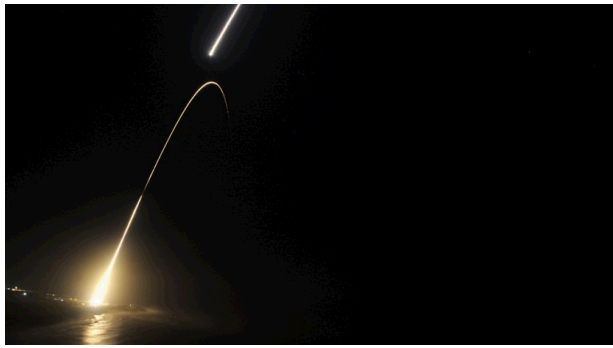
SAND2014-20723C

Exceptional service in the national interest

Sandia National Laboratories





Rapid Prototyping of Hardware Using Real-Time HWIL Simulation Environments

Jonathan F. Torres and Scott A. Kowalchuk

AIAA Modeling and Simulation Technologies Conference

January 05, 2015

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

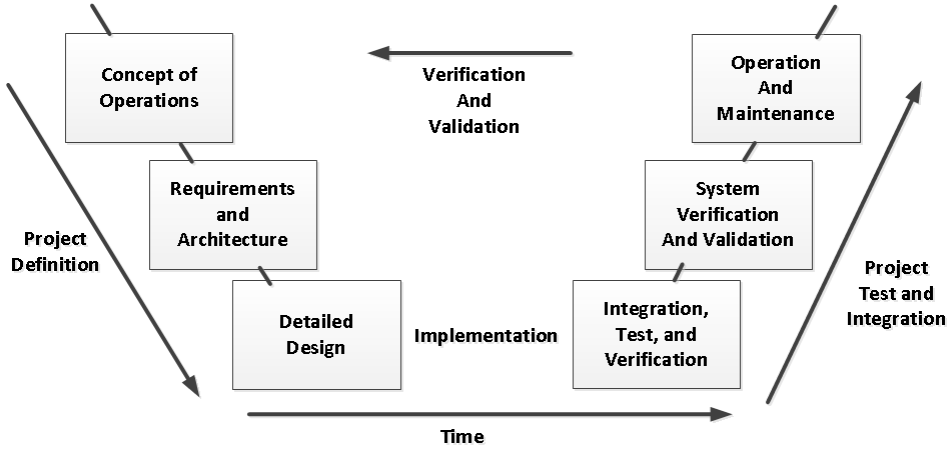
Overview

Sandia National Laboratories

- Traditional V-Model
- V-Model Detailed Design Process Flow
  - Implementation of COTS/prototype hardware to meet system requirements
  - HWIL Simulation Testing
- V-Model Design Phase Process Flow
- Component Tests
- Hardware Development
- System Verification

Traditional V-Model

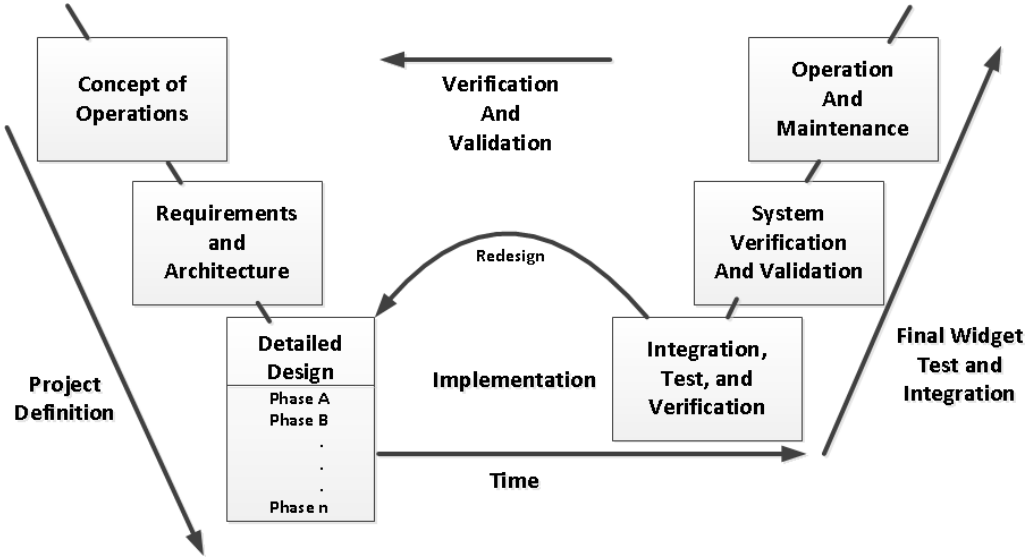
- Based on four phases of product Development
  - System requirements
  - Modeling
  - Target implementation
  - Validation
- Objective: catch design problems early in design phase.



