination of the above.

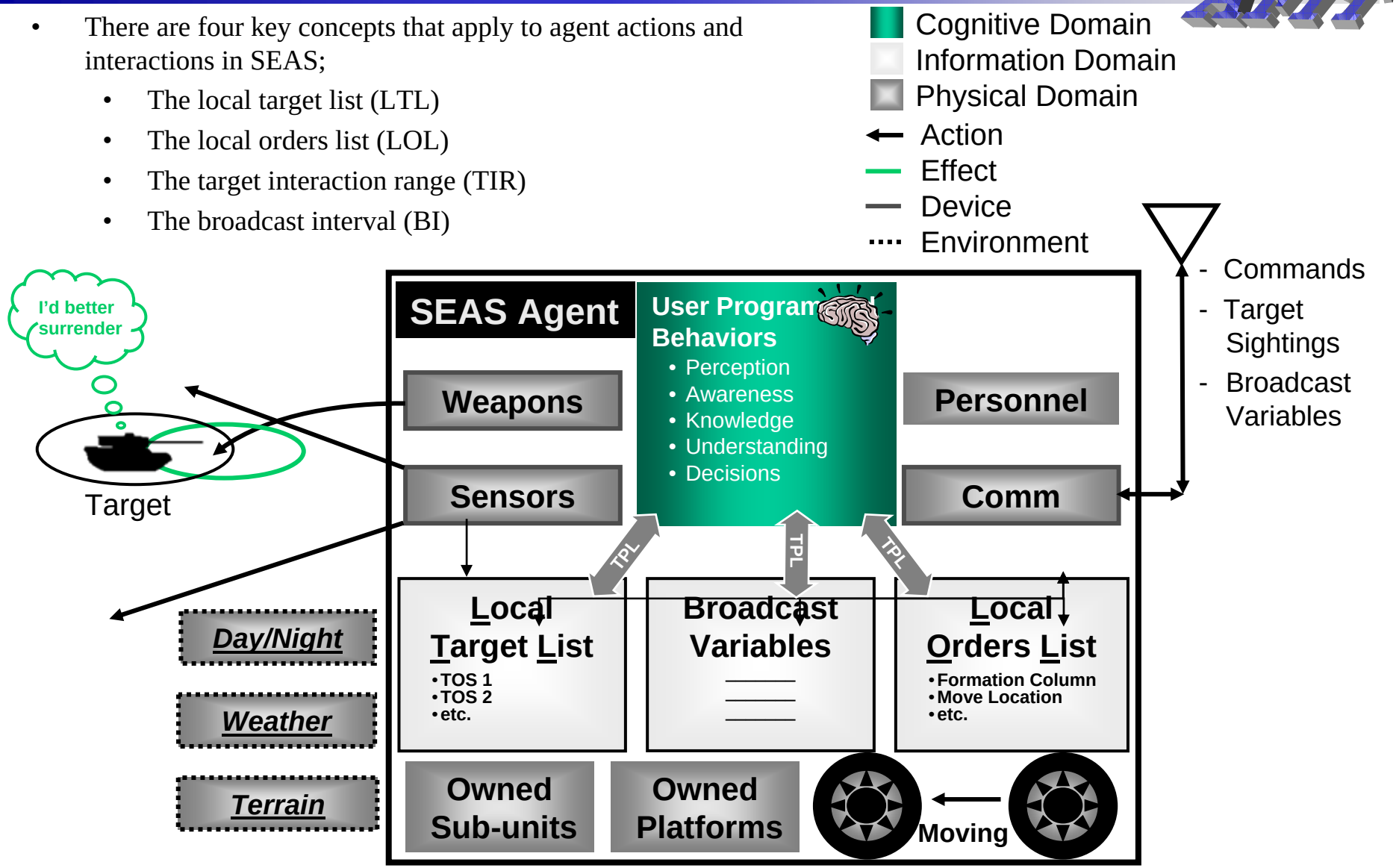
I can also decide to do any of these things on my own as well as provide other services to fellow agents like; tell them where to go, tell them what targets to attack, etc.

When I move or shoot I use resources that must be replenished after awhile or I won't be able to move and or shoot.

I am basically a pretty aggressive guy and if I see an emeny agent and I am within range I will try and kill him unless you tell me not to.

