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Secure & Resilient Functional Modeling for Navy Cyber-Physical Systems

FY17 Quarter 2 Technical Progress Report

DoD sponsoring/monitoring agency: Office of Naval Research
875 North Randolph Street
Arlington, VA 22203-1995
Contract number: N00014-16-C-2005
Period: January 1, 2017 – March 31, 2017
Total contract amount: $932,742
Costs during period: $73,714
Costs to date: $115,280
Estimate to complete: $932,742

Milestones and Deliveries

Work Package	Milestone or Delivery	Scheduled Delivery or Completion	Actual Date of Delivery or Completion
Attack Generator (UCI)	Attack Models	April 2017	Pending.
Functional Editor (SCCT)	FME Demonstration (Virtual demo)	May 2017	Pending.
Simulation Engine (SCCT)	Simulation Engine Demonstration	August 2017	Pending.
Functional Modeling Compiler (SCCT)	FMC Demonstration (In Princeton)	October 2017	Pending.
Functional Modeling Compiler (SCCT)	FM Compiler and Key Performance Indicators (KPI)	May 2018	Pending.
Model Management Backbone (SCCT)	MMB Demonstration	April 2018	Pending.
Agent-based Distributed Runtime (UCI)	ADR Demonstration	October 2018	Pending.
All	End-to-end Use Case Demonstration	September 2019	Pending.

Summary of Progress and Major Accomplishments

Work Package	Progress	Major Accomplishments
All	The SCCT and UCI teams held a workshop on 1/31 at UCI. The following topics were discussed:	Described for the individual work packages.

Work Package	Progress	Major Accomplishments
	- Definition of the work plan for the entire project (milestones and deliveries presented above). - Navy use case (Ship Chilled Water Distribution System). - Details of the attack models, and definition of the content of a corresponding research paper. - Approaches to implement the agent-based distributed runtime. - KPIs for single/multicore controllers and temporal/spatial domains. - Integration of the model management backbone. - Plan of an internship for a PhD student to work on the simulation engine at SCCT during the summer of 2017.	
Attack Generator (UCI)	The UCI team defined the following attack models for cyber-physical systems: - 6 basic attacks targeting signals. - 1 basic attack targeting control parameters. - A model for coordinated attacks that provides any combination of basic attacks in order to target robust systems more effectively. The attack models were implemented in MATLAB/Simulink as simulation models and evaluated with an example system model of an engine cooling system. The UCI team is preparing a technical report with the results of the attack generator work package.	The modelling approach consisting of basic and coordinated attack models provides a large set of concrete attack models, exceeding the proposed number of attack models to develop in the project. The practical evaluations in the simulator show the negative effects of the attacks on the original system. The theoretical definition of the attacks, the implementation approach and the early results of the practical evaluation were encompassed in the research paper “Modeling and Simulation of Cyberattacks for Resilient Cyber-Physical Systems” and submitted for publication to IEEE Conference on Automation Science and Engineering (CASE) 2017.
Functional Editor (SCCT)	The development of the web-based functional modelling editor is close to completion. The following features have been implemented: - Hierarchical block structure for multi-level functional models. - User-defined block types and connection port types for increased modeling flexibility. - Automatic drawing of block connections. - Type checking for port connections and visual indication of type mismatches for flows. - Generic block attributes for specifying arbitrary domain-specific and	The server of the SCCT prototype was migrated from C++ and SQLite to JavaScript (Node.js) and MongoDB, thereby retaining or improving the original functionality while embracing a new and modern software platform that supports multiple operating systems and deployments to cloud architectures. Block and port templates can be defined by the user in JSON format without changing the application code.

Work Package	Progress	Major Accomplishments
	application-specific information in the functional model. - Dynamic loading of block and port template definitions in JSON format. - Portable and web-enabled implementation based on Node.js and MongoDB	The web-based editor combines SVG and HTML for optimal display of graphical models and model data.
Functional Modeling Compiler (SCCT)	The SCCT team has carried out conceptual work in order to define the implementation strategy for the Functional Modeling Compiler. The following approaches have been studied: - Functional model to architecture and architecture to simulation conversions as presented in “Functional Model-based Design Methodology for Automotive Cyber-Physical Systems” (Wan et al. 2014) - Methods combining symbolic representations and satisfiability solvers (ASP, SMT), as well as constraint programming. The NIST Functional Basis taxonomy is being studied as a common input language for the Functional Modeling Compiler.	The SCCT team has identified the potential benefits of combining algorithmic and constraint programming approaches for the Functional Modeling Compiler: - Generation of more complete attack scenarios targeting all existing attack points in the system. - Generation of more complete cybersecurity functions protecting all existing attack points in the system. - Optimal integration of control functions and cybersecurity functions. - Optimal generation of control code for the important KPIs under consideration.
Simulation Engine (SCCT)	SCCT has obtained licenses for LMS Amesim, and is currently in the process of obtaining licenses for MATLAB/Simulink. The plan for working on the simulation engine was defined during the workshop at UCI. The attack models from the Attack Generator work package will be combined with the generated models from the Functional Modeling Compiler as a first step.	Work has not started.
Agent-based Distributed Runtime (UCI)	Not started.	
Model Management Backbone (SCCT)	Not started.	

Anticipated Problems

Work Package	Explanation of Anticipated Problem	Actions Being Taken to Correct Problem
Attack Generator (UCI)	The request to ONR for the determination on fundamental research required by UCI caused a delay in the work plan.	The UCI team concentrated its efforts on the Attack Generator work package in order to deliver results by the end of April 2017. The work on the Simulation Engine has been scheduled for the summer of 2017.
Attack Generator (UCI)	The modeling of the control parameter attack models currently requires some modification to Simulink blocks.	The MATLAB/Simulink API for interacting with Simulink models will be studied further in order to develop a solution that works with standard MATLAB/Simulink blocks without modification.
Functional Editor (SCCT)	The migration to Node.js has caused some synchronization issues in the web-based editor.	The current implementation using timeouts will be modified to use synchronization functions.

Points of Contact

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