

# **Final Report on the Identification of Modeling and Simulation Capabilities by Acquisition Life Cycle Phase**

**Prepared for the  
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# Presentation Outline

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- **Genesis of the Topic**
- **NDIA Systems Engineering Modeling and Simulation Committee – Subcommittee on the Topic**
  - Charter
  - Participants
  - Process
- **Some Sources of Information**
- **Issues Encountered**
- **Industry Inputs**
- **Results of the Study:**
  - M&S Categories and Definitions
  - Examples From Each Phase
  - Examples of Prevalent M&S Tools
- **Summary**

## Genesis of the Topic

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- **Discussions between NDIA SE M&S Committee leadership and ODASD(SE/SA) representatives, November 2011**
  - Interest in M&S Capabilities by Acquisition Life Cycle Phase
- **Discussions with NDIA SE Division leadership, November 2011**
  - Interest in identifying M&S tools prevalent in systems engineering
- **Proposed 2012 task included in NDIA SE M&S Committee report at December NDIA SE Division Planning Meeting:**
  - “Assessment of M&S capabilities, and prevalence of specific M&S tools, used in each phase of the Systems Acquisition process”
- **U.S. Air Force (Col Ogawa) presentation at December NDIA SE Division Planning Meeting:**
  - Citation of Objective 2.2 in U.S. Air Force SE Strategic Plan on “Standard practices, tools, metrics ... Focus on modeling & simulation across life cycle”
- **Resulting action item from SE Division planning meeting:**
  - “(NDIA SED) Consider: state of the art in M&S, M&S across the life cycle. Reusable architectures. Physics-based modeling, support architectures w/ M&S.”

## Subcommittee Charter

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- **Consider the state of the art and practice of modeling and simulation (M&S) across the Defense Systems Acquisition Life Cycle**
- **For each phase of the life cycle, identify systems engineering and acquisition functions that need to be performed that can be enabled by the use of M&S**
- **For each engineering/acquisition function, identify specific existing M&S capabilities that can contribute to the performance of that function**
- **For each M&S capability, identify government and industry M&S tools that are prevalent in helping to provide that capability**
- **In performing the above activities, keep in mind such things as reusable architectures, support of architectures using M&S, physics-based modeling, and similar activities that are enabled by the use of M&S**

## Subcommittee Meeting Participants

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- **Jim Coolahan (JHU)**
- **Jeff Bergenthal (JHU/APL)**
- **Tim Ewart (US Air Force)**
- **Michael Heaphy (Booz Allen Hamilton)**
- **Ken (“Crash”) Konwin (Booz Allen Hamilton)**
- **Robert Leach (Dynamic Animation Systems)**
- **Margaret Loper (GTRI)**
- **Joe McDonnell (Dynamic Animation Systems)**
- **Kirk Michealson (Lockheed Martin)**
- **Katherine L. Morse (JHU/APL)**
- **Hans Polzer**
- **John Lohse (Raytheon)**
- **Tammy McNeley (Lockheed Martin)**
- **Frank Salvatore (DRC)**
- **Greg Pollari (Rockwell Collins)**
- **Jeff Wallace (Intelligent Integration)**
- **David Broyles (US Navy)**
- **David Allsop (Boeing)**
- **Kevin Flood (AGI)**
- **George Harris (US Army)**
- **George Hazelrigg (NSF)**
- **Favio Lopez (Trideum)**
- **Dennis Pippy (SAF/AQ Ctr)**
- **Steve Reading (Cutlass Systems Engineering)**
- **Anne Ricks (Cutlass Systems Engineering)**

## Subcommittee Process

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- **Initial subcommittee formation at 21 February 2012 NDIA SE M&S Committee meeting**
- **Bi-weekly teleconferences scheduled**
- **Data collection spreadsheet designed and distributed**
- **Sources of information identified**
- **Individual subcommittee members did research on different sources and parts of the problem**
- **Face-to-face meetings at numerous NDIA SE M&S Committee meetings**
- **Presentations by industry team members in bi-weekly teleconferences, August – October 2012**
- **Construction and evolution of master Excel workbook, linking acquisition activities, M&S capabilities, and example M&S tools – Spring/Summer 2013**

