Missions and Means Framework (MMF) Demonstration: The Storyboard Model

Richard S. Sandmeyer
U.S. Army Research Laboratory

International Test and Evaluation Association
Modeling and Simulation Conference
December 12-15, 2005

Presented by Richard Sandmeyer
richsand@arl.army.mil

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Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE **DEC 2005**	2. REPORT TYPE	3. DATES COVERED **00-00-2005 to 00-00-2005**
4. TITLE AND SUBTITLE **Missions and Means Framework (MMF) Demonstration: The Storyboard Model**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Research Laboratory,Computational and Information Sciences Directorate,White Sands Missile Range,NM,88002**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **Modeling and Simulation Conference, 2005 Dec 12-15, Las Cruces, NM**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**26**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Objective

To present an overview of

the Missions and Means Framework

and of

its first demonstration,

which may impact future application of

Modeling and Simulation to

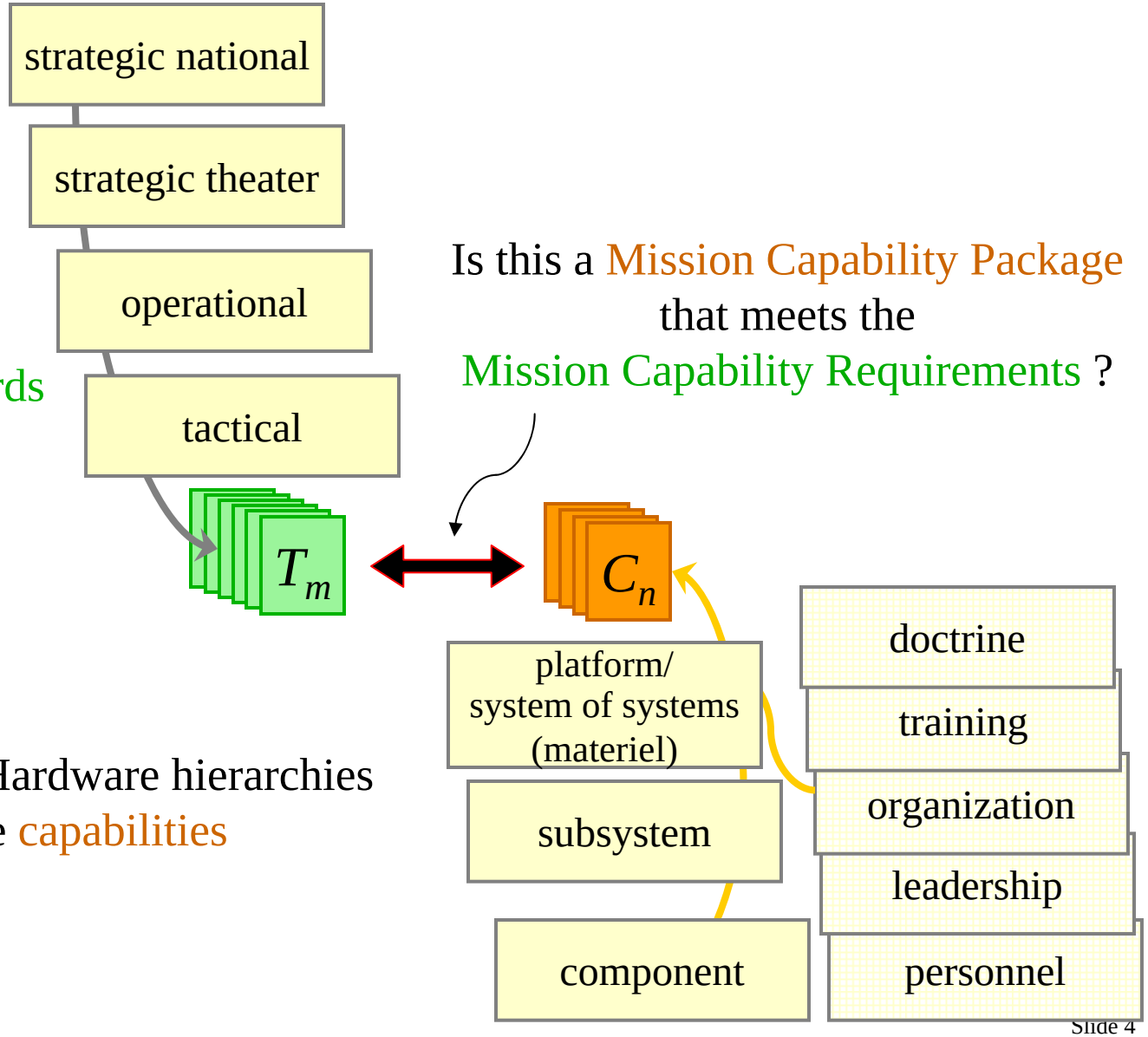
Test and Evaluation.

Outline

- MMF Background
  - What is it?
  - What is different from previous approach?
  - Relevance to SoS analysis
- MMF Demonstration 2004-2005
  - Mission-to-Task Decomposition
  - Degraded Capability States
  - Task Requirements versus Unit Capabilities
  - Storyboard Model
  - Outputs
- Conclusions and Path Forward

Missions and Means Framework: What Is it?

Mission hierarchy
induces
tasks, conditions, standards



Is this a Mission Capability Package
that meets the
Mission Capability Requirements ?

Personnel & Hardware hierarchies
induce capabilities

What Is Different?