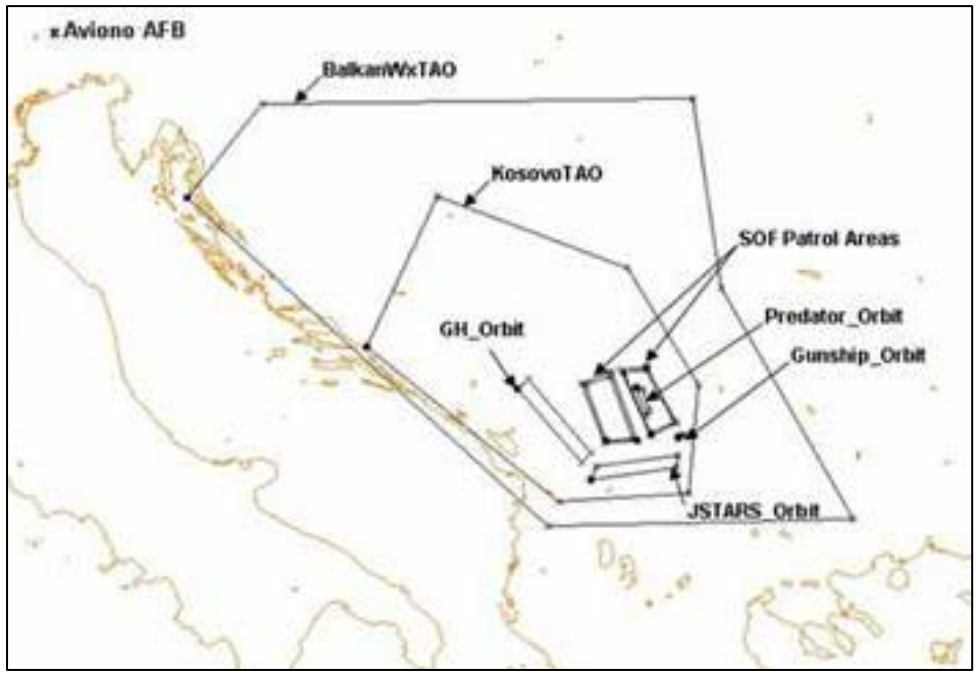
Conceptual View of a SEAS Agent

- There are four key concepts that apply to agent actions and interactions in SEAS;
  - The local target list (LTL)
  - The local orders list (LOL)
  - The target interaction range (TIR)
  - The broadcast interval (BI)



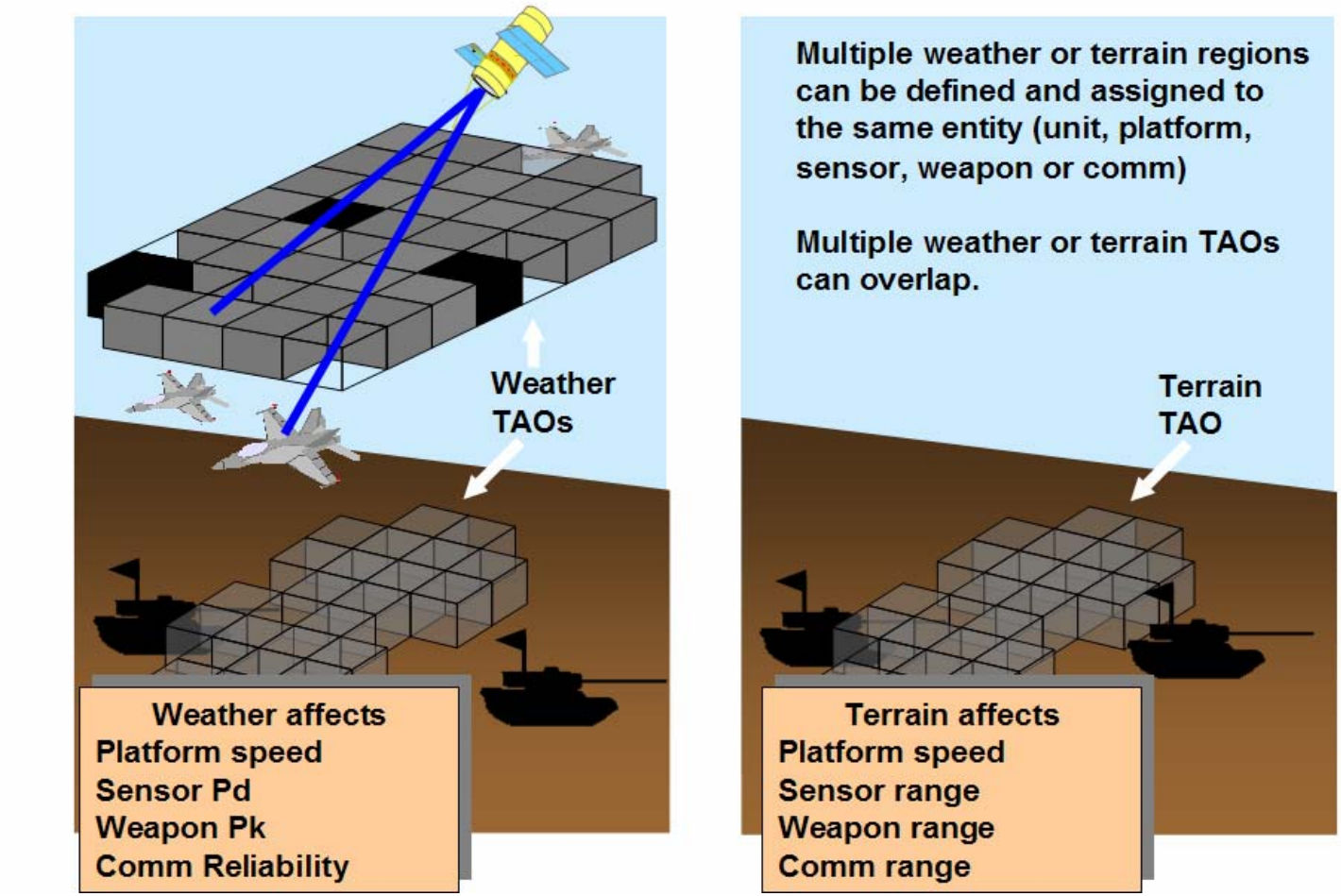
Kosovo Scenario - Overview

- Kosovo Scenario - created by Space and Missile Center Developmental Planning (SMC/XR)
  - Programmed to represent operations in Kosovo conflict during 1999



Kosovo Scenario – Weather/Terrain Objects Overview

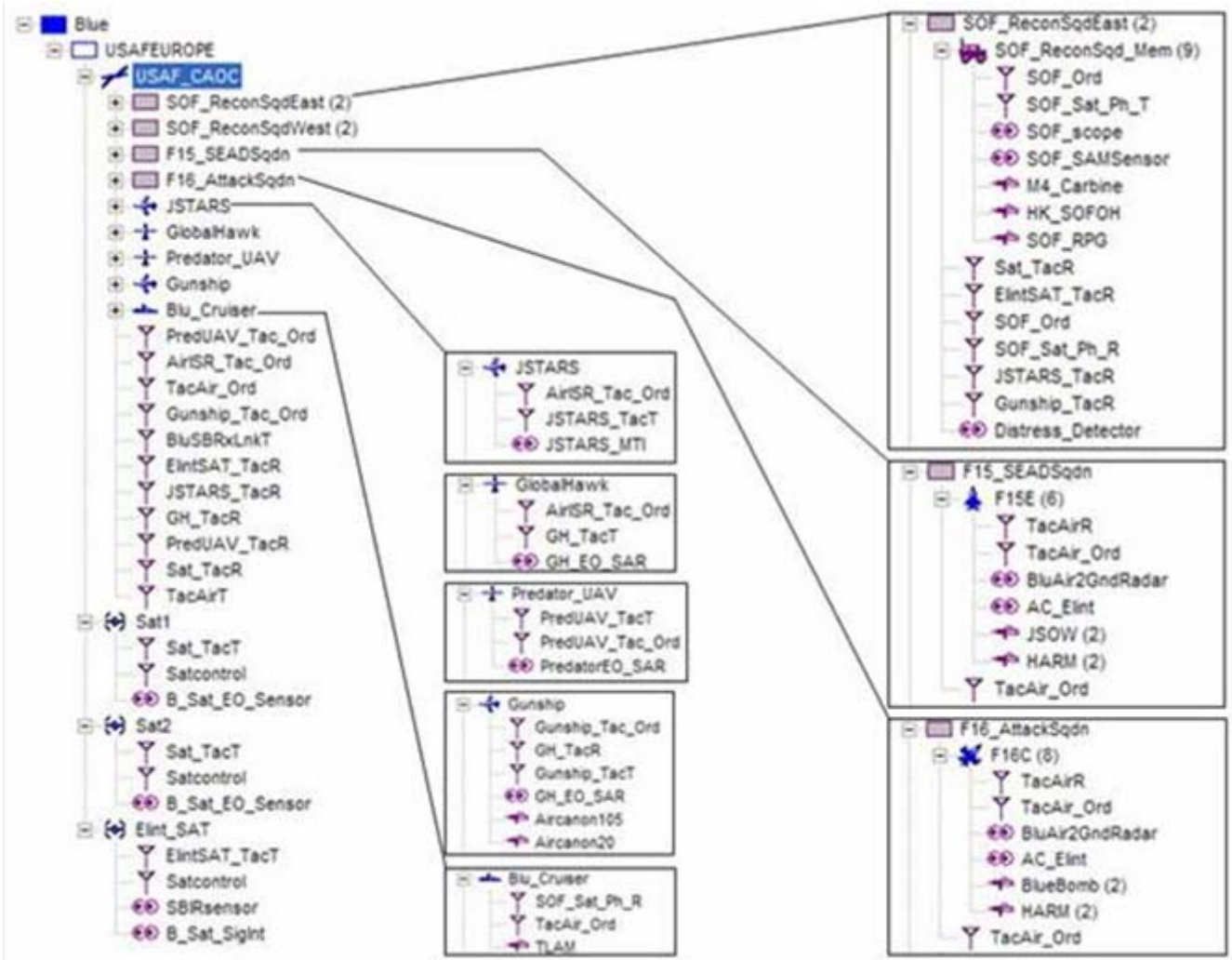
- **Weather** affects Platform speed, **Sensor Pd, Weapon Pk, and Comm Reliability**
- **Terrain** affects Platform speed, **Sensor range, Weapon range, and Comm range**