## Some Sources of Information

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- **Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System (the Defense Acquisition University “wall chart”), Jun 2010**
- **A Roadmap for Simulation Based Acquisition (Appendix C), Dec 1998**
- **NDIA SE M&S Committee report, “M&S Support to the New DoD Acquisition Process,” Feb 2004**
- **Final Report, Study on Management Concepts for Broadly-Needed Modeling and Simulation Tools, Jun 2010**
- **DoD M&S Catalog**
- **CBA Handbook – A Guide for Implementing Capabilities-Based Analysis (CBA), Jun 2010**
- **"M&S Across the System Acquisition Life Cycle" (Campbell and Lashlee), 2010**
- **Materiel Solution Analysis Activities and Descriptions (Riski), Jun 2012**
- **Defense Acquisition Guidebook, <https://dag.dau.mil/Pages/Default.aspx>**
- **DOD Product Support Business Case Analysis Guidebook, 2011**
- **DoD M&S Glossary**

# Data Collection Template

System Acquisition Activities		Supporting M&S Capabilities		Prevalent M&S Tools	
Activity	Source Document	Capability	Source Document	Acronym	Name



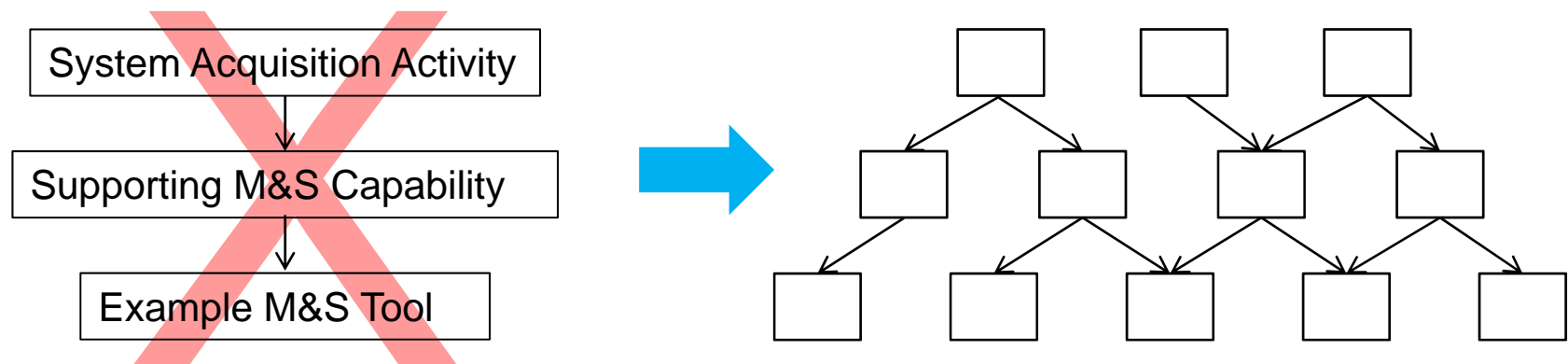
## Issues Encountered (1 of 2)

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- **There is no accepted taxonomy for describing “M&S Capabilities”**
  - **Need to have a “level” set of descriptors**
    - ◆ Not too high-level (e.g., “Constructive simulations”)
    - ◆ Not too low-level (e.g., “EADSIM simulation”)
- **As an adjunct to this study, needed to either develop a taxonomy, or advocate for its creation**
- **It was too difficult for the subcommittee to determine what M&S tools are “prevalent” (wording in charter**
  - **Decided to cite “example” M&S tools**

## Issues Encountered (2 of 2)

- Mapping of “system acquisition activities in a phase” to “supporting M&S capabilities” to “example M&S tools” is not a hierarchical tree structure
  - Some supporting M&S capabilities could be applicable in multiple system acquisition activities in multiple phases
  - Some example M&S tools could be used in providing multiple M&S capabilities
  - A two-dimensional spreadsheet is not a good way of representing the structure, since there will be many replications
    - ◆ Is a relational database a sufficient structure?
    - ◆ Do we have to go to an ontology?