- Platform state represented by its current capabilities, which can be compared to current task requirement(s), instead of by a weighted average of probability of having/not having functionality to perform randomly selected mission
  - Higher resolution
  - Permits more accurate damage accumulation
  - Less “averaging too early”
- Tasks described in terms of standard sets (AUTL, UJTL, LSI tasks)
  - Standardization across user, R&D, and T&E communities
- Better representation of residual platform and (ultimately) unit capabilities throughout simulation should enable better representation of resource allocation/reallocation:
  - To develop alternative task sets to achieve the higher level mission
  - To explore alternative courses of action
  - To model capabilities “borrowed” from other platforms and units
  - To model capabilities spread across multiple platforms

Relevance to SoS Analysis

Decomposition of missions into low-level tasks allows cleaner and simpler modeling of alternative means for completing them

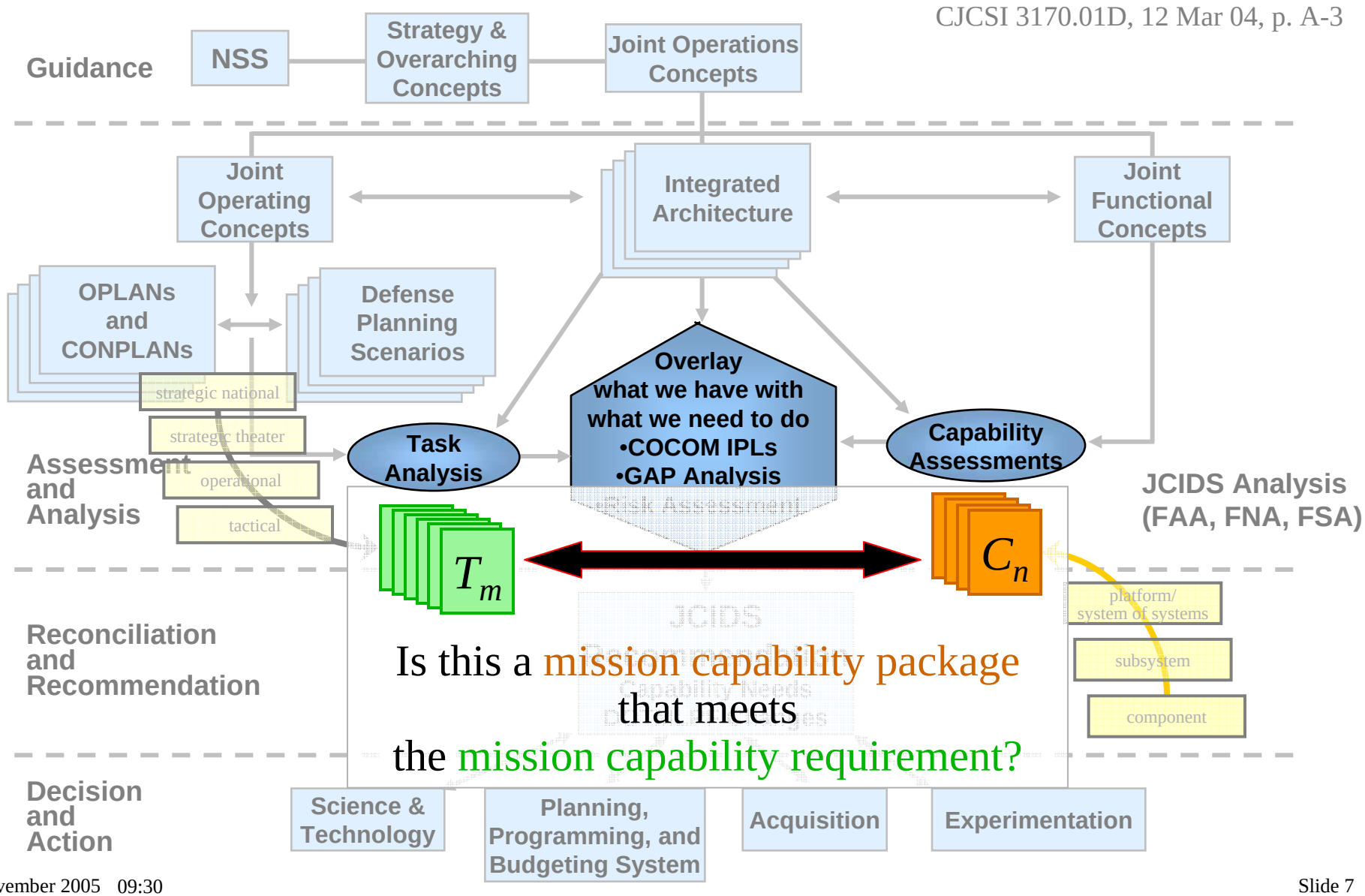
- What does the current task require?
- What composite capabilities can my current force attain by combining the platforms' individual capabilities?
- What capabilities can I "borrow" over the network?
- How do all these capabilities change over time as damage, failure, repair, and resupply events occur?

This capability supports higher-fidelity and more relevant analysis

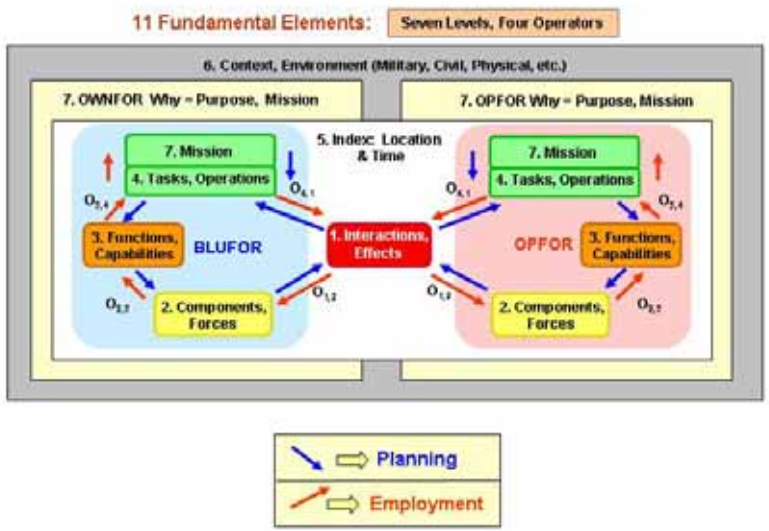
- What's my per-task completion rate over some reasonable sample of scenarios?
- What causes my failures: DOTMLPF? other?
- What are some suitable corrective actions?