- Simulation can be used to verify requirements in design phase.

V-Model Detailed Design Process Flow

- Provides engineer with confidence that final design is accurate and potential for redesign is decreased.
- Testing starts at earlier stage.
- HWIL Simulation developed at earlier stage.
  - HWIL developed at design and system verification phase
  - Allows engineer to test product at component stage.



V-Model Design Phase

- Outline of how design phase is related to the HWIL and system requirements.

Design Phase	Objective of Phase	Hardware/ Software	Real-Time HWIL	Pre-Verification Requirement
A	Test IO Function	COTS	IO Test	x
B	Confidence to satisfy req. y	Prototype 1	Detail to satisfy req. y	y
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
n	Confidence to satisfy req. z	Prototype n	Detail to satisfy req. z	z

- Assume requirements have been defined.
  - Objective of HWIL system at design stage: verify that individual requirements operating correctly.
  - Not necessary that final product be developed . Start with COTS HW.
    - Only test that IO is functioning properly.
    - Identical IO between COTS hardware and final widget not necessary.

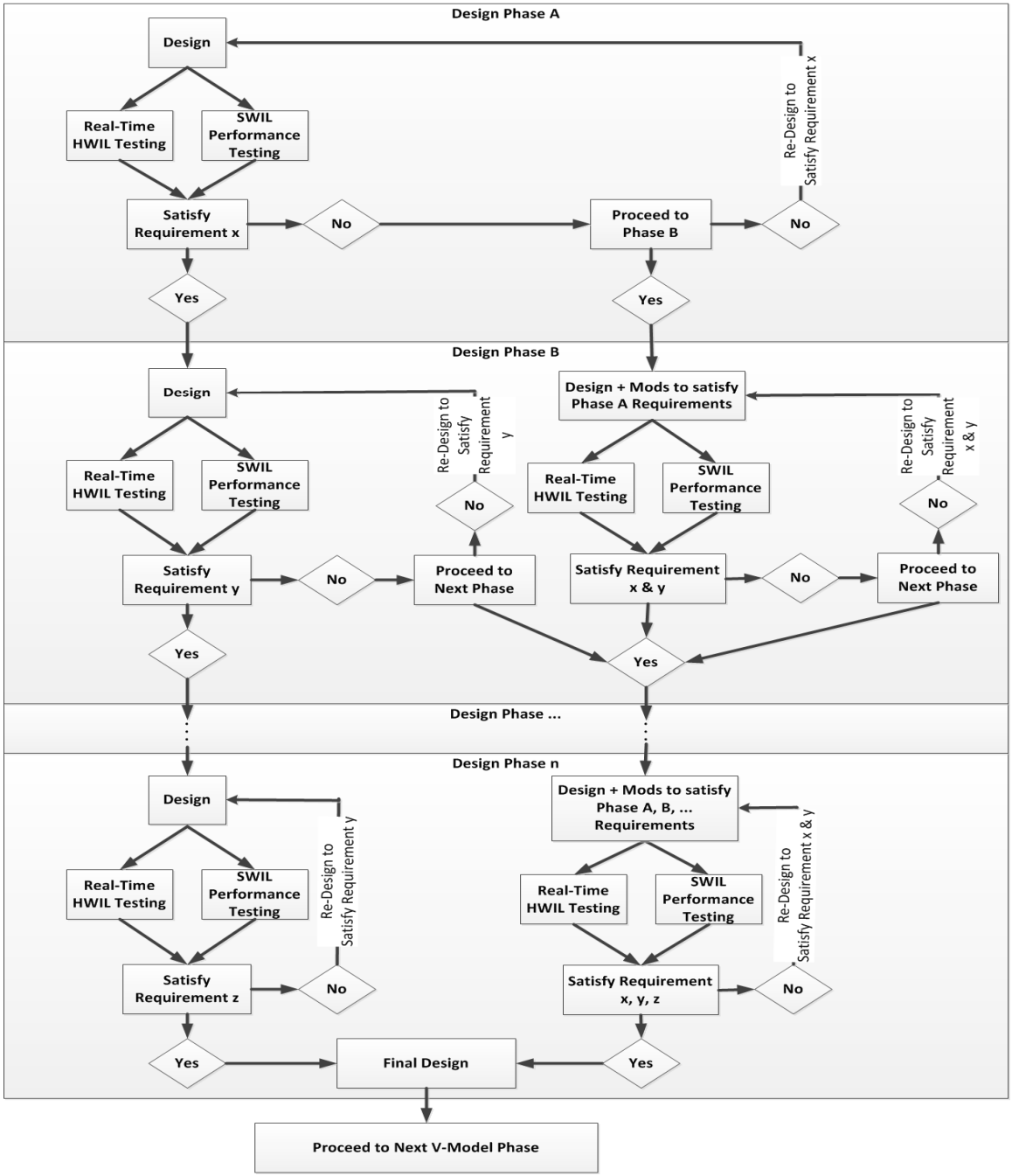
V-Model Design Phase (cont.)

Sandia National Laboratories

- Use prototypes to check if requirements are being fulfilled.
  - If requirement not working, correct mistake early in design.
- More requirements that are satisfied with prototype builds, less risk of error occurring when final widget built.
  - Verify Hardware and software requirements.
- During each phase of design, check that previous and current phases are being fulfilled using most current prototype.

Design Phase Flow Process

- Progress through different requirements until final widget release.
- Early stages cannot expect 100% accuracy when attempting to fulfill requirements.
  - More design phases are complete, requirement accuracy can increase.



Component Test

Sandia National Laboratories

- Two simulation methods for component tests:
  - HWIL: model the dynamics of the system in a real-time environment incorporating hardware.
  - SWIL: execute simulation faster than real-time and supports robustness of the software through analysis.
- Test models will be developed for each piece of hardware that will be integrated into HWIL simulation.
  - Much easier to debug one piece of hardware.
  - Better understanding of the individual piece of hardware.
  - Also valuable from safety perspective
    - less risk of damaging equipment when integrating with one another

Component Test (cont.)

Sandia National Laboratories

- Easier Debug Process
  - Test model to refer to as the prototype hardware iterates through several revisions.
- Component tests aren't specific to an individual piece of hardware.
  - Component Tests can be formed at the subsystem level.
  - Debug: engineer only has to pinpoint the problem down to the subsystem level.
- When valid, SWIL and HWIL simulations should be run to satisfy desired requirement.
  - Comparing SWIL and HWIL results should be done at component and system level.

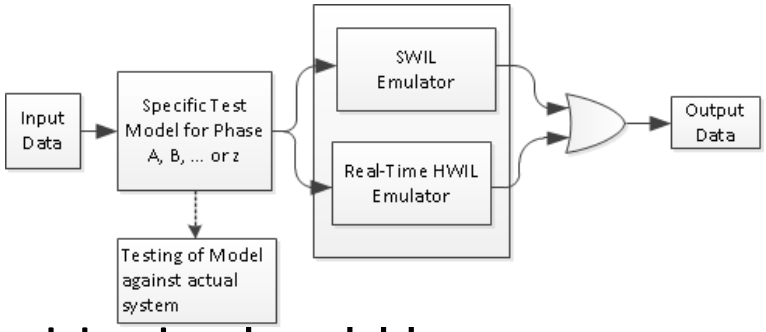
Hardware Development

Sandia National Laboratories

- Hardware should be characterized into specific functions.
  - HWIL system can be developed in parallel.
  - If hardware not available, COTS hardware can be used until prototype is ready.
- Development using COTS hardware is advantageous.
  - Foundation developed for prototype hardware
  - Familiarize with the desired functionality of the hardware
  - Time efficient
- Once design phase is complete, each piece of hardware will need to be verified using SWIL and HWIL simulation environments.

Development of Component Tests

- NGC Department Tools for Component Tests
  - Revision control
  - Mathworks' Simulink Project
  - Structured Model-Based Design Flow



- Blocks that are specific to component tests should be contained in Simulink Library.
- Common Input Data set for every test model
- Revision Control: tag component test models for each design phase.
- Report generated for every revision of the test model.
- Analysis scripts should be designed for every test model.

System Verification

Sandia National Laboratories

- System testing will be used to measure fidelity of the HWIL/SWIL simulation.
  - System testing can be performed at the component or subsystem level.
- As each widget is built, they can be integrated into system testing.
  - Same process used when verifying component requirements in design phase.
- Several iterations of system testing can allow the engineer to fine-tune the SWIL/HWIL so that it is as close to the actual system as possible.

Conclusion

Sandia National Laboratories

- V-Model detailed design phases allow engineer to test mission requirements via HWIL and SWIL testing while hardware is being developed.
  - Mission requirements will be verified to a defined confidence level during the design phase.
- Once final product built, engineer can incorporate final widget into HWIL system to verify proper behavior.
  - Reduces risk during the system integration testing phase
- System testing then performed to ensure the system meets mission requirements and output data will be compared against SWIL and HWIL data.

The V-Model Diagram approach has proven to support rapid prototyping and provide high confidence that hardware/software requirements will be satisfied.