



Performance Prediction Approach to Test & Evaluation for System of Systems

The T&E of System-of-Systems Conference

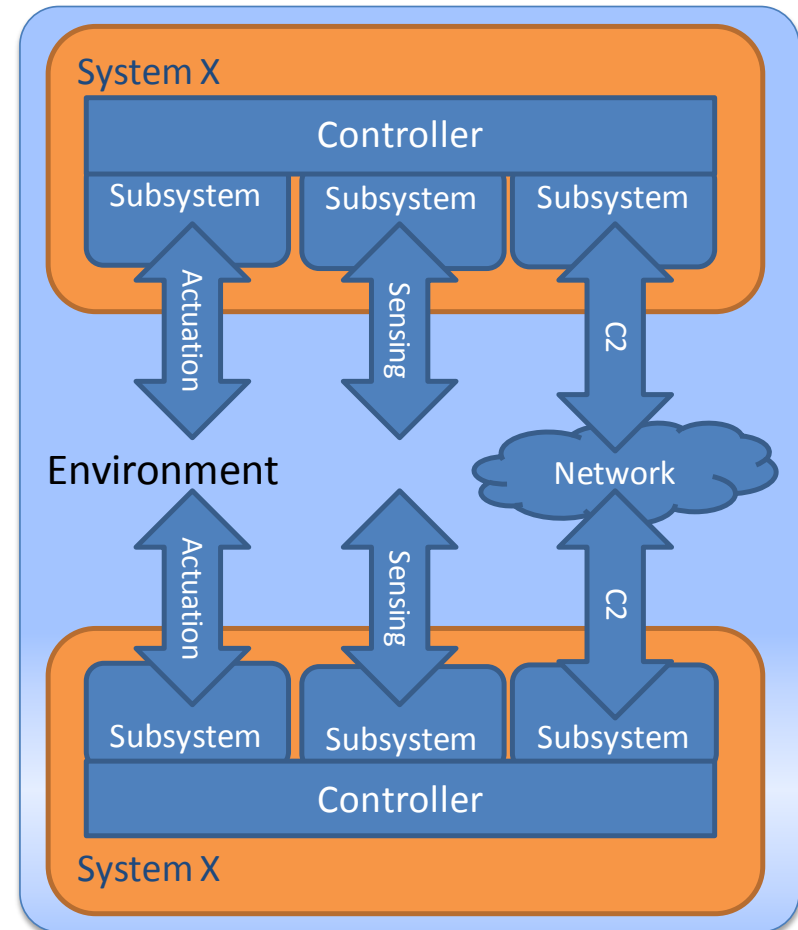
January 26, 2012

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Motivation: Test & Evaluation of System of Systems

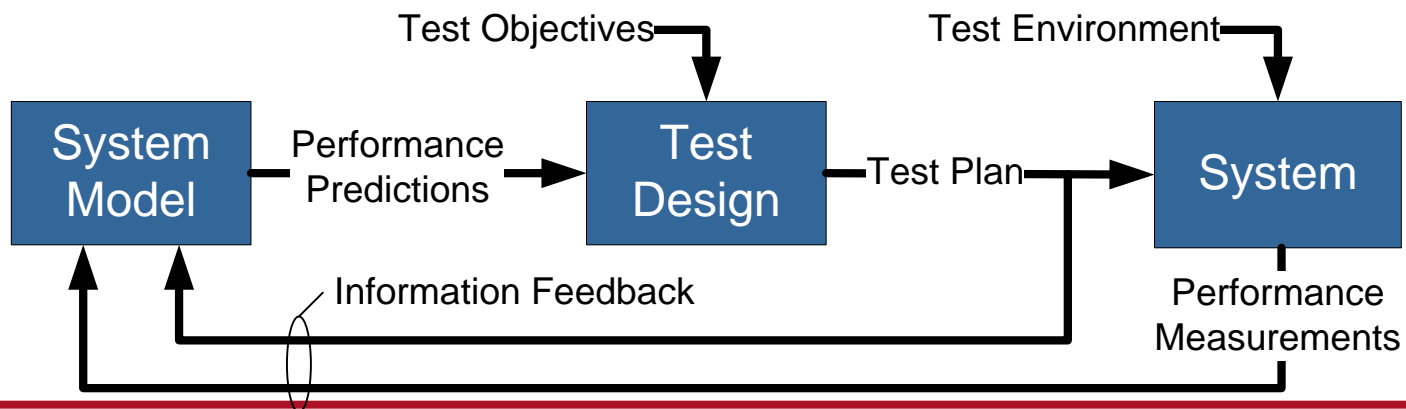
- Future systems characterized by
 - Increased complexity
 - Seamless interoperability
 - Greater autonomy
- When combined these system
 - Adapt to the presence of other systems
 - Coordinate to maximize collective capabilities
 - Discover novel applications of system capability



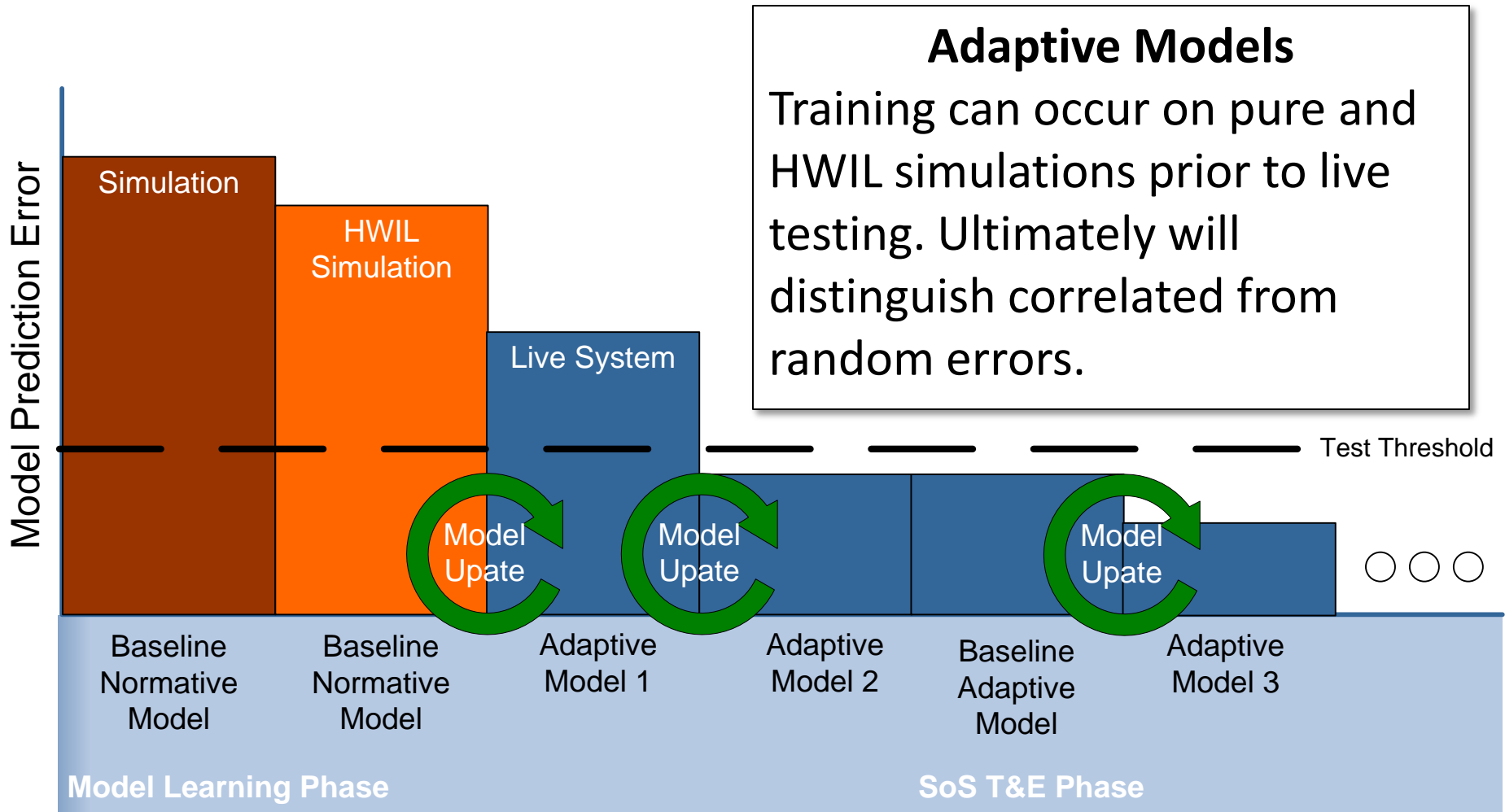
Methods are required that can actively manage test parameters