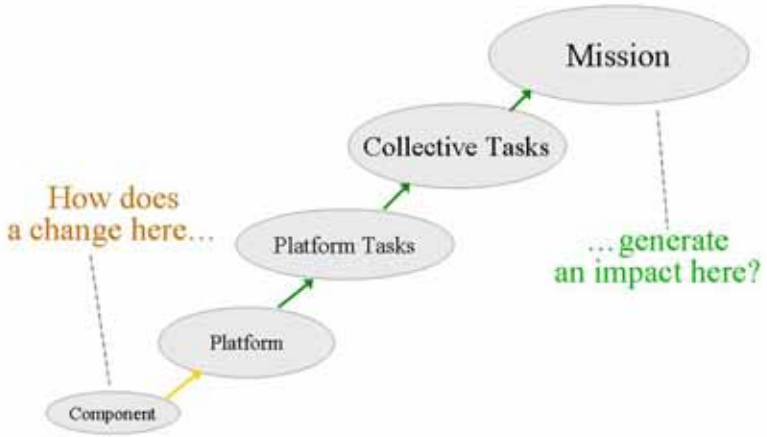
How MMF Supports JCIDS

(Joint Capabilities Integration and Development System)



MMF Demonstration: What is it?





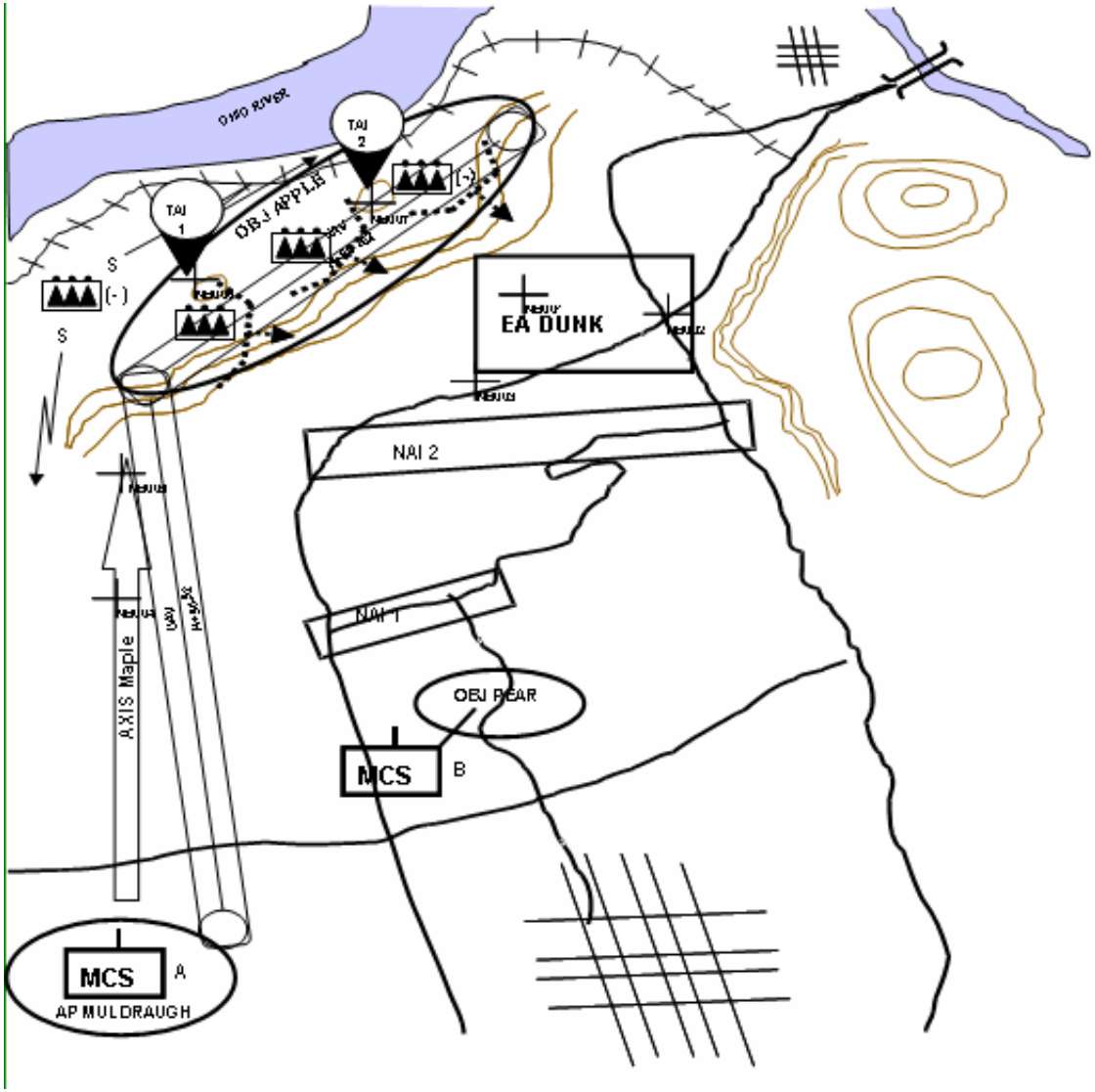
- End-to-end execution of a simple vignette.
- Direct application of warfighter tasks demonstrating System of Systems effects that features:

  Task Requirements for standardized tasks,
  Degraded Capability States at platform level,
  Effects of damage, reliability, repair, etc. down to component level,
  and indicates when alternative courses of action needed.

The Demonstration: Basic Elements

- Vignette (from Map Exercise by Dynamics Research Corporation):
  - map with movement paths
  - time-ordered event list
- Time-ordered list of tasks required (scripted for this demo – negligible dynamics)
  - Derived from event list
  - Each task tagged with platform type to perform it and capabilities required
- Platform capability representation (Degraded Capability States) as function of time (as damage, failures, repairs occur according to script)
- Miscellaneous platform performance characteristics represented in various levels of degradation (from none to total)

Vignette battle plan



MISSION:

Attack north on AXIS Maple and seize OBJ APPLE NLT 0600 hrs. Establish attack by fire positions on OBJ APPLE and engage enemy forces already in or entering EA DUNK IOT block enemy forces from moving north to support rebel leadership vic Westpoint or support enemy forces defending in and around Louisville.

ENDSTATE:

Enemy forces vicinity of Knox remain south of EA DUNK until friendly operations vicinity of Westpoint are completed.

