Bridging the Information Gap Between Diverse Modeling and Simulation Tools

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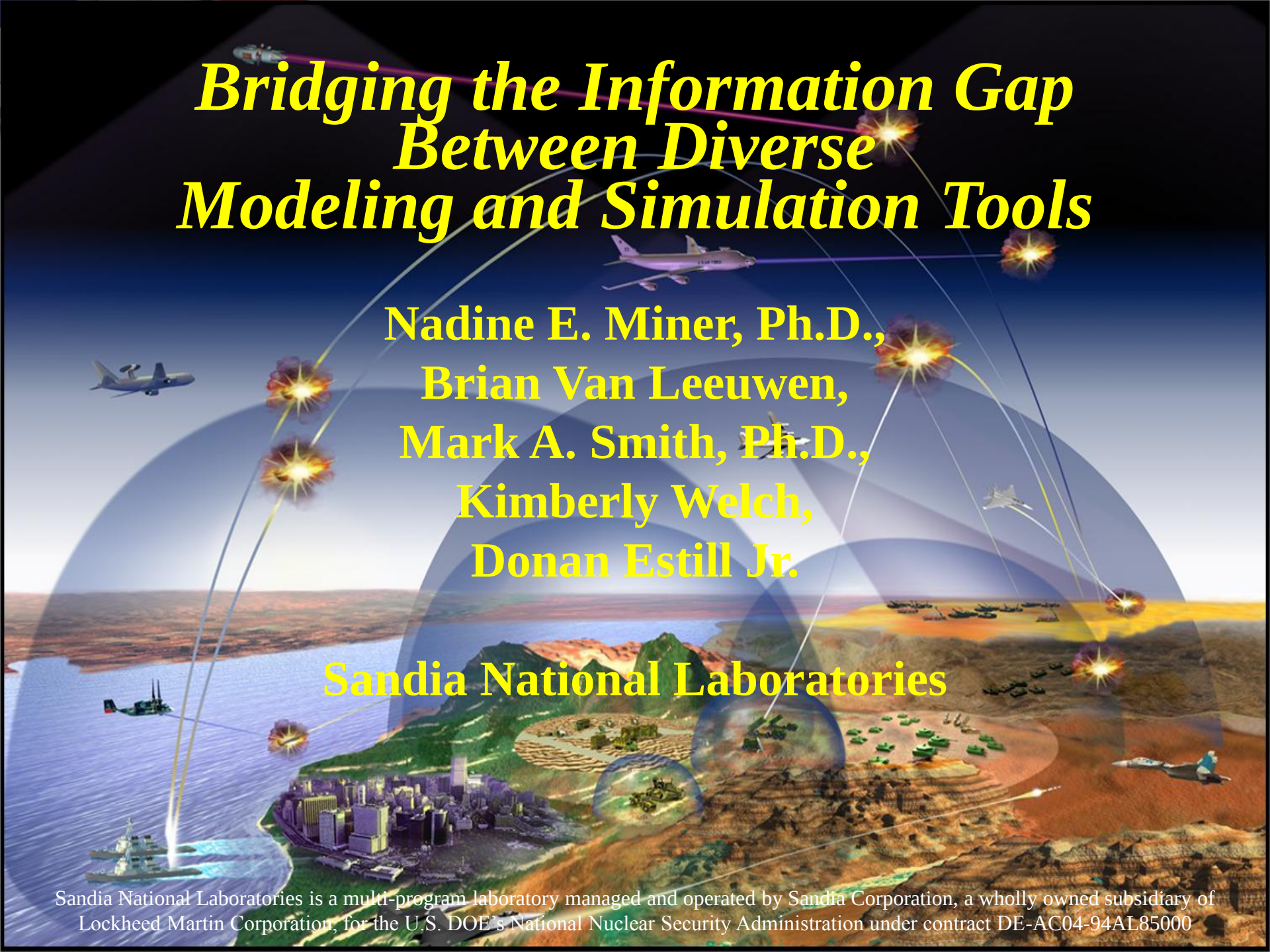