- **Two distinct Industry groups:**
  - **Providers of Commercial-Off-The-Shelf models and simulations**
  - **System developers who use M&S**
- **M&S capabilities are broadly used across all phases of the acquisition life cycle**
  - **Use of an M&S capability is generally not limited to a single phase**
  - **Models and simulations are often linked together to achieve the desired capability**
- **Challenges remain to more fully exploiting the value of M&S across the acquisition life cycle**
  - **Data availability and interchange**
  - **Confidence, trust, relevancy, ROI**
  - **Etc.**

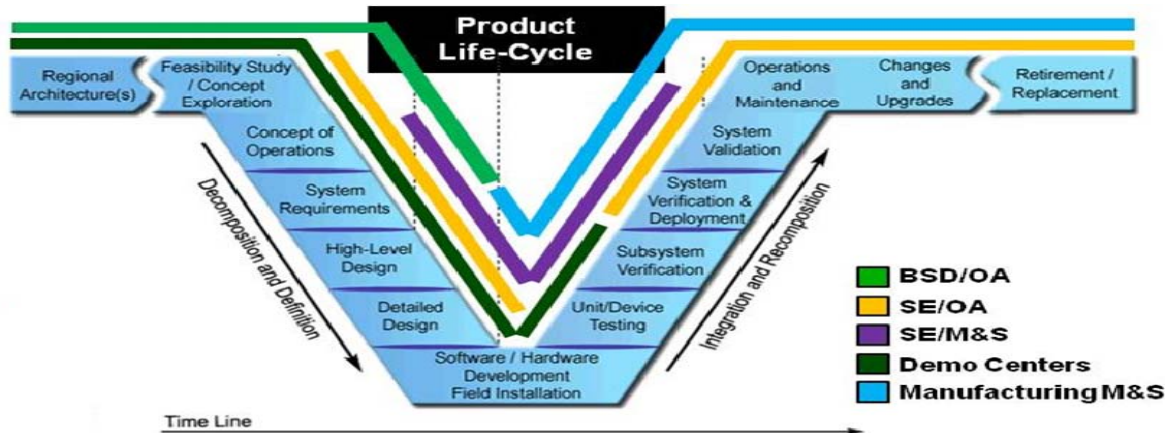
# Use of COTS M&S During Technology Development Phase

## Objective: Reduce technical risks

- System integration
- ✓ Design
- ✓ Prototyping
- ✓ Military utility assessment
- ✓ Model environment and demonstrate technology
- ✓ Interoperability & supportability analysis
- ✓ Operational suitability
  - Assess manufacturing risks
  - Industrial/Manufacturing capability & readiness assessment
  - Life-cycle sustainment planning
- ✓ Survivability analysis
- ✓ Update AoA
- ✓ Affordability assessment
- ✓ Estimate manpower/cost
- ✓ Model system to performance specifications
- ✓ Design/ Develop System Concepts
- ✓ System threat assessment
  - Environment, Safety, and Occupational Health (ESOH) Models
- ✓ Human System Integration
- ✓ T&E Planning

# Model & Simulation Usage Areas

- Business Support & Operations Analysis
- Demo Centers
- Model-Based Systems Engineering (MBSE)
- Computer Aided Design (CAD)
- Product Data and Lifecycle Management
- Manufacturing M&S
- Training & Education



**M&S Deeply Engrained w/in ALL Lines of Business and Throughout Life-Cycle**

# M&S Capability Categories

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- Campaign-level simulation
- Engagement-level simulation
  - Specific type dependent on system
- Human Systems M&S
  - Human factors modeling
  - Human-system integration simulation
- Maintenance training simulation
- Mission-level simulation
  - Specific type dependent on system
- RAM modeling / simulation
  - Fault tree modeling
  - Obsolescence modeling
  - Reliability modeling
  - Supply chain modeling
  - ... (and more)
- Cost modeling
  - Disposal cost modeling
  - Investment cost modeling
  - O&S cost modeling
- Engineering-level simulation
  - ASIC/FPGA modeling and design
  - Communications modeling
  - Computational fluid dynamics simulation
  - Electromagnetic propagation modeling
  - Mechanical design modeling
  - Structural mechanics modeling
  - Thermal analysis simulation
  - ... (many more)
- Operator training simulation
- Virtual system simulation