Modeling SoS Testing as a Control System

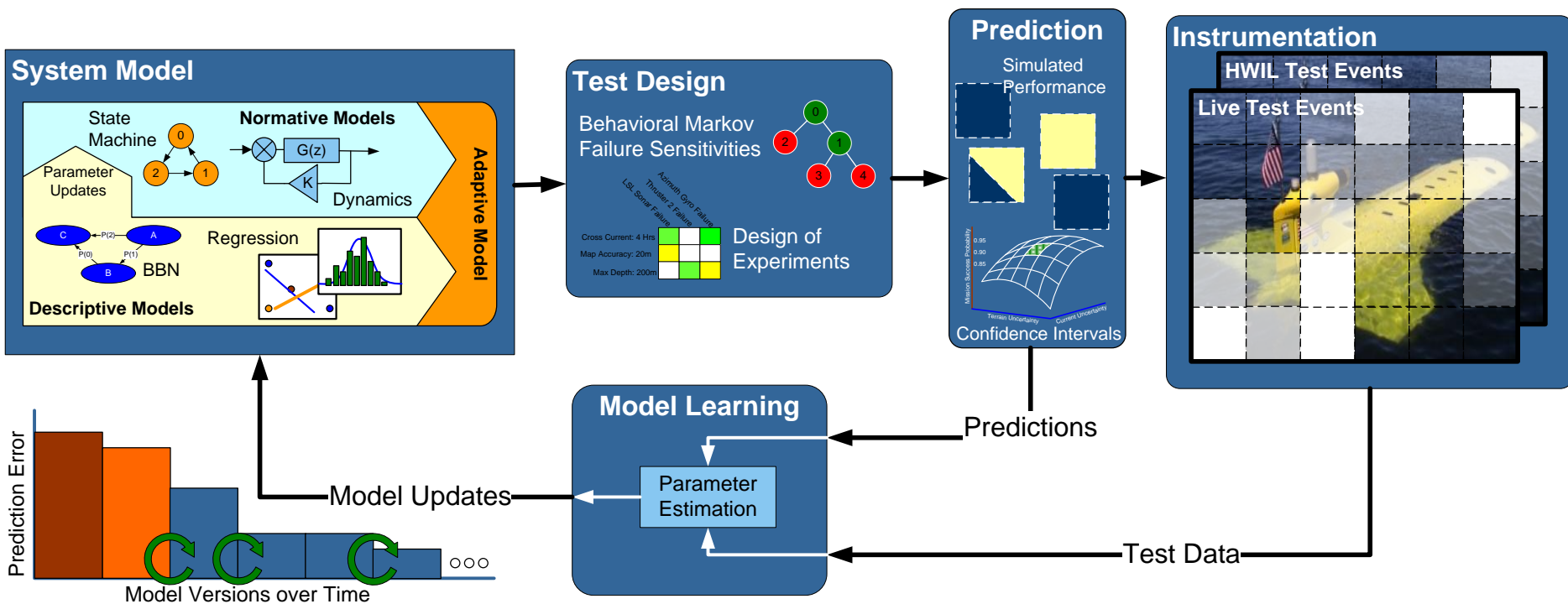
- Benefit of Modeling for Test & Evaluation
 - Predict test event performance
 - Data-driven approach to test design and execution
 - Simulation, virtual tests, and hardware-in-the-loop testing
- Benefits of Information Feedback
 - Improved model/test accuracy
 - Reduced sensitivity to uncontrolled parameters
 - Increased stability with respect to test objectives