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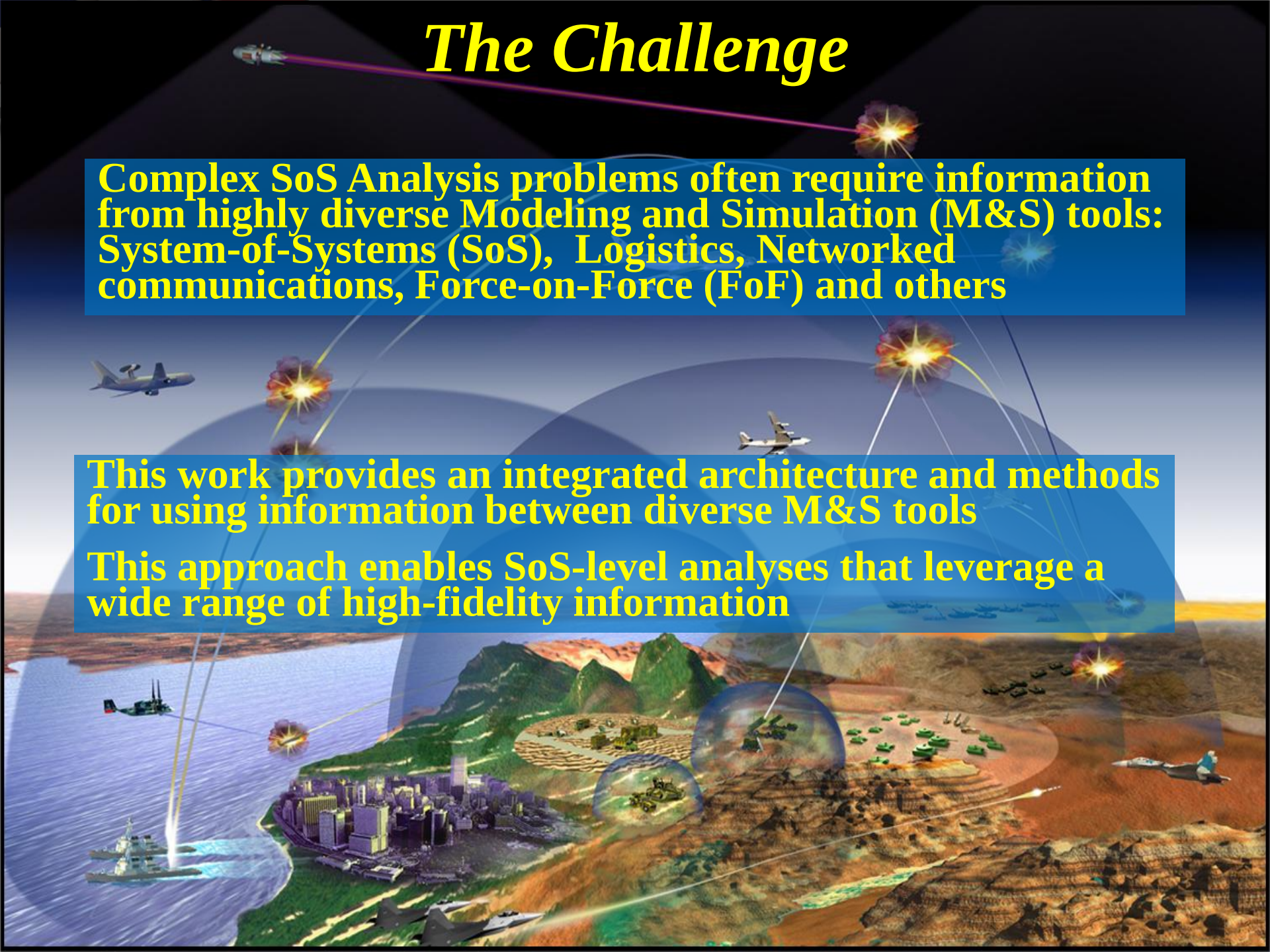
The Challenge