Reference: SPARTA, Inc. SEAS Training Course : slide 274

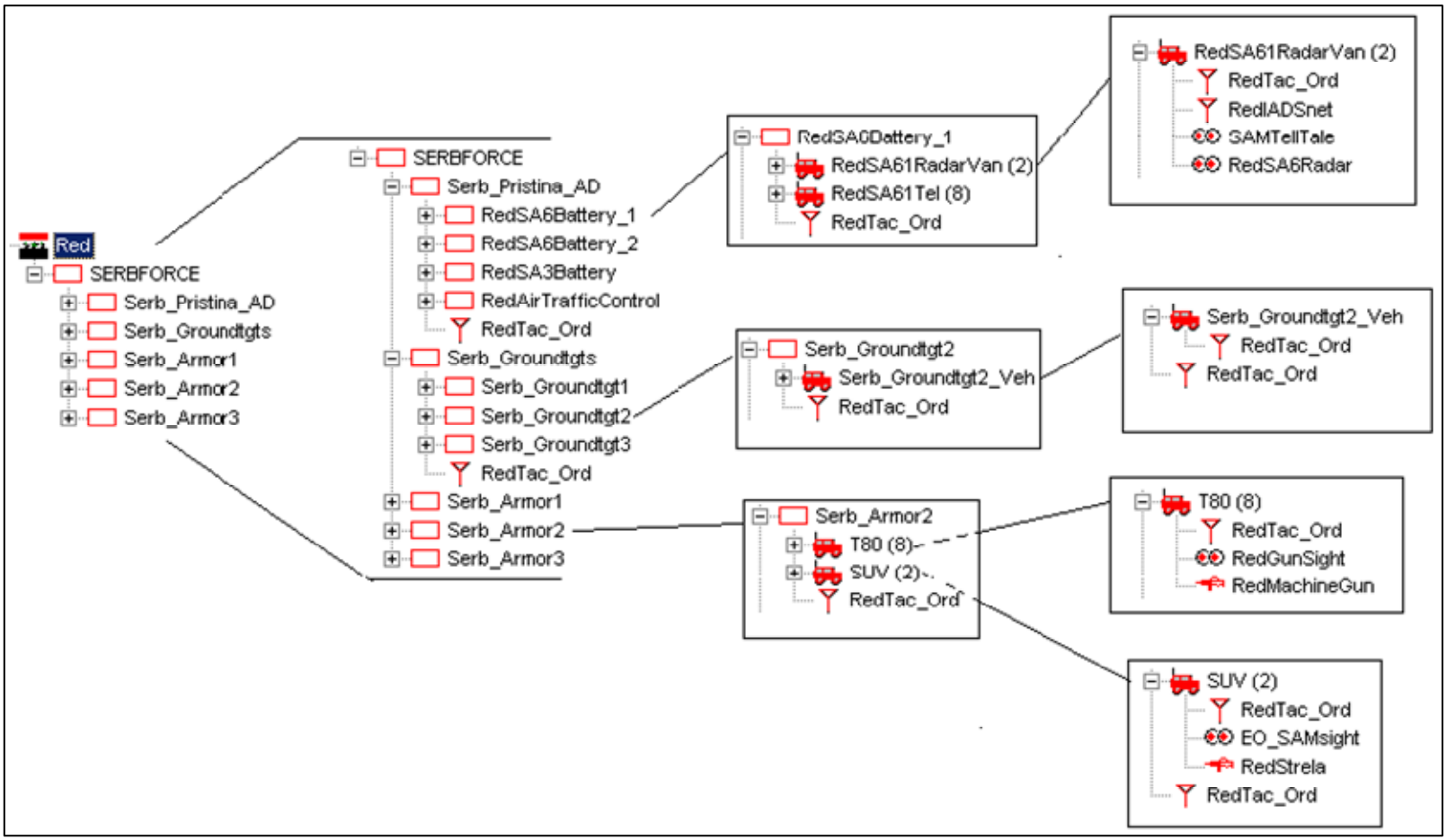
Kosovo Scenario

- Blue USAFE Force



Kosovo Scenario

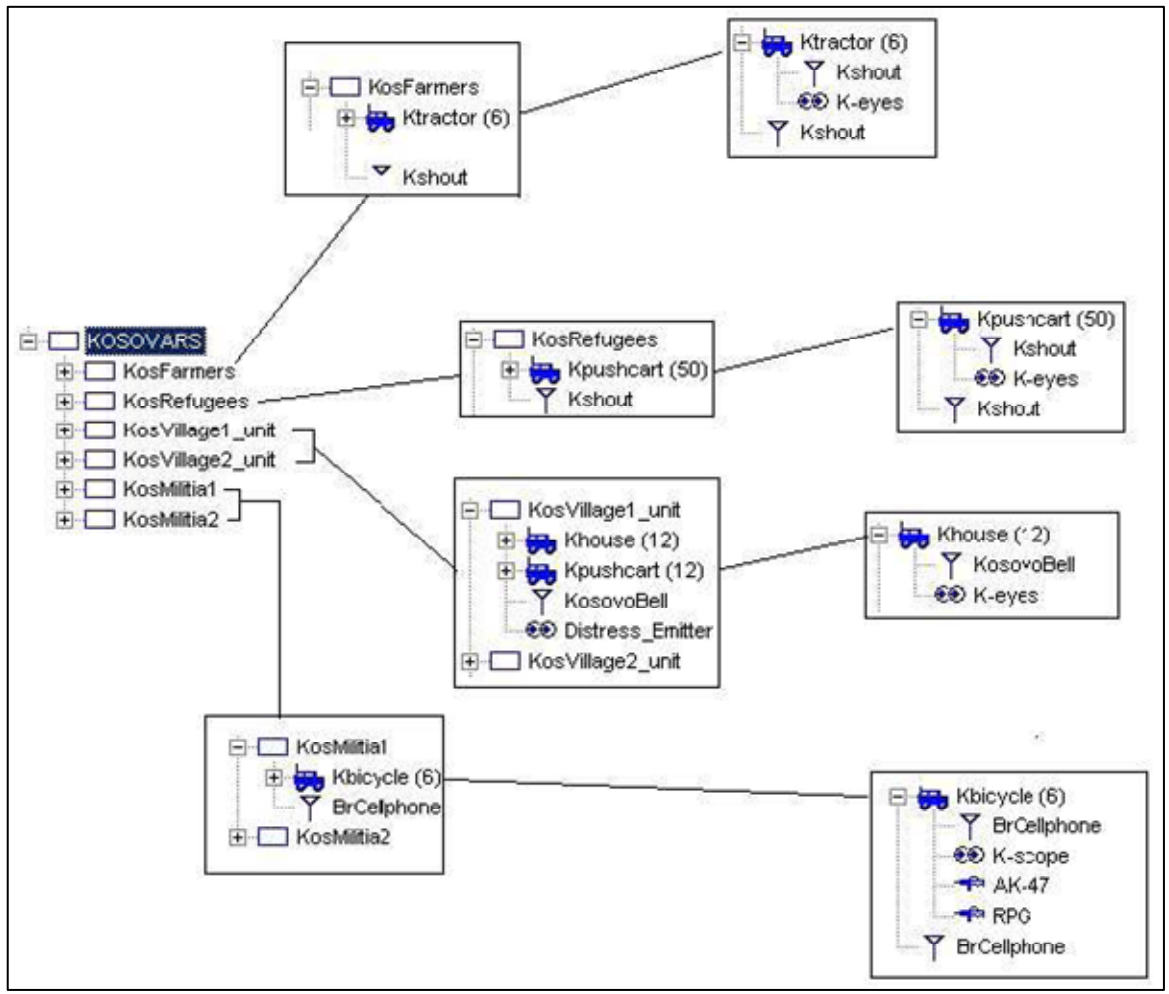
- Red Serbian Force



Reference: DeStefano, 2004:3-6

Kosovo Scenario

- Brown Kosovar Force



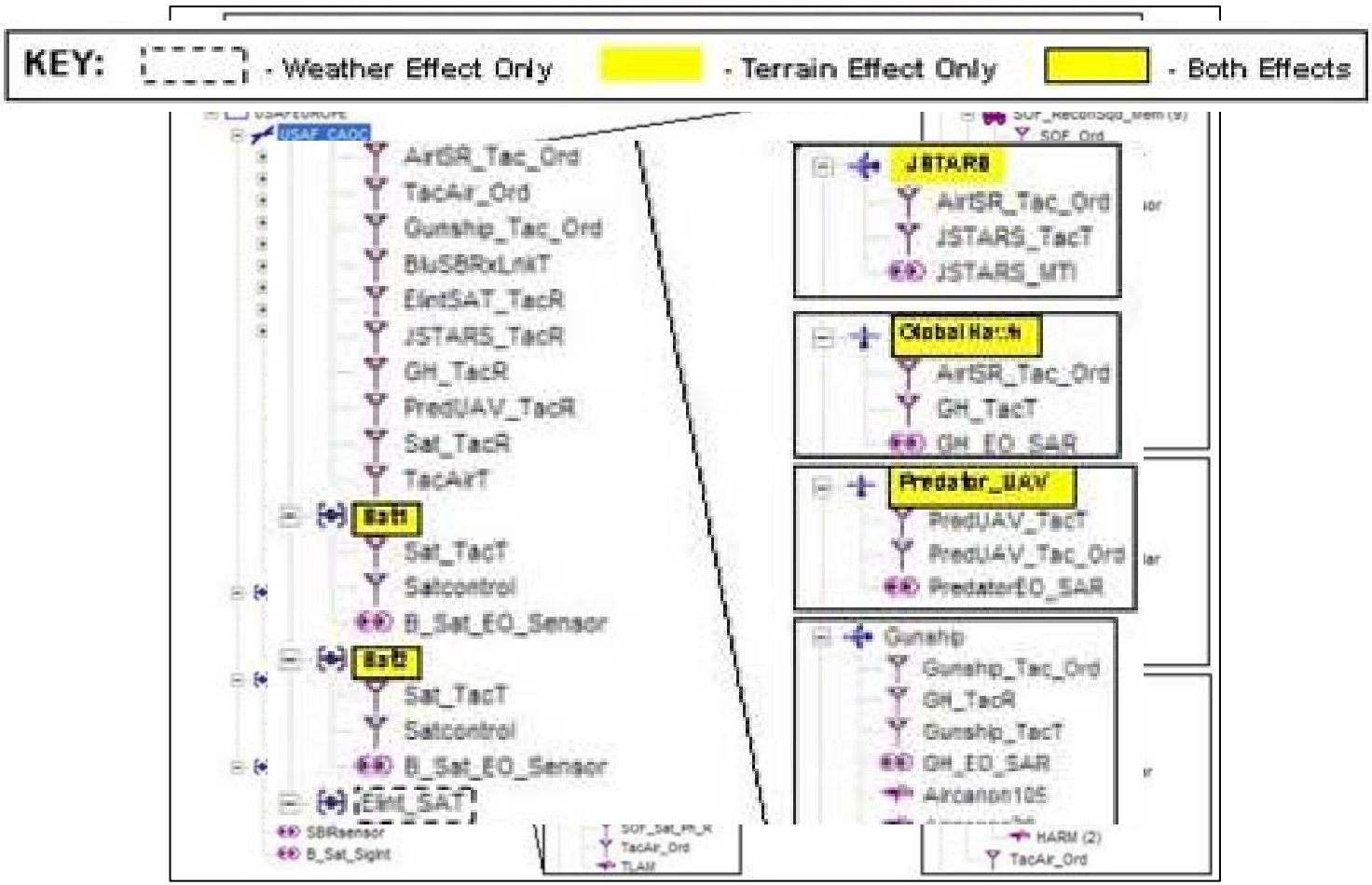
Reference: DeStefano, 2004:3-7

Measures of Effectiveness

- Physical Domain
  - Target Detection Distance
- Information Domain
  - Communication Channels Message Loading
- Cognitive Domain
  - Effect on the Kill Chain