Model Lifecycle for Test & Evaluation



Performance Prediction Throughout T&E Lifecycle



Expand Boundaries for T&E in SoS Lifecycle

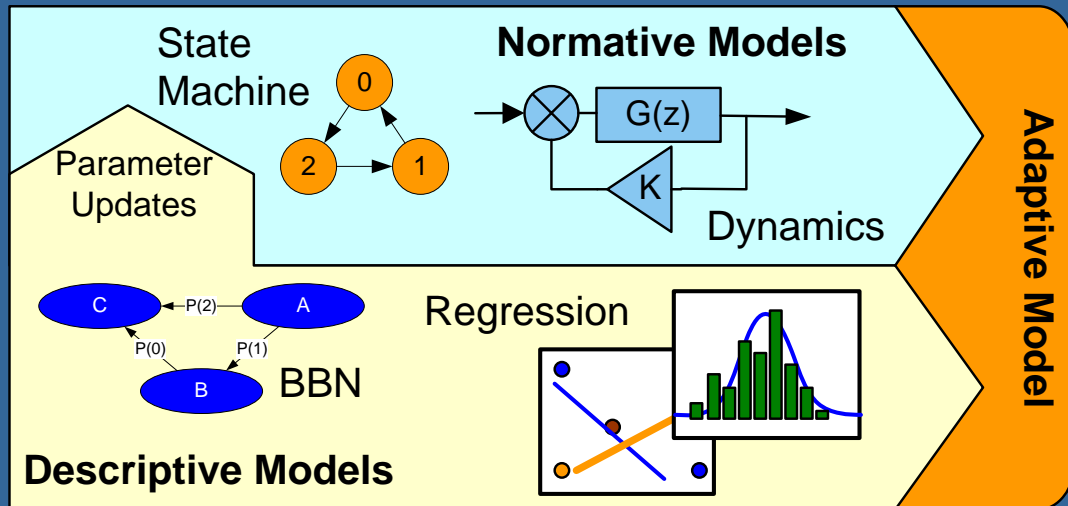
Leverage adaptive models early for Development and into Operations to speed re-certification after system updates

System Model: Adaptive/Learning Approach

Normative Models

characterize behavior, performance, and reliability *analytically*

System Model



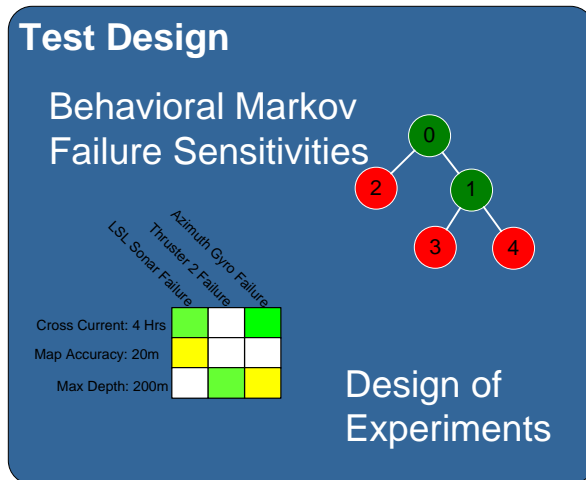
Model Integration

Parameterized for adaptation and aligned with test observables for model validation