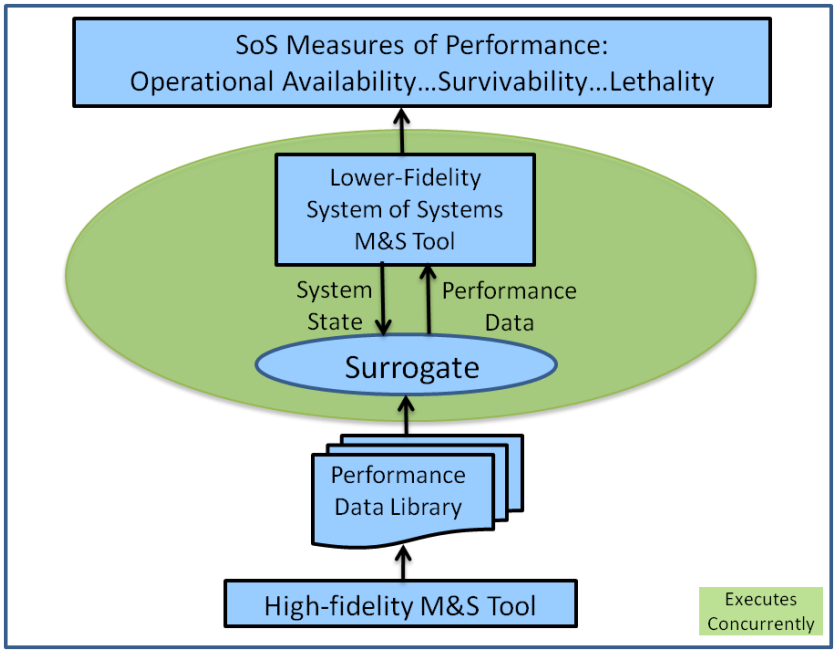
Complex SoS Analysis problems often require information from highly diverse Modeling and Simulation (M&S) tools: System-of-Systems (SoS), Logistics, Networked communications, Force-on-Force (FoF) and others

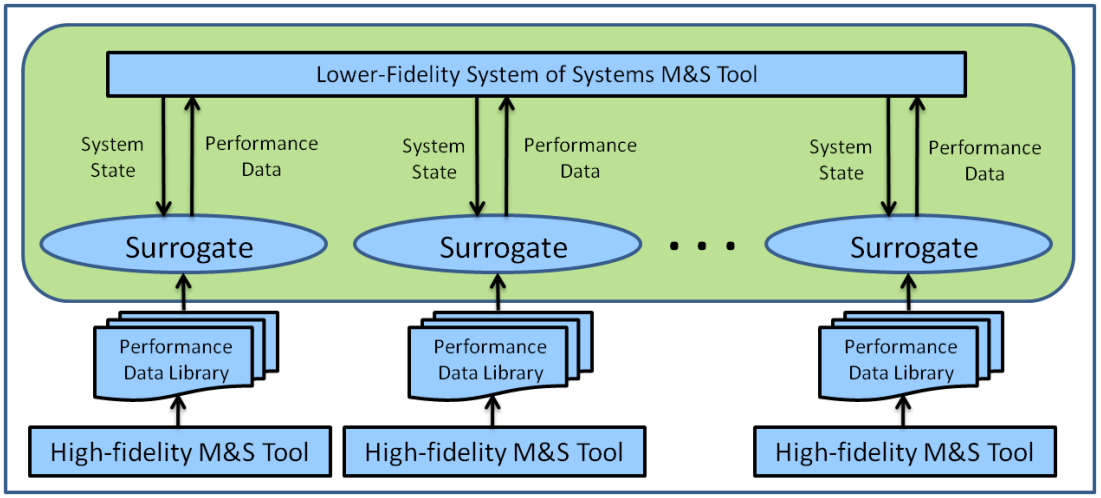
This work provides an integrated architecture and methods for using information between diverse M&S tools

This approach enables SoS-level analyses that leverage a wide range of high-fidelity information



M&S Information Linkage Architecture





- General purpose methodology uses intermediate surrogate model to bridge the information gap between diverse modeling and simulation tools
- Decoupled architecture allows M&S tools to run asynchronously, enabling statistical characterization of high-fidelity performance information
- Intermediate surrogate model provides real-time, dynamic access to high-fidelity performance characterizations as SoS state changes
- Approach allows for linkage between many diverse M&S tools simultaneously – only limited by compute power