Analysis Overview

- Used coded Blue Force chart as guide for focusing analysis



Analysis – Physical Domain

Target Detection Distance

- Performed Paired-t Test to compare average of detection distance outputs over ***30 runs***

Satellites Paired-*t* Test Detection Distance Analysis

Satellite #1

Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	178.30	(166.38,190.23)	**Yes**	**-13.75**
Terrain Only	174.57	(165.88, 183.26)	**Yes**	**-13.46**
Weather Only	15.91	(3.18, 28.63)	**Yes**	**-1.23**

Satellite #2

Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	176.66	(164.02, 189.30)	**Yes**	**-13.80**
Terrain Only	164.00	(154.65, 173.35)	**Yes**	**-12.81**
Weather Only	18.05	(0.36, 35.75)	**Yes**	**-1.41**

Paired-*t* Test Results for F-15's

F-15 Squadron Paired-*t* Test Detection Distance Analysis

F-15E#1

Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	-0.44	(-6.19, 5.31)	**No**	**1.05**
Terrain Only	-6.56	(-11.71, -1.41)	**Yes**	**15.78**
Weather Only	1.56	(-4.75, 7.87)	**No**	**-3.75**

F-15E#4

Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	0.38	(-8.22, 8.97)	**No**	**-0.92**
Terrain Only	-2.15	(-8.45, 4.16)	**No**	**5.20**
Weather Only	3.07	(-2.83, 8.97)	**No**	**-7.42**

All 6 F-15's Together

Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	0.49	(-3.39, 4.37)	**No**	**-1.18**
Terrain Only	-3.07	(-7.05, 0.91)	**No**	**7.38**
Weather Only	0.62	(-2.99, 4.23)	**No**	**-1.49**

Paired-*t* Test Results for JSTARS and Global Hawk

JSTARS and Global Hawk Paired-*t* Test Detection Distance Analysis

JSTARS

Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	0.21	(-2.09, 2.51)	**No**	**-0.33**
Terrain Only	0.28	(-2.48, 3.05)	**No**	**-0.44**
Weather Only	-0.63	(-3.05, 1.79)	**No**	**0.98**

Global Hawk

Difference Between Baseline and:	$\overline{Z}(n)$	95 % Confidence Interval	Statistical Difference?	Percentage Change from Baseline:
Full Effects	-0.06	(-0.18, 0.05)	**No**	**0.24**
Terrain Only	-0.06	(-0.12, 0.00)	**No**	**0.24**
Weather Only	0.13	(0.03, 0.23)	**Yes**	**-0.53**

Analysis – Information Domain

Standard Comm Output from SEAS

- **SEAS standard output comm file tracks information on three types of channels:**
  - "_Sit_" = situation report (i.e. target sighting)
  - "_Var_" = broadcast variable (user-defined; e.g. target priority, delay time)
  - "_Ord_" = orders (commands)
- **For each channel type, SEAS tracks:**
  - *Add* = number of messages *added* per time step
  - *Cur* = number of messages *broadcast* (currently held on the channel) per time step
  - *Rem* = number of messages *removed* per time step

Analysis – Information Domain

Standard Comm Output from SEAS

- Example of Communications raw data from SEAS

Run	#1		
Time	JSTARSQ_Sit_Cur	JSTARSQ_Sit_Add	JSTARSQ_Sit_Rem
8	0	0	0
9	0	0	0
10	0	0	0
11	4	4	0
12	4	0	0
13	4	0	0
14	4	0	0
15	0	0	4
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	14	14	0
22	14	0	0
23	14	0	0
24	14	0	0
25	0	0	14
26	0	0	0

Analysis – Information Domain

Average Message Loading

- Calculated average number of messages handled by all channels over ***10 runs*** of the scenario

	BASELINE - No Effects		Terrain Only		Weather Only		Full Effects	
Channel	Count	Average	Count	Average	Count	Average	Count	Average
JSTARSQ_Sit_Rem	2262.00	0.51	2260.00	0.46	1077.00	0.48	**3728.00**	**0.61**
GShipQ_Sit_Rem	1985.00	0.43	1800.00	0.34	131.00	0.09	424.00	0.10
GHQ_Sit_Rem	3362.00	0.68	3197.00	0.56	180.00	0.16	833.00	0.15
SBRQ_Sit_Rem	22302.00	4.90	21321.00	4.11	5328.00	2.65	18781.00	3.23
TacAirQ_Sit_Rem	22302.00	4.90	21321.00	4.11	5328.00	2.65	18781.00	3.23
GShip_OrdQ_Ord_Rem	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Air_OrdQ_Ord_Rem	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00
ImSatQ_Sit_Rem	64.00	0.01	21.00	0.01	27.00	0.01	14.00	0.00
ElintSATQ_Sit_Rem	233.00	0.06	205.00	0.04	172.00	0.04	216.00	**0.06**
SOF_OrdQ_Ord_Rem	342.00	0.21	**567.00**	0.13	189.00	0.08	207.00	0.13
SOF_Sat_PhQ_Sit_Rem	336.00	0.05	131.00	0.04	**512.00**	0.05	311.00	**0.06**
RTac_OrdQ_Var_Rem	11342.00	2.14	**13448.00**	**2.26**	**13367.00**	**2.19**	11342.00	2.12
RTac_OrdQ_Ord_Rem	11198.00	1.93	7138.00	1.73	7118.00	1.86	**11578.00**	**1.99**
RIADSQ_Sit_Rem	827.00	0.18	**1250.00**	**0.20**	765.00	0.18	**1205.00**	**0.25**
RSRTQ3_Sit_Rem	371.00	0.20	367.00	0.09	369.00	0.11	353.00	0.20
KSHQ_Sit_Rem	218.00	0.04	**303.00**	0.04	**264.00**	**0.04**	**237.00**	0.04
KSHQ_Ord_Rem	283.00	0.05	**310.00**	**0.05**	256.00	0.05	249.00	0.05
KBellQ_Sit_Rem	3652.00	0.45	3635.00	0.42	**9828.00**	**0.62**	**6742.00**	**0.78**
KBellQ_Ord_Rem	24.00	0.00	24.00	0.00	24.00	0.00	24.00	0.00