TAI - Targeted Area of Interest

K - Key Terrain

MCS Engagement Area

NAI - Named Area of Interest

TOEL Generated to Drive Vignette Execution in the Storyboard Model

Time Ordered Event List

SEQ #	TIME	ACTIVITY
	0200-0400	PHASE I
P101		MCS A in AP Muldraugh and preparing for movement to OBJ APPLE
P102		C2V establishes ACA MAPLE, min alt 500 ft AGL, max alt 1000 ft AGL, ES860930, ET850050, ET880050, ES890940, eff 0200-0600
P103		C2V disseminates ACA MAPLE coordinates to CAB
P104		C2V launches UAV 1 from AP Muldraugh vic ES864943
P105		UAV 1 travels from AP Muldraugh (ES 864943) to perform route reconnaissance. Route ACPs: ES865945 (SP) to ET 883011 to ES866957 to ET875045 (OBJ APPLE)
P106		C2V monitors incoming data from UAV 1 visual and sensor feeds as it travels north along AXIS MAPLE
P107		MCS A plts conduct perimeter security in AP Muldraugh with their respective ARV-Rs
P108		MCS A plts perform precombat checks in preparation for movement north to OBJ APPLE
P109		UAV 1 remains on OBJ APPLE and conducts reconnaissance of TAI's 1 and 2. UAV 1 Route ACPs: ET876050, ET856040, ET880005, ET876050. UAV performs continuous loop on OBJ APPLE.
P110		C2V monitors incoming data from UAV 1 visual and sensors feed as it conducts reconnaissance of OBJ APPLE
P111	Interaction 1	*UAV 1 detects suspected enemy activity vic TAI 2 with IR sensor*
P112		UAV 1 sends sensor report to C2V
P113		C2V receives IR sensor report of enemy activity vic TAI 2
P114		C2V updates the COP and informs MCS A Cdr
P115		Updated COP disseminated to higher and lower echelons
P116		C2V continues to monitor UAV 1 sensor feeds
P117		C2V tasks UAV 1 to stare at suspected enemy activity position to achieve better fidelity for target identification
P118		UAV 1 IFF sensor does not confirm friendly force
P119	Interaction 2	*UAV 1 detects elements of a suspected enemy INF squad vic ET 877036*
P120		UAV 1 transmits information to C2V
P121		C2V receives UAV 1 information and cannot confirm or deny enemy forces and continues to monitor activity
P122		UAV 1 maintains surveillance of TAI's 1 and 2 and OBJ APPLE
P123		MCS plts begin to assemble in order of march formation and prepare for tactical movement
P124		NLOS-C/M receives updated COP and plans targeting data for TAI 2.
P125		C2V and MCS A Hq prepares for movement toward OBJ APPLE
P126		MCS A plts task ARV-R 2 & 3 to move north along AXIS MAPLE with a limit of advance of 3km from plt main body and conduct reconnaissance. ARV-R 2 will travel route ES871948 (SP), ES873966, ES876987, ET875008, ET878018 ARV-R 3 will travel route ES862951 (

Tasks as Function of Time

1	Vignette Times			
2			TASKS	PLATFORM
51	0200-1000	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	ARV 2
52	0412-0417	ART 7.2	*LSI A1.6.2.1.1.4.3 Report Enemy Information	ARV 2
53	0200-1000	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	ARV 3
54	0757-0802	ART 7.2	*LSI A1.6.2.1.1.4.3 Report Enemy Information	ARV 3
55	0200-1000	ART 7.2	*MTP 07-1-1COP.07-C332 Establish the Common Operational Picture	C2V
56	0200-0205, 0253-0258, 0308-0313, 0341-0346, 0437-0442, 0525-0530, 0633-0638, 0707-0712, 0800-0805, 0849-0854	ART 7.2	*ART 7.2.5 Disseminate Common Operational Picture and Execution Information	C2V
57	0200-1000	ART 7.2	LSI A2.3.1 Collect Relevant Information ART 7.2.1	C2V
58	0200-1000	ART 7.2	MTP 07-1-WT06.07-C332 Conduct Battle Tracking	C2V
59	0200-1000	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	C2V
60	0255-0300, 0313-0318, 0339-0344, 0410-0415, 0523-0528, 0612-0617, 0706-0711, 0750-0755, 0844-0849	ART 7.2	*LSI A1.6.2.1.1.4.3 Report Enemy Information	C2V
61	0210-0542	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	UAV 1
62	0250-0255, 0305-0310, 030-0335	ART 7.2	*LSI A1.6.2.1.1.4.3 Report Enemy Information	UAV 1
63	0340-0835	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	UAV 2
64	0431-0436, 0715-0720	ART 7.2	*LSI A1.6.2.1.1.4.3 Report Enemy Information	UAV 2
65	0543-1000	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	UAV 3

TIMELINES / P-Lines / Sheet3

Platform Capabilities Modeled by Degraded Capability States

C2V (2)

NLOS (6)

ARV-RISTA (3)

Class-II UAV (3)

Mobility (5)
M0 No Mobility Degradation
M1* Reduced Maximum Speed
M2 Reduced Maneuverability
M3* Stop After T Minutes
M4 Reduced Acceleration
M5 Total Immobilization

Firepower (12)
F0 No Firepower Degradation
F1 Lost Ability To Fire Buttoned Up Main
F2 Degraded Delivery Accuracy of Main
F3 Degraded Initial Rate of Fire of Main
F4 Degraded Subsequent Rate of Fire of Main
F5 Degraded Maximum Range Main
F6 Lost Reload Capability
F7 Total Loss of Firepower Main
F8 Lost Ability to Fire Buttoned Up Secondary
F9 Degraded Delivery Accuracy of Secondary
F10 Degraded Initial Rate of Fire of Secondary
F11 Degraded Subsequent Rate of Fire of Secondary
F12 Total Loss of Firepower Secondary

Communication (8)
X0 No Communication Degradation
X1 Reduced Range
X2* Lost Line-of-Sight (LOS) Data (ex. JTRS)
X3* Lost LOS Voice
X4* Lost Non-LOS Data (ex. SATCOM)
X5 Lost NLOS Voice
X6 Lost Internal Communications
X7 Lost External Communications
X8 Lost All Communications

Survivability (6)
S0 No Survivability Degradation
S1 Lost NBC Protection
S2 Lost Ability to Deploy Obscurants
S3 Lost Silent Watch Capability
S4 Lost Active Protection System
S5 Lost Threat Warning Capability
S6 Lost Fire Suppression Capability