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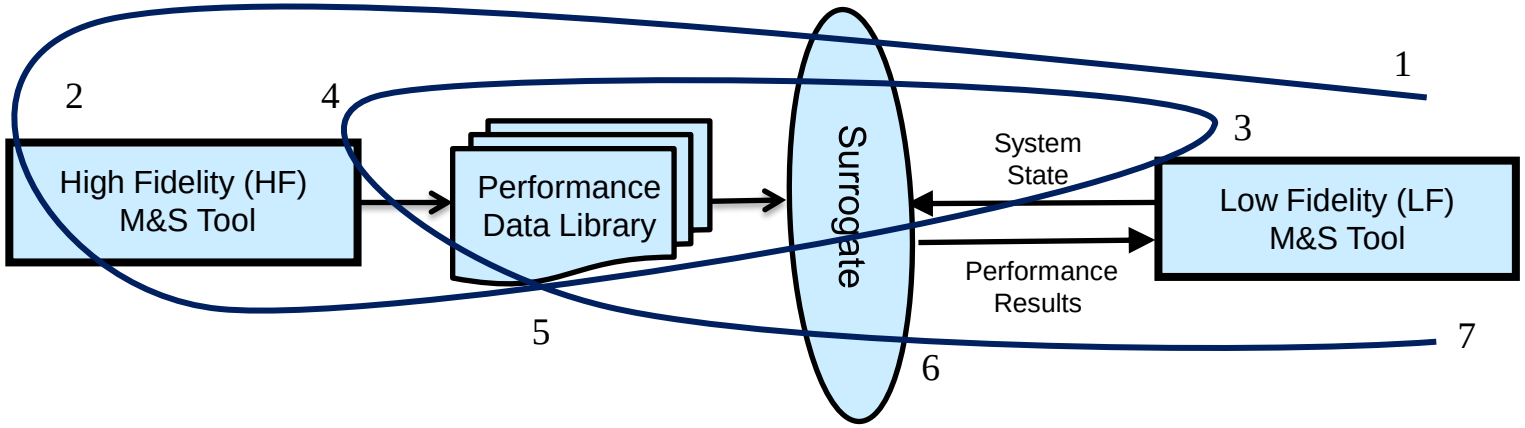
Multi-Step M&S Linkage Process

Employs an Iterative Systems Engineering Approach where the Driving Force is the Target Customer Question



1. Define Question to be answered by Low Fidelity(LF) M&S tool
2. Scenario Definition: What are scenario(s) that apply to this specific question?
3. Define LF information parameters needed to answer the question and the subset of dynamic parameters that comprise the System State
4. Define High Fidelity (HF) parameters and measures of effectiveness (MOEs) needed supply surrogate and LF tool with necessary information
5. Define information to be stored in data library and required data processing/transformations
6. Specifications of information that surrogate will provide to LF (SoS) tool
7. Define LF (SoS) experiments and outputs

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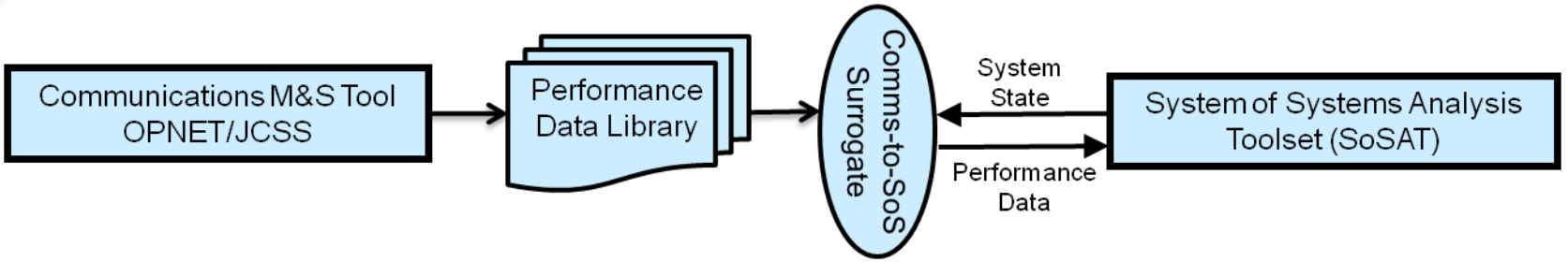
Example Linkage Using this Approach: High-Fidelity Communications-to-SoS



- Situational Awareness (SA) applications depend on communication system performance
- Driving Question: What is SA availability at a SoS-level with various communication technologies and operating conditions:
  - Varying network configurations: wireless, ground-based radio (EPLRS) versus satellite
  - Number of relay points available
  - UAV available or not
  - Varying background traffic, terrain and mission conditions

Provide quantitative SoS-level assessment of communications application performance under different operating conditions