# Some M&S Capability Definitions (1 of 2)

M&S Capability Name	M&S Capability Category	M&S Capability definition/description	Definition Source (reference citation - state if verbatim or adapted from; or defined here)
Life-cycle cost modeling	Cost modeling	The modeling of total Government cost for a program over its full life, to include the cost of research and development, investment in mission and support equipment (hardware and software), initial inventories, training, data, facilities, etc., and the operating, support, and, where applicable, demilitarization, detoxification, or long term waste storage.	Adapted from: - AR 70-1, Ch 1-6.c. - DOD 5000.4-M, Para C3.3.7
Operations and support (O&S) cost modeling	Cost modeling	The modeling of materiel readiness and operational support costs to operate, maintain and support a fielded system (and its associated manpower and facilities).	Adapted from the DAG, Ch.3.7, Principles for Life-Cycle Cost Estimates; Para 3.7.1.3 Operating and Support (O&S) Cost Element Structure
Active protection system simulation	Engagement-level simulation	Simulation of a system in a limited scenario, such as one-on-one, few-on-few or sometimes many-on-many. Evaluates the effectiveness of an individual platform and its weapon systems against a specific target or enemy threat system. Relies on system performance, kinematics, and sensor performance from engineering-level simulations. Provides measures of system effectiveness for mission-level simulations	Defense Systems Acquisition Management College, Acquisition Manager's Guide for the Use of Models and Simulations, September 1994.
Acoustic propagation modeling	Engineering-level simulation	Simulation of detailed engineering characteristics, to estimate measures of performance of components, subsystems, or systems; provides the basis for design trades.	Derived from Defense Systems Acquisition Management College, Acquisition Manager's Guide for the Use of Models and Simulations, September 1994.



## Some M&S Capability Definitions (2 of 2)

M&S Capability Name	M&S Capability Category	M&S Capability definition/description	Definition Source (reference citation - state if verbatim or adapted from; or defined here)
Virtual team training simulation	Mission training simulation	Virtual simulations involve real people operating simulated systems. Virtual team training simulations are virtual simulations that train two or more persons to achieve a common goal.	Adapted and expanded upon from the DoD M&S Glossary
Air drop mission simulation (Air Force)	Mission-level simulation	Simulation of the ability of a multi-platform force package to accomplish a specific mission objective, which might span a period of hours. Produce measures of effectiveness typically at the force package level rather than at the level of the individual platform and its weapon system.	Defense Systems Acquisition Management College, Acquisition Manager's Guide for the Use of Models and Simulations, September 1994.
Level-of-repair modeling	RAM modeling / simulation	Level of repair identifies not only the repair location, but also determines the extent of maintenance to be performed at organic, intermediate, and depot levels as well as the resources needed to support the repair process.	Adapted from: Proceedings of the IEEE 1988 National Aerospace and Electronics Conference: NAECON 1988 (Cat. No.88CH2596-5)
Supply chain modeling	RAM modeling / simulation	Models to support the analysis and improvement of the effectiveness of supply chain management and related supply chain improvement activities.	Defined here (JJB)
Live-Virtual-Constructive (LVC) simulation environments		An interacting set of simulations and supporting tools and resources, which includes live simulations, virtual simulations, and constructive simulations.	Defined here (JEC)



# Acquisition Activities and M&S Capabilities (1 of 5)

- Excerpt From Materiel Solution Analysis Phase

Acquisition Activity (Level 1)	Acquisition Activity (Level 2)	Acquisition Activity (Level 3)	Modeling / Simulation Capability
Conduct AoA	Characterize candidate materiel solutions	Identify key attributes and performance measures (differentiators)	
		Develop CONOPS/concepts of employment	Use-case modeling Scenario definition modeling
		Identify Intel, Logistics, Information Support Needs/Constraints	
		Identify key operational dependencies and inter-relationships	Mission-level simulation
	Perform operational effectiveness analysis	Develop appropriate scenarios and threats	Scenario definition modeling
		Determine mission tasks	
		Determine MOEs and MOPs for mission tasks	
		Determine analysis methodology	
		Select models and data	M&S catalogs and repositories
		Develop database	
		Conduct operational effectiveness analysis against selected MOEs and MOPs	Campaign-level simulation Mission-level simulation
		Perform sensitivity analyses	
	Perform initial cost analysis	Develop life cycle cost models	Life-cycle cost modeling
		Conduct cost vs. operational effectiveness analysis	Value modeling
		Perform sensitivity analysis	
	Perform risk analysis for each candidate materiel solution	Identify technical risks	
		Identify schedule risks	
		Identify cost risks	
		Identify operational risks	
	Synthesize operational, cost, and risk analyses results and rank candidate materiel solutions		
Develop range of requirements to support development of initial KPPs			
Document results in AoA Final Report			