Target Acquisition (3)
A0 No Acquisition Degradation
A1 Lost Daylight Sights
A2 Lost Night Sights
A3 Lost Range Finder

Surveillance (4)
Z0 No Surveillance Degradation
Z1 Lost Primary Sensor
Z2 Lost Secondary Sensor
Z3 Lost Tertiary Sensor
Z4 Lost All Surveillance

Crew (7)
C0 No Crewmember Incapacitated
C1 Commander Incapacitated
C2 Squad Leader Incapacitated
C3 Driver Incapacitated
C4 Operator 1 Incapacitated
C5 Operator 2 Incapacitated
C6 Gunner Incapacitated
C7 Loader Incapacitated

Passengers (1)
P0 No Passengers Incapacitated
P1 Passengers Incapacitated

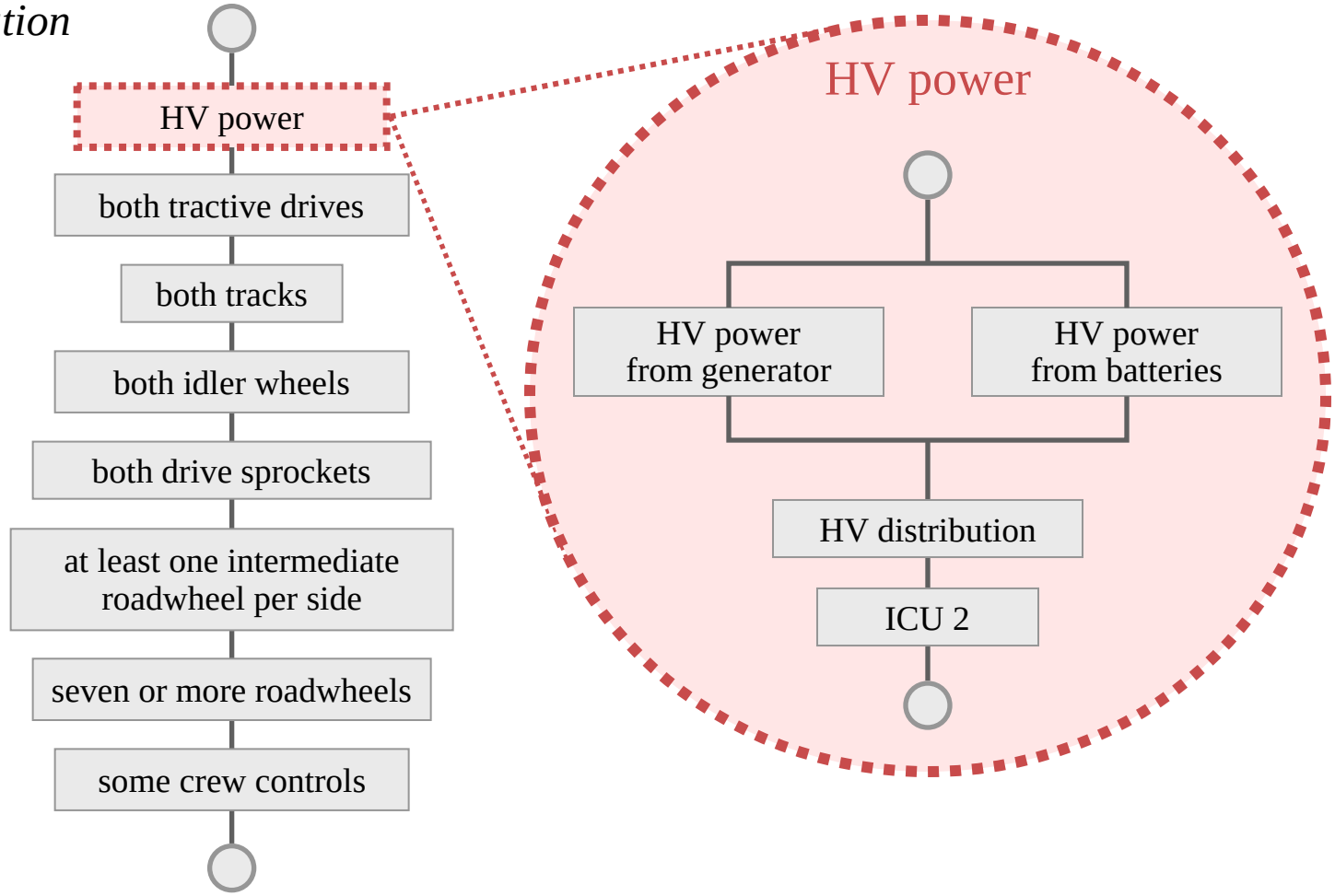
Other (3)
01 Lost Situational Awareness
02 Lost Unmanned System Control
03 Lost Automated C^2

Catastrophic Loss (1)
K0 No Catastrophic Loss
K1 Lost Every Capability

** assigned degradation factor according to the variation in components affecting speed or bandwidth.*

System Capabilities Depend on Subsystems and Components

Cutting this fault tree results in a total immobilization



Task Requirements to Platform Capability Mapping

1	Vignette Times				How DCS affects task: green=pass, red=fail, yellow=maybe							
2			TASKS	PLATFORM			Comms					
51	0200-1000	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	ARV 2			x0		x2	x3	x4	
52	0412-0417	ART 7.2	*LSI A1.6.2.1.1.4.3 Report Enemy Information	ARV 2			x0		x2	x3	x4	
53	0200-1000	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	ARV 3			x0		x2	x3	x4	
54	0757-0802	ART 7.2	*LSI A1.6.2.1.1.4.3 Report Enemy Information	ARV 3			x0		x2	x3	x4	
55	0200-1000	ART 7.2	*MTP 07-1-1COP.07-C332 Establish the Common Operational Picture	C2V			x0	x1	x2	x3	x4	x5
56	0200-0205, 0253-0258, 0308-0313, 0341-0346, 0437-0442, 0525-0530, 0633-0638, 0707-0712, 0800-0805, 0849-0854	ART 7.2	*ART 7.2.5 Disseminate Common Operational Picture and Execution Information	C2V			x0	x1	x2	x3	x4	x5
57	0200-1000	ART 7.2	LSI A2.3.1 Collect Relevant Information ART 7.2.1	C2V			x0	x1	x2	x3	x4	x5
58	0200-1000	ART 7.2	MTP 07-1-WT06.07-C332 Conduct Battle Tracking	C2V			x0	x1	x2	x3	x4	x5
59	0200-1000	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	C2V			x0	x1	x2	x3	x4	x5
60	0255-0300, 0313-0318, 0339-0344, 0410-0415, 0523-0528, 0612-0617, 0706-0711, 0750-0755, 0844-0849	ART 7.2	*LSI A1.6.2.1.1.4.3 Report Enemy Information	C2V			x0	x1	x2	x3	x4	x5
61	0210-0542	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	UAV 1			x0	x1				
62	0250-0255, 0305-0310, 030-0335	ART 7.2	*LSI A1.6.2.1.1.4.3 Report Enemy Information	UAV 1			x0	x1				
63	0340-0835	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	UAV 2			x0	x1				
64	0431-0436, 0715-0720	ART 7.2	*LSI A1.6.2.1.1.4.3 Report Enemy Information	UAV 2			x0	x1				
65	0543-1000	ART 7.2	*MTP 17-5-0011.17-KCRW Establish and Maintain Communications	UAV 3			x0	x1				