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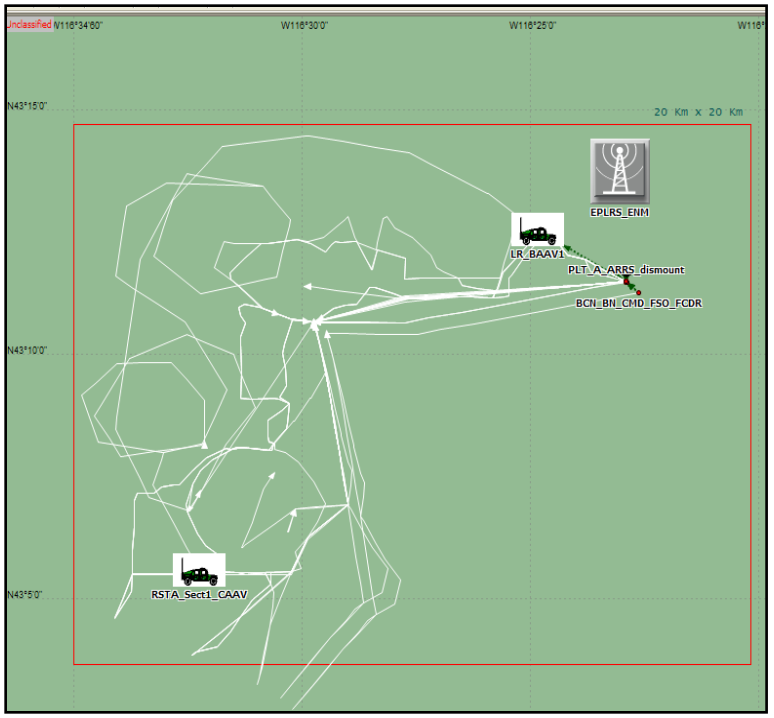
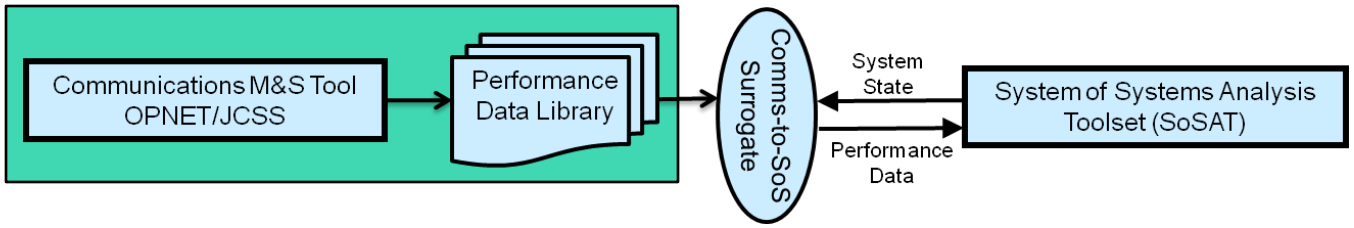
Communications Modeling: OPNET Modeler™ with JCSS

- OPNET Modeler provides communication network modeling and simulation with detailed protocol modeling and analysis
- Joint Communication Simulation System (JCSS) provides military network models
- Use case employs notional OPNET/JCSS scenario - company-level deployment, 20 platforms, 20x20 km area, random seed
- Performance Data Library created by capturing comms measures of performance (MoPs) over multiple simulation runs
  - Variations: network types, # relay points, background traffic, UAV, etc.
  - MoPs: Comms application availability (mean up time) and mean down time





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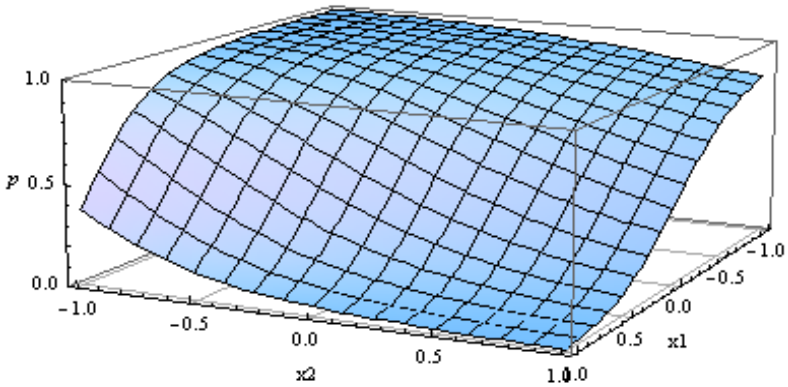
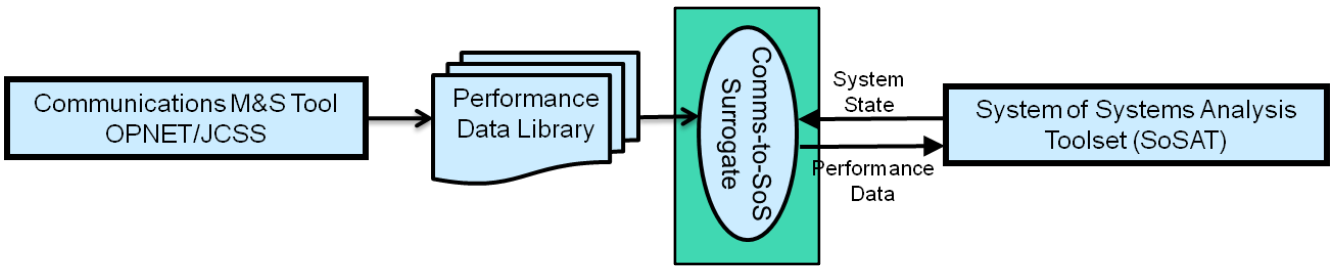
Intermediate Surrogate Model Approach