# Acquisition Activities and M&S Capabilities (2 of 5)

- Excerpt from Technology Development Phase

Acquisition Activity (Level 1)	Acquisition Activity (Level 2)	Acquisition Activity (Level 3)	Modeling / Simulation Capability
	Development & technology risk reduction		Engineering-level simulation
			Virtual system simulation
			Mission-level simulation
	System integration		Engineering-level simulation
			Mission-level simulation
			Virtual system simulation
	Design		Engineering-level simulation
			Virtual system simulation
			Mechanical design modeling
			Software modeling
			Manufacturing process modeling/simulation
			Reliability modeling
			Maintenance simulation
			Survivability simulation
	Life-cycle cost modeling		
	Prototyping		Engineering-level simulation
			Mission-level simulation
			Virtual system simulation
Military utility assessment			Mission-level simulation
Model environment and demonstrate technology			Modeling of the natural environment
Interoperability & supportability analysis			Mission-level simulation
			Reliability modeling
			Maintenance simulation
			Survivability simulation
			Life-cycle cost modeling
Assess manufacturing risks			Supply chain modeling
			Investment cost modeling
			Manufacturing process modeling/simulation

# Acquisition Activities and M&S Capabilities (3 of 5)

- Excerpt From EMD Phase

Acquisition Activity (Level 1)	Acquisition Activity (Level 2)	Acquisition Activity (Level 3)	Modeling / Simulation Capability
	Develop affordable and executable manufacturing process		Manufacturing process modeling/simulation
	Ensure operational supportability		Operational availability modeling Supply chain modeling Logistics simulation
	Reduce logistics footprint		Logistics simulation
	Human Systems Integration		Operator training simulation Mission training simulation Human factors modeling Human-system integration simulation Engagement-level simulation Virtual system simulation
	Design for producibility		Manufacturing process modeling/simulation Engineering-level simulation
	Demonstrate system integration		Constructive battle simulation Virtual system simulation
	Demonstrate system interoperability		Constructive battle simulation Virtual system simulation
	System threat assessment		Engagement-level simulation Constructive battle simulation Virtual system simulation
	Material Operational availability assessment		Operational availability modeling
	Prototyping		Engineering-level simulation Constructive battle simulation Virtual system simulation
	Integrated T&E		Engineering-level simulation Virtual system simulation

# Acquisition Activities and M&S Capabilities (4 of 5)

- Excerpt From Production and Deployment Phase

Acquisition Activity (Level 1)	Acquisition Activity (Level 2)	Acquisition Activity (Level 3)	Modeling / Simulation Capability
	Manufacturing development		
	Interdependency & interoperability summary		
	Risk management		
	Technology maturity assessment		Engagement-level simulation
	Industrial/manufacturing readiness assessment		
	CBRN survivability analysis		
	Human Systems Integration		Operator training simulation
			Mission training simulation
			Human factors modeling
			Human-system integration simulation
			Virtual system simulation
	Military equipment valuation		
	Corrosion prevention & control		
	Support & cost baseline		Life-cycle cost modeling
			Operations and support (O&S) cost modeling
			Investment cost modeling
	Supply chain management		Supply chain modeling
			Logistics simulation
	Refine life-cycle sustainment plan		Supply chain modeling
			Logistics simulation
	Production qualification testing		
	IOT&E		Constructive battle simulation
			Engagement-level simulation
		Engineering-level simulation	
		Virtual system simulation	
Joint interoperability certification/testing		Constructive battle simulation	
		Virtual system simulation	
Modify HW/SW Specifications and configurations			
Verify and validate production configuration		Engineering-level simulation	

# Acquisition Activities and M&S Capabilities (5 of 5)

- Excerpt From Operations and Support Phase

Acquisition Activity (Level 1)	Acquisition Activity (Level 2)	Acquisition Activity (Level 3)	Modeling / Simulation Capability	
	Post-production software support		Software modeling	
	Supply chain management		Supply chain modeling	
	Monitor performance & adjust product support			Operational availability modeling
				Product support optimization modeling
	Training	Operator training		Virtual system simulation
				System/range instrumentation
				Task-oriented constructive simulation
				Game-based simulation
		Mission Training		Live-Virtual-Constructive (LVC) simulation environments
				Constructive battle simulation
	Maintenance training		Virtual team training simulation	
			Game-based simulation	
			Hardware-in-the-loop simulation	
			Virtual system simulation	
	Revalidate BCA			
	Refine life-cycle sustainment plan			Life-cycle cost modeling
	Supportability assessments	Level-of-repair analysis		Level-of-repair modeling
		Support optimization		Product support optimization modeling
		Obsolescence analysis		Obsolescence modeling
	Disposal planning	Environmental analysis		
Hazardous material analysis				
Recycling analysis				
Business case / business model analysis			Disposal cost modeling	
Validate failures & determine root causes				
Determine system risk/ hazard severity				