TIMELINES / P-Lines / Sheet3

Vignette Platforms

Developed Degraded Capability State Fault Trees

2 - Command and Control Vehicles (C2V)
3 - Armed Robotic Vehicles (ARV)
3 - Unmanned Air Vehicles (UAV)
6 - Non-Line-Of-Sight Cannons (NLOS-C)
9 – Maneuver Combat Systems (MCS)

To drive Platform Capability side of demo:

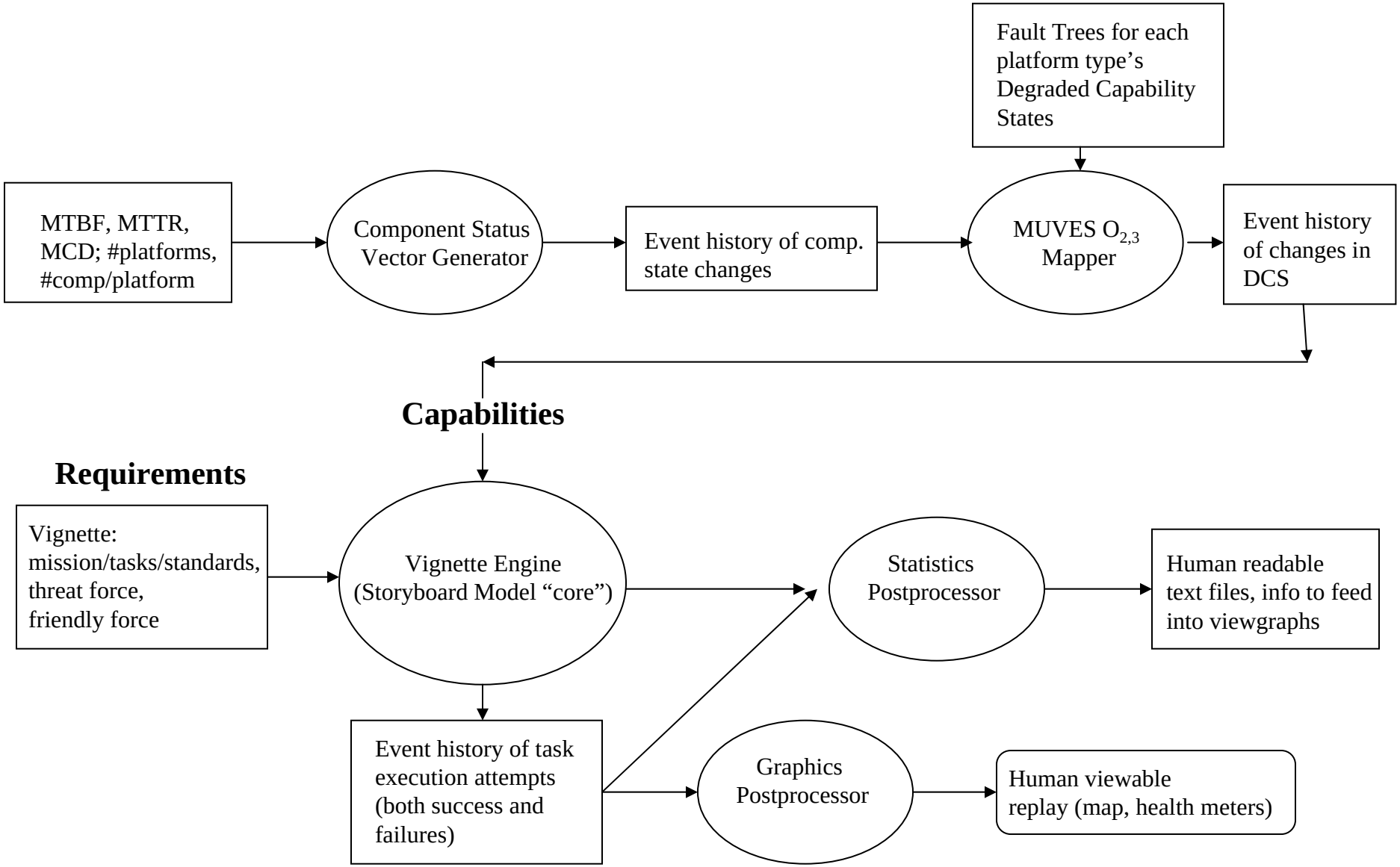
- Generated component status vectors.
- Evaluated Degraded Capability State fault trees.
- Results were fed into the Storyboard model as time-ordered list of platform state change events.

Component level and DCS level data were generated for fourteen platforms.