- Useful in identifying channels seeing highest activity
- Provided comparison test between baseline and three degraded cases
- **Inactive time-steps (zero messages) skewed the averages**

Analysis – Information Domain
Active Time-Step Loading

- Next, calculated total number of messages and active average message loading for top five channels over ***one simulation run***

Average Channel Loading for *Active Time-Steps*

BASELINE - NO EFFECTS CASE

Channel	JSTARSQ_Sit	SBRQ_Sit	TacAirQ_Sit	RTac_OrdQ_Var	RTac_OrdQ_Ord
Number of Active Minute Time-Steps	196.00	324.00	179.00	513.00	1132.00
Average Message Activity per Time-Step	7.18	64.82	117.34	27.16	14.77

FULL EFFECTS CASE

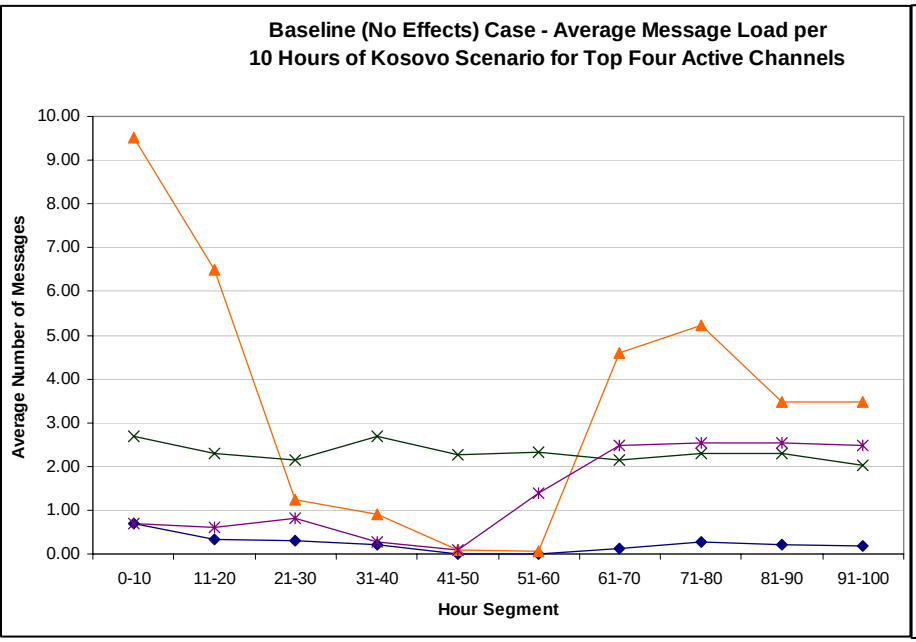
Channel	JSTARSQ_Sit	SBRQ_Sit	TacAirQ_Sit	RTac_OrdQ_Var	RTac_OrdQ_Ord
Number of Active Minute Time-Steps	352.00	293.00	187.00	525.00	882.00
Average Message Activity per Time-Step	10.43	58.02	90.91	23.60	14.88

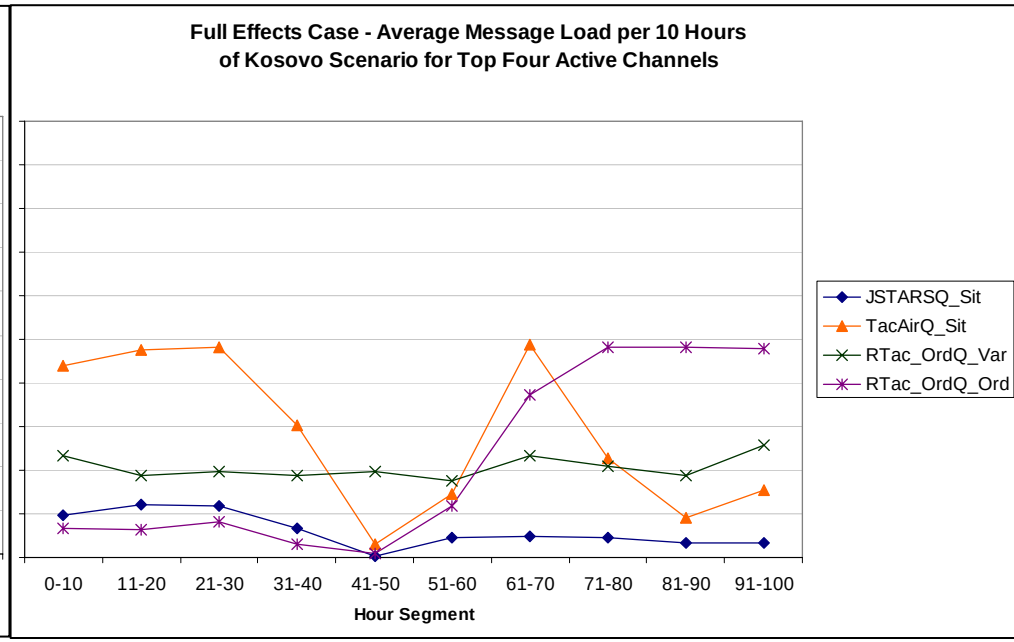
- **A slightly better metric than overall average message load because influence of zero message time-steps is removed**