Descriptive Models

characterize behavior, performance, and reliability *statistically*

Test Design: Adapting Models/Evaluating System



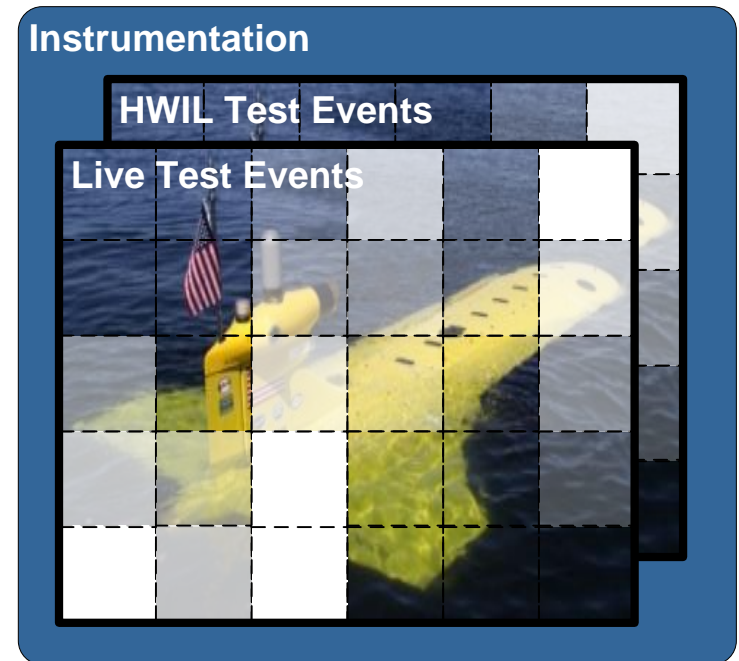
Test Objectives

- *Minimize cost & schedule*
- *Maximize information gain*
- *Offset cost of live testing with simulation/HWIL*

- Model learning phase test objectives
 - Reduce prediction error
 - Augment low order model fidelity
- SoS T&E Phase Objectives
 - Assess critical capabilities & limitations
 - Safety boundaries
 - Performance extremes
- Prioritize test objectives based on system sensitivities
 - Component reliability (hardware/software)
 - Environmental factors

Instrumentation & Testing

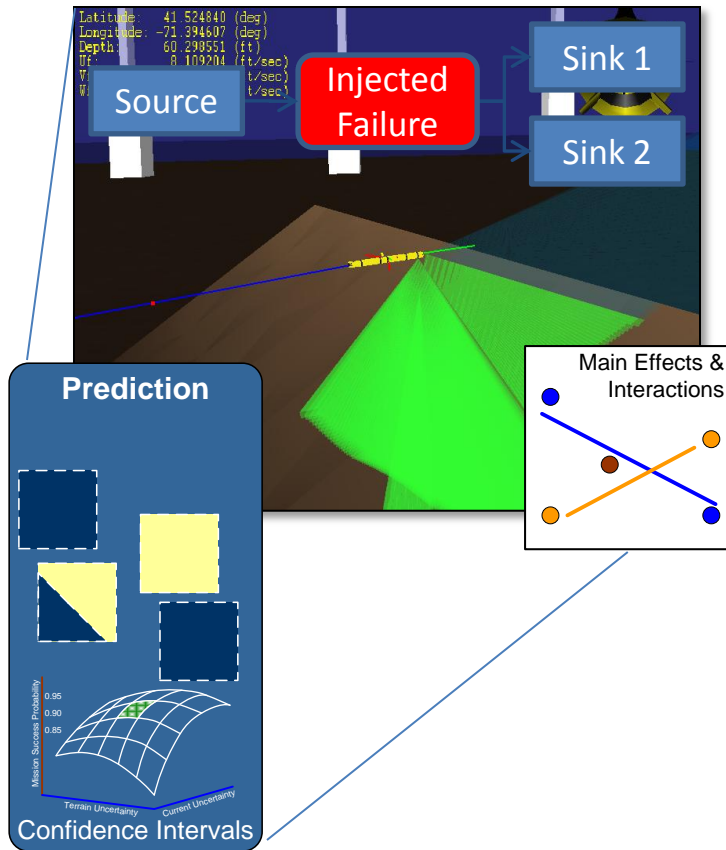
- HWIL Test Events
 - System Model Simulation combined with HWIL Test
 - Partial Validation (Update) of System Model for Subsystems
 - Subsystem-level Test & Evaluation
- Live Test Events
 - Traditional Assessment of Critical Capabilities & Limitations
 - Validate (Update) System Model
 - System-level Test & Evaluation



Instrumentation

- *Access measurements required for model-driven test and evaluation*
- *Support for HWIL testing*

Performance Predictions



- Identify “operating point” for HWIL and Live Test Events
- Generate model-based predictions
 - Reduced order adaptive model simulations
 - Confidence estimation for untested scenarios and situations
- Develop model sensitivity metrics
 - Assess Nominal and Off-Nominal Scenarios (failure injection)
 - Characterize environment impact on performance

Conclusions

- Objectives of predictive SoS model-based testing
 - Leverage model predictions to identify risk, reduce cost and schedule
 - Predict confidence in system (through SoS) performance in untested scenarios
- Adaptive models and control system analogies
 - Provide framework of many possible solution methods (linear/non-linear/robust control)
 - Clear development/communication of test plans within constraints