Summary of Storyboard Model

- Inputs (mostly scripted):
  - Event history of tasks demanded of each platform as vignette unfolds, defined in terms of capabilities required
  - States that pass/fail requirements of each task
  - Event history of platform state changes and resulting residual capabilities
  - Platform performance parameters, communications network
- Storyboard Model processing:
  - Execute scripted movements to extent platform states allow
  - Maintain Situation Awareness as network status permitted
  - Monte Carlo target acquisitions, message delay times, some aspects of fire missions
  - Comparison of each platform's current capability state to task requirements then demanded of it
  - Assessment of whether available unit resources are sufficient to cover for "failing" platforms
- Outputs (written to "log" file):
  - For generating text files of statistics
  - For graphic replay: map and "health" meters

MMF Demonstration: Storyboard Model and Data



Storyboard Model (SBM) Outputs

- Base case and two excursions run:
  - Base case: No C2V kill
  - C2V killed at specified time, but back-up takes over quickly
    - No effect on mission accomplishment rate
  - C2V and its “back-up” both killed at specified times
    - Mission failure if both are lost early enough in vignette
- Statistical Outputs
  - Fraction of time spent in each degraded condition by platform type
  - Fraction of time having required capabilities by platform type and task
  - Fraction of time BLUE commander’s intent met without drawing on external resources
  - Various correlations and conditional probabilities
- Graphical Displays
  - Map
  - “Health Bars”

Demonstration Output – Platform Level Degradations

Mean percentage of vignette time during which platforms of each type endure each element of capability degradation

	Mobility				Firepower loss					Acquisition loss		Surv./recon. loss			
	m_1 Reduced max speed	m_2 Reduced maneuv.	m_3 Stop after t min	m_4 Immobilized	f_1 Buttoned-up ability	f_2 Deliv. accuracy	f_3 Init. rate of fire	f_4 Subs. rate of fire	f_5 Total	a_1 Daylight sights	a_2 Night sights	z_1 Primary sensor	z_2 Secndry. sensor	z_3 Tertiary sensor	z_4 Vision blocks
C2V	13	12	2	12	0				0	0	0	0	0		0
NLOS-C	12	16	4	8		6	12	12	6						2
ARV	12	15	4	10					5	4	3	5	3	3	
UAV	25	27	25	25								26	25	25	

Demonstration Output — success rate by task

Success rate*	Time succeeding (min) / time required (min)	Platform type	Task
1.000	1,280 / 1,280	C2V	Report enemy information
1.000	9,600 / 9,600	C2V	Establish and maintain comms
1.000	480 / 480	C2V	Employ fire support
0.999	9,588 / 9,600	C2V	Establish COP
0.999	9,588 / 9,600	C2V	Collect relevant information
0.999	9,588 / 9,600	C2V	Conduct battle tracking
0.990	1,584 / 1,600	C2V	Disseminate COP
0.969	7,501 / 7,740	NLOS-C	Conduct tactical maneuver
⋮	⋮	⋮	⋮
0.665	5,012 / 7,540	UAV	Fly UAV mission
0.648	2,312 / 3,570	UAV	Conduct tactical reconnaissance
0.595	773 / 1,300	UAV	Detect and locate surface targets

*Of the cumulative time the platform needed ability to perform the task, the portion during which it could actually do so.

More Statistics

- Correlation tables for mission versus task, mission versus degradation, mission versus component, task versus degradation, task versus component, and degradation versus component.

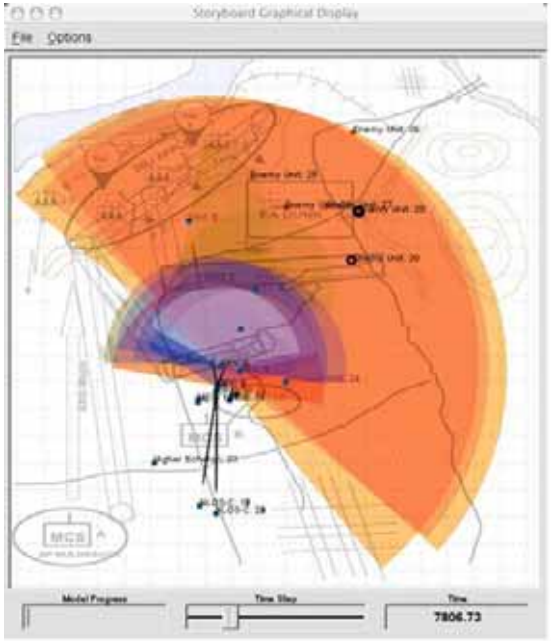
Task #25 LSI A1.5.2 Occupy an Attack/Assault Position ART 2.5.2 for platform type NLOS-C

```
 Task 25 versus DCS state m1 (Reduced Max Speed)
P(Task failing | this degradation) = 0.981962
Sample size = 20640
    Raw data
    3103     57
    1176     16304
mean and std dev for X = 0.846899  0.360085
mean and std dev for Y = 0.792684  0.405384
Covariance of X and Y = 0.118599
Correlation of X and Y = 0.812475
```

- Additional tables showed the fraction of cases each task resulted in causing mission failure and fraction of cases commander's intent was achieved without asking for outside resources

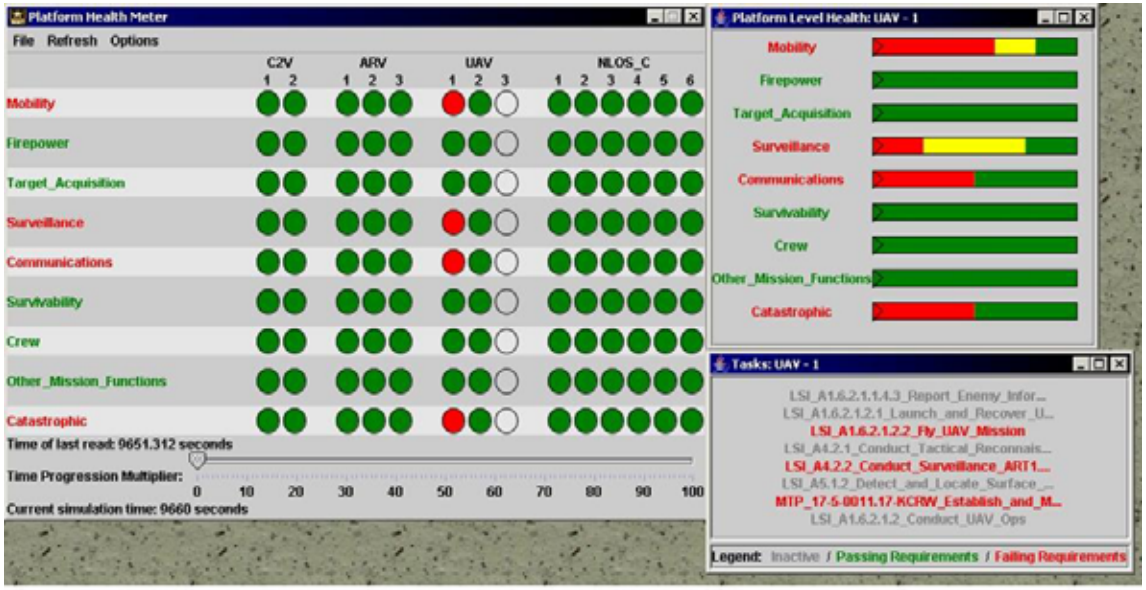
- All of the demonstration outputs were based on fictitious or surrogated data