Analysis – Information Domain

Average Message Load Over Time

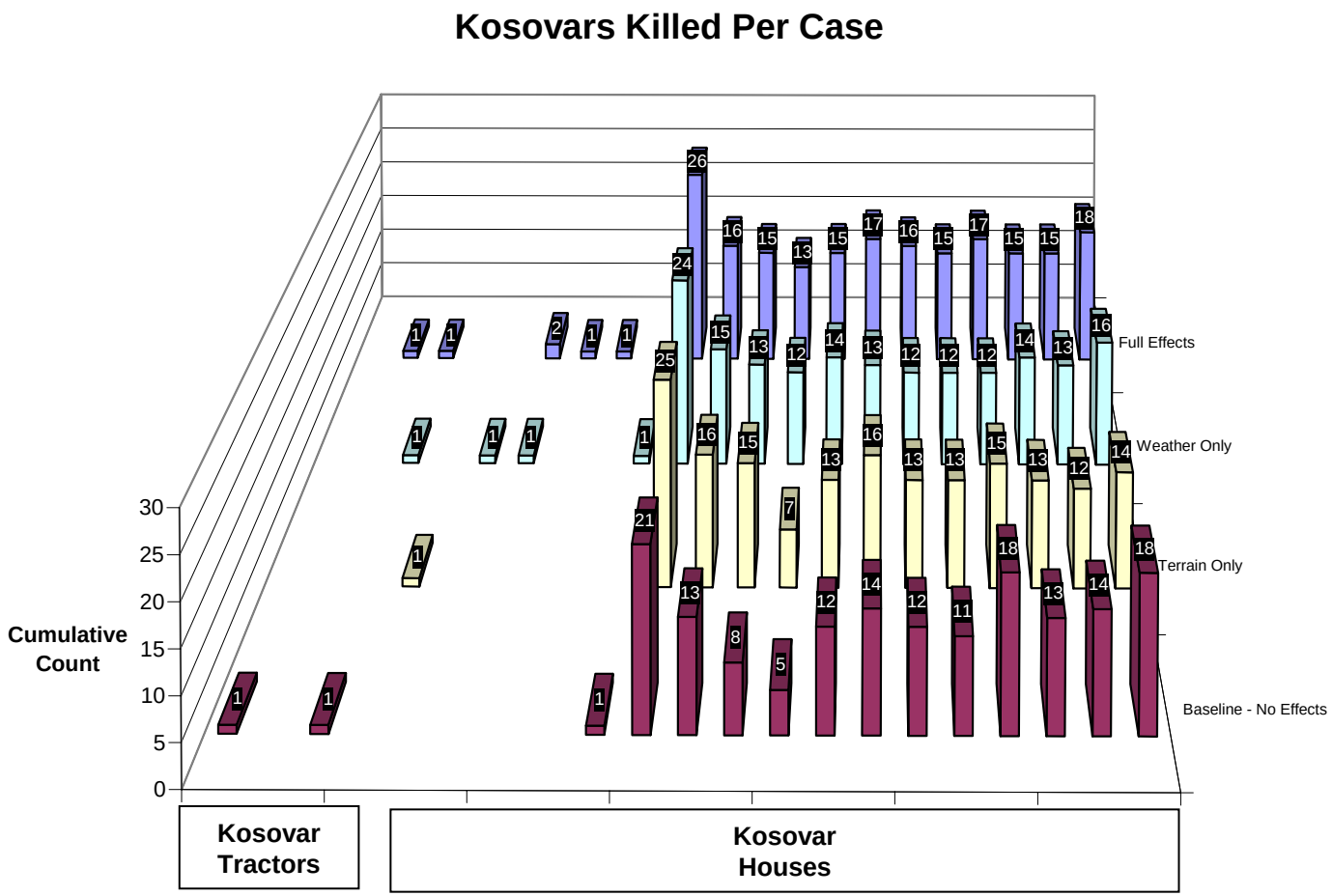
- Finally, calculated and plotted average message loading per 10-hour segment over ***one simulation run***
- Provides most insight into communication channel activity





Analysis – Cognitive Domain
Effect on the Kill Chain

- A kill represents the conclusion of the kill chain
  - The ***Act*** of the OODA Loop (Observe, Orient, Decide, Act)



Analysis – Cognitive Domain

Effect on the Kill Chain

- Consistent trends seen in the degraded cases versus the baseline case for this admittedly rough and highly aggregated measure
  - Fewer kills and higher losses for Blue, more kills and less losses for Red, and higher losses for Brown
- **Cognitive Domain is by far the most difficult to capture with an exact quantitative measure**

Conclusions – Analysis Summary

- **Physical domain – Satellite performance was captured well by average detection distance metric**
- **Information domain – Average message loading over time provided insight into Blue's primary target sighting channel**
- **Cognitive domain – Number of kills, although highly aggregated, showed expected trends**

QUESTIONS?

Thank You