- Objective of Surrogate: For a given set of inputs, produce an output that corresponds as closely as possible to the high-fidelity model output for the same inputs
- We use a multi-dimensional, best-fit response surface for the intermediate surrogate model
- This approach
  - Provides intermediate information for states which do not have exact high-fidelity simulation results and does so more quickly than running the high-fidelity model
  - Provides *dynamic* information based on current SoS system state
- For this use case example, the communications surrogate provides SoSAT with:
  - Communications application failure rate (1/mean up time)
  - Average time to repair (equivalent to mean down time)



Example response surface depending on two parameters x_1 and x_2



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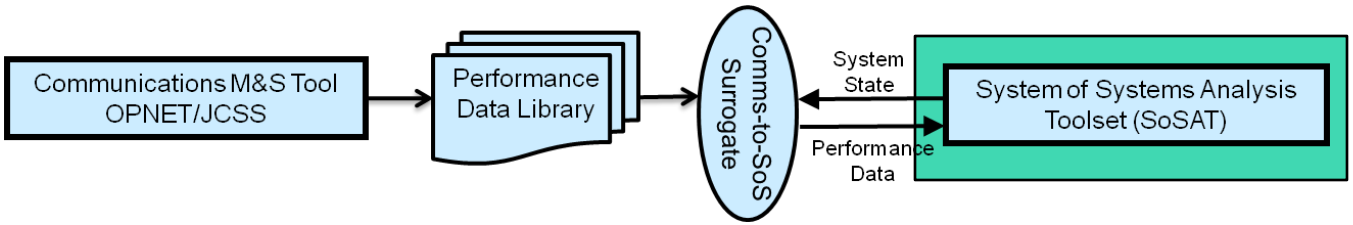
Sandia Laboratories-Developed System of Systems Analysis Toolset (SoSAT)

- Time-based, stochastic modeling and simulation tool that models multi-echelon activities and assesses SoS operations
- Simulate *any or all* of a SoS hierarchical organizational structure and multiple mission segments
- Basic Modeling Features
  - System element reliability failures
  - Consumable usage and depletion
  - Maintenance activities including any spares, services and supply reorder
- Advanced Modeling Features
  - Combat Damage Modeling
  - Network Modeling
  - Prognostics and Health Management
  - Time-Based changes to model attributes (External Conditions)
  - System Referencing (interdependencies)
- Provides data to assess key performance objectives
  - Operational Availability (Ao), Foot print reduction and trade-off decisions
- Undergoing formal Verification, Validation & Accreditation



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Example Performance Results of Comms-to-SoS Linkage

SoS-level Situational Awareness Availability over
Ground-based Radio versus Satellite
with Varying Network Communications Operating Conditions
(node densities, background traffic and network type)

Approach enables impacts of high-fidelity communication information to be explored at a SoS-level

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Conclusions

- Benefits of this approach:
  - Allows information to be used between diverse M&S tools in a dynamic, efficient way
  - Increases fidelity of SoS results by incorporating high-fidelity, statistical performance information based on current SoS state
  - Provides a useful alternative to expensive, brute-force, high-fidelity simulations that would be impossible to execute in parallel
- Future work includes
  - Exploring the general applicability of the methodology to a wider range of scenarios and M&S tools
  - metric identification and mapping scenarios to dynamic parameters
  - Exploring alternative surrogate implementations, technologies and methodologies
- The methodology and approach are ready to be leveraged immediately in new research and application projects

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