Demonstration Output – Graphical Displays



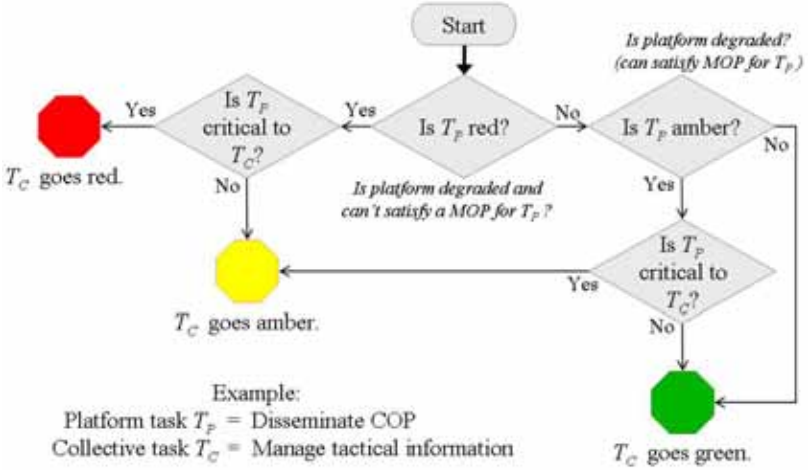
Key

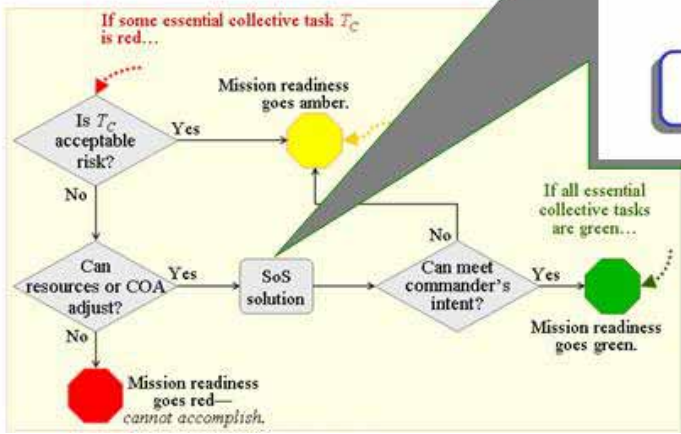
- OWNFOR platforms
- OPFOR platforms
- SA message
- longest-range sensor FoV
- secondary sensor FoV (if any)

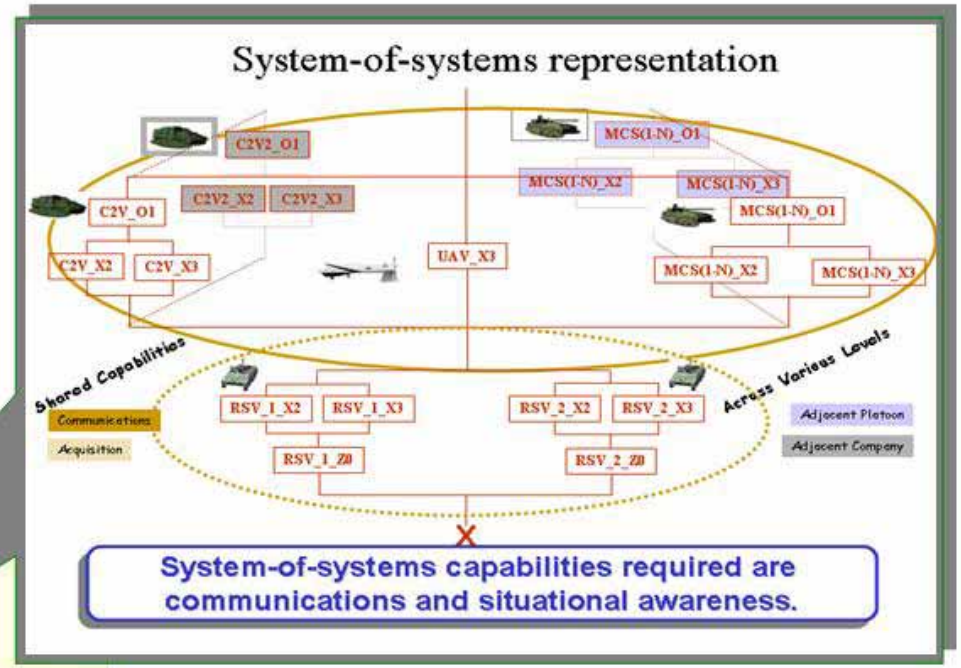


Task Effects

Effect of platform tasks degradation on collective task







What options are available from the SoS?

Implications

- There was wide-spread acceptance of and agreement with demonstration results by key Army leadership
- DCS data has multiple applications; force level modeling, training, simulation, and System-of-System evaluation
- MMF data development for production studies will require close collaboration within the modeling and analysis communities in TRADOC, RDECOM, and ATEC
- Demo is first step toward a methodology for assessing the effectiveness and feasibility of proposed courses of action

MMF demonstrated the linkage from low-level state changes to task/mission success

Conclusions and Path Forward

- Demo showed that mission/task pass/fail could be tied to low-level state changes as claimed prior to demo
- To fully exploit MMF in future analyses and evaluations:
  - Improve dynamics (i.e., reduce scripting)
  - Enlarge vignette
  - Improve process for generating input data
- DUSA-OR has directed that MMF next be applied to a live exercise