# Excerpt From Example M&S Tools (1 of 2)

M&S Capability Name	M&S Capability Category	Example tools						
Disposal cost modeling	Cost modeling	SEER-H	TruePlanning	SEER for Mfg	ProModel Suite			
Life-cycle cost modeling	Cost modeling	ACEIT	ProModel - Portfolio Simulator	SEER-H	SEER-SEM	SEER-IT	TruePlanning	PRICE
Operations and support (O&S) cost modeling	Cost modeling	OSCAM	COHORT	OSMIS	SEER-H	SEER-SEM	SEER-IT	TruePlanning
Investment cost modeling	Cost modeling	SEER-H	TruePlanning	SEER for Mfg	ProModel Suite			
Fixed wing aircraft system simulation	Engagement-level simulation	Brawler	ESAMS	Radguns	MOSAIC			
Land vehicular system simulation	Engagement-level simulation	OneSAF	JANUS					
Missile defense system simulation	Engagement-level simulation	EADSIM	AFNES	WILMA				
Missile system simulation	Engagement-level simulation	ESAMS	MOSAIC	WILMA				
Rotary wing aircraft system simulation	Engagement-level simulation	OneSAF	ATCOM					
Electrical printed circuit design simulation	Engineering-level simulation	P-Spice	Zuken	Lattice	Expedition			
Electromagnetic propagation modeling	Engineering-level simulation	TEMPER	ICEPIC	ISM				
Structural dynamics simulation	Engineering-level simulation	DYNA-3D	LS-DYNA	SolidWorks				
Structural mechanics modeling	Engineering-level simulation	NASTRAN	SolidWorks	VAPO				
Thermal analysis simulation	Engineering-level simulation	FLOTHERM	FLOPACK	Saber				

## Excerpt Example M&S Tools (2 of 2)

M&S Capability Name	M&S Capability Category	Example tools			
Anti-submarine warfare mission simulation (Navy)	Mission-level simulation	Battle Force Engagement Model (BFEM)	Naval Simulation System (NSS)		
Anti-surface warfare mission simulation (Navy)	Mission-level simulation	Extended Air Defense Simulation (EADSIM)			
Command and control mission simulation (Air Force)	Mission-level simulation	Joint Integrated Mission Model (JIMM)	Suppressor	EADSIM	AFNES
Counterair mission simulation (Air Force)	Mission-level simulation	Joint Integrated Mission Model (JIMM)	Suppressor	EADSIM	AFNES
Counterland mission simulation (Air Force)	Mission-level simulation	Joint Integrated Mission Model (JIMM)	Suppressor	AFNES	
Countersea mission simulation (Air Force)	Mission-level simulation	Joint Integrated Mission Model (JIMM)	Suppressor	AFNES	
Electronic combat mission simulation (Navy and Air Force)	Mission-level simulation	Joint Integrated Mission Model (JIMM)	Suppressor	AFNES	IMOM
Fires mission simulation (Army)	Mission-level simulation	FireSim	AFNES		
Anti-submarine warfare mission simulation (Navy)	Mission-level simulation	Battle Force Engagement Model (BFEM)	Naval Simulation System (NSS)		
Level-of-repair modeling	RAM modeling / simulation	Computerized Optimization Model for Predicting and Analyzing Support Structures (COMPASS)	LORA 9.32		
Logistics simulation	RAM modeling / simulation	OPUS10	SIMLOX	ProModel Suite	
Operational availability modeling	RAM modeling / simulation	Total Life Cycle Management - Assessment Tool (TLCM-AT)	OPUS10	SIMLOX	
Campaign-level simulation	Campaign-level simulation	Synthetic Theater Operations Research Model (STORM)	Joint Analysis System (JAS) [now archived]	System Effectiveness Analysis Simulation (SEAS)	CTEM

# Summary

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- **The study Final Report is nearing completion**
  - Small clean-up on Phase spreadsheets for consistency
  - Finish writing report
  - Goal is finish the report in October 2013
- **The Final Report will be available for download through the NDIA web site**
- **Open items:**
  - Process for requesting and updating the data for the Phases and the M&S tools
  - We developed a fairly level set of M&S descriptors, however a complete taxonomy of “M&S Capabilities” is still necessary