BAE Systems Land & Armaments

Model Based Software Development for DDG 1000 Advanced Gun System

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Advanced Gun System on the Zumwalt DDG 1000

AGS Key Features

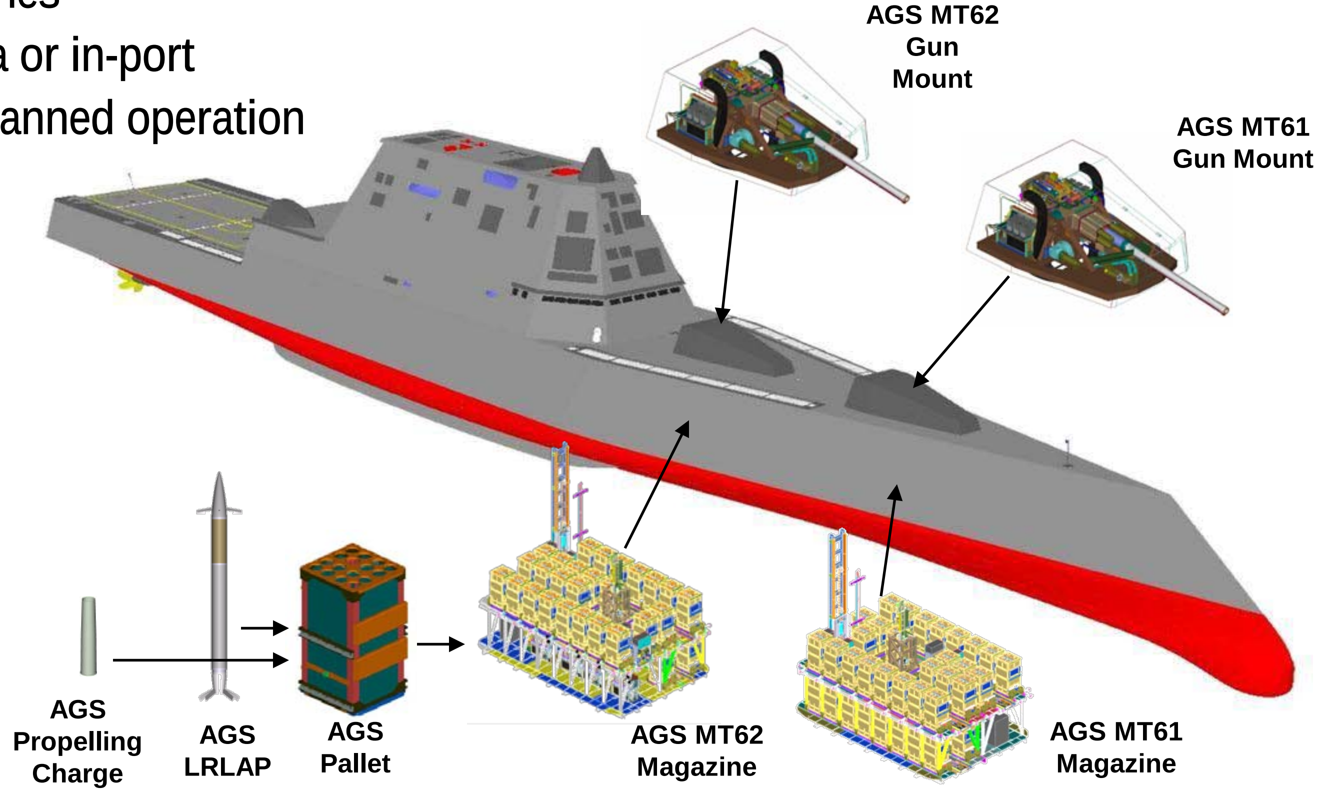
155 mm / 62 caliber vertical load mount

10 rounds per min continuous rate-of-fire

(2) 300 round magazines

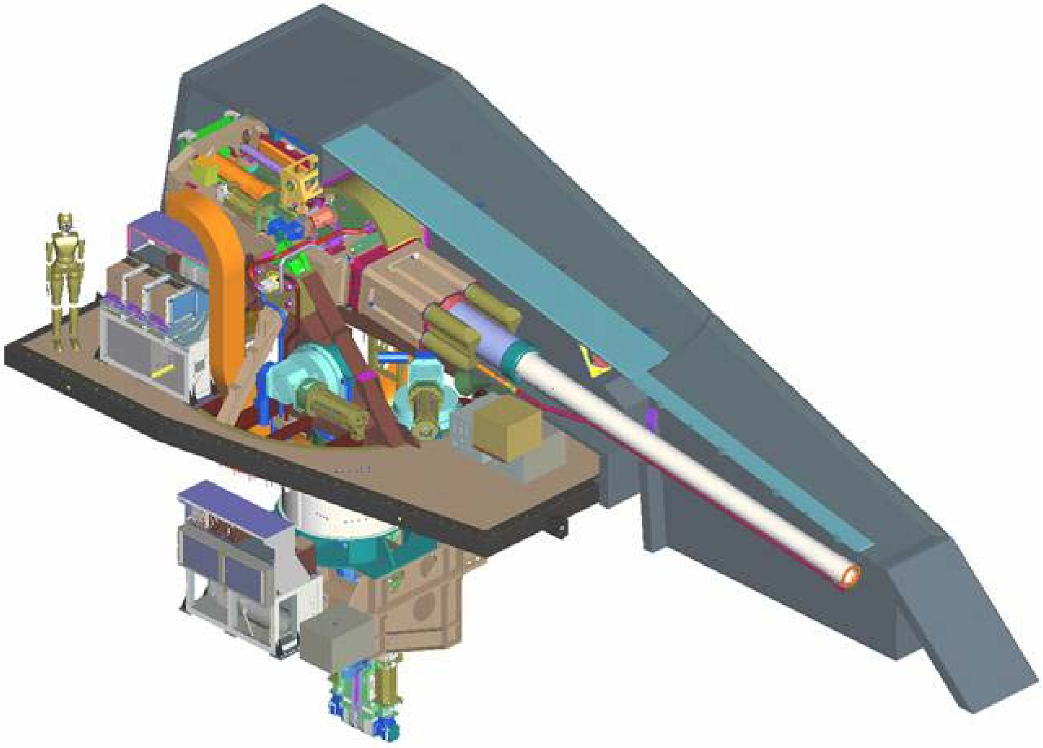
Replenishment at-sea or in-port

Fully-automated unmanned operation



AGS Overview

- Advanced Gun System (AGS) is a 155 mm vertical load gun employing a fully automated magazine and gun loading system
  - 84 electric brushless DC drives
  - Largest motor - 250 HP
  - 850 KW Peak power draw per gun mount
  - 4 VME Chassis with 15 Single Board Computers
  - 100 lb cased propellant
  - 220 lb, 14.5 cal (88") LRLAP



Application Trade Study

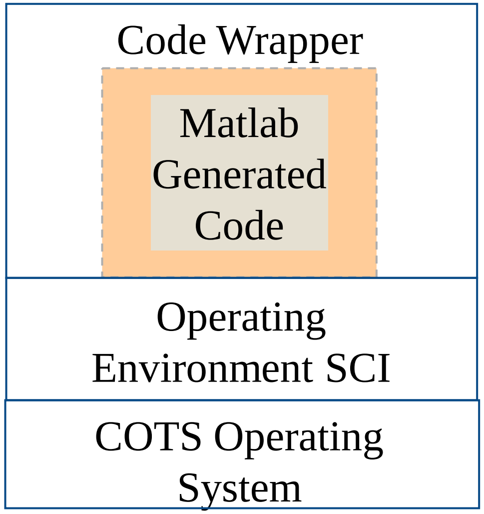
- Trade criteria of hand code versus model based design (Matlab/Simulink)
  - Cost / Risk / Performance
- Model Based Design Selected:
  - Control systems
  - Logic diagrams / state machines
  - Sensor filtering
  - Sequencing, BIT, fault handling
- Hand Code Selected:
  - Queuing problems
  - Linked lists
  - Database applications
  - Operating system interface
  - Hardware drivers

Costs		
	Safety critical code compliance	
	ODP process compliance	
	Design	
		Design Development Effort
		Design review / verification
		Requirements traceability
		Configuration management
	SW Test	
		Unit level code & test
		SCI level test (host)
		Test vector development
	HW/SW Integraton	
		Integration against emulated environment
		Integration test (HW/SW integration)
	Maintenance (LCC)	
	Training / Tools (Resource availability)	
Risk		
	Ability to meet schedule	
	Ability to meet cost	
	Technical performance (Design intent implementation (reqmts interpretation))	
Performance (of end product)		
	Reliability	

Implementation Trade Studies

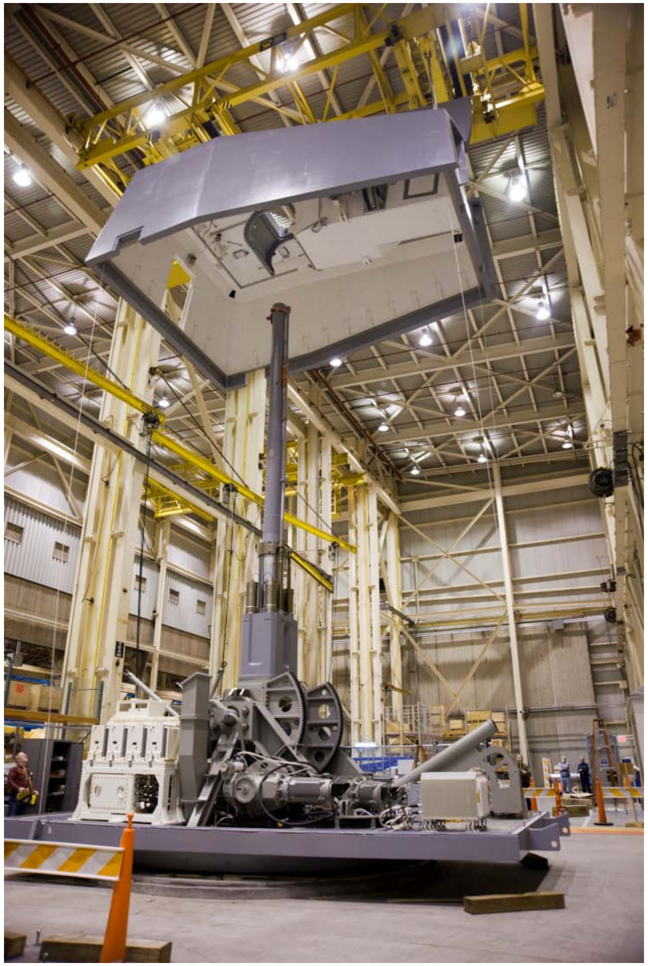
- Mix hand code and auto generated code?
  - Selected a separation where all the application functions on the processor are in the model
  - Simplified team organization and integration
- Interface directly to operating system?
  - Chose to use a OE layer which separates the application from the operating system
- Embed hand code into models?
  - Not required based on application requirements
  - Limit to interfaces
- Interface generated code only through a top level generated subroutine call?
  - Used direct OE calls through s-functions
  - Top level model called by frequency based scheduler

Processor Software Stack



Software Safety Implications

- The AGS is the first weapon system for which the U.S. Navy Weapon System Explosives Safety Review Board (WSESRB) Software Systems Safety Technical Review Panel (SSSTRP) gave concurrence for using a model based software development approach
  – Several possible approaches evaluated including certified code generators
  – To meet safety expectations a software safety process is required
- Qualification approach chosen with native Matlab code generator
  – Code generator treated like a new compiler
  – Limited set of base library blocks used
  – Usage enforced through automated script checking
  – Style guide checks also enforced through automatic scripts



Matlab Autocode Qualification Process Steps

1. **Identify "Core" Building Blocks**
   – Only those building blocks necessary for AGS.
2. **Unit Test**
   – Complete Model Coverage
     • No Dead Code
     • All Logic Tested
3. **Peer Review**
   – Review "Core" Block Construction
     • Verify Safe Construction
     • Eliminate Unnecessary Blocks
   – Confirm Coverage and Results
4. **Code Generation Inspection**
   – Code Generate Models and Test Vectors
   – Inspect Code
     • Tailored AGS Coding Standards
     • Verify Generated Code Correctness
     • No Dead Code Generated
5. **Target Compile And Execute**
   – Compile Generated Code On Target
   – Execute Test Results
6. **Validate Test Results**
   – Validate results with those from graphical model-base testing.

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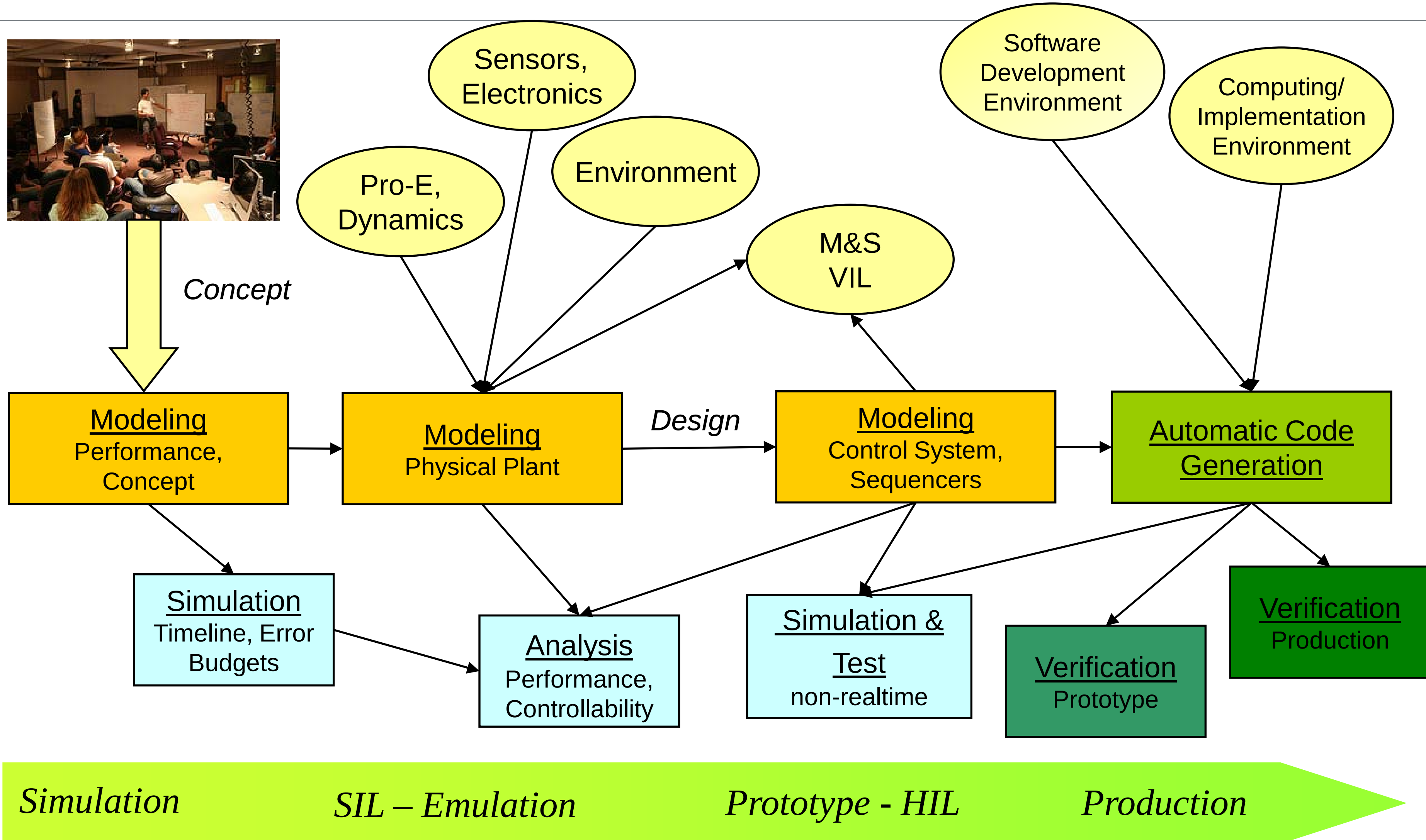
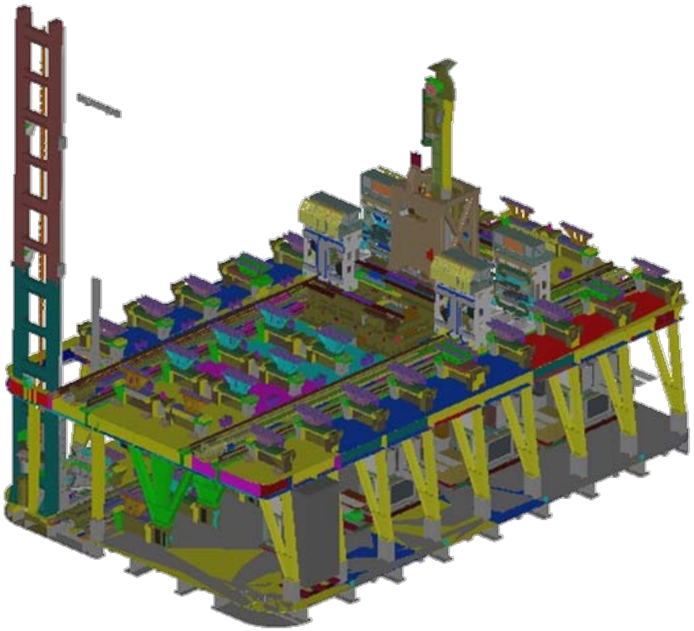
Product Development Flow



Development Artifacts

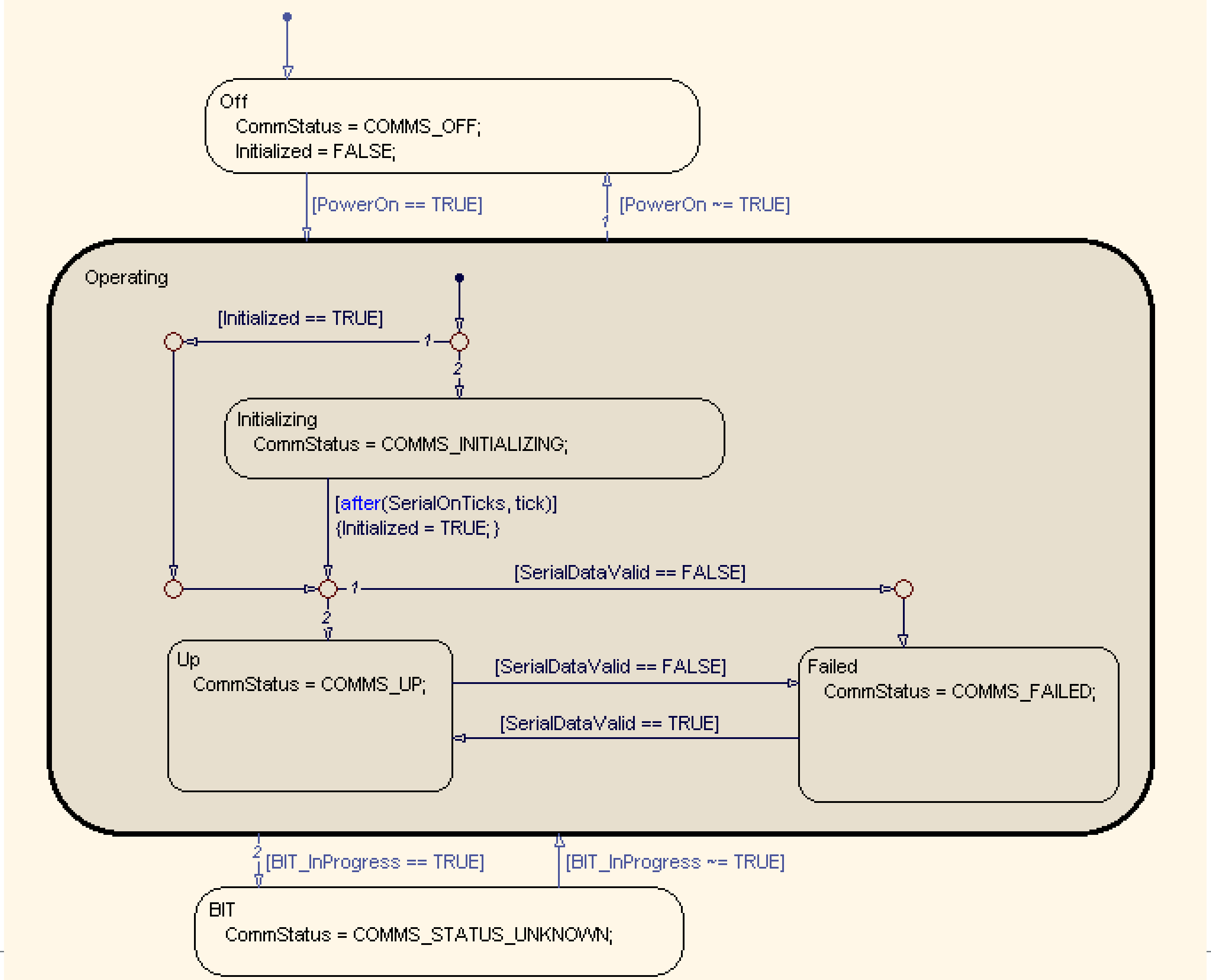
- Generic model library components
- Unit level tests
  - Model based with execution in simulation and on target processor
  - Coverage analysis
  - Peer review with SME
  - Automatic script checks for block usage and style guide
  - Code review if safety critical
- Independent test team
  - Integration functional testing against requirements
- Configuration management in Clearcase
  - Models, unit tests, coverage analysis



Benefits of Model Based Design

- Subject matter expert direct implementation
  - Less detailed requirement decomposition
  - No algorithm translation issues
- Subject matter expert review of graphical logic
  - Design accessible by system, electrical and mechanical engineers
- Powerful automation tools available
  - Model style checking, unit test development, coverage analysis, regression testing and code generation
- Cost and schedule savings
  - Prototype applications five times less costly than traditional hand code
  - AGS objective production code actual costs were two times less than traditional hand code estimates
    - Improved performance expected as processes mature

Advantages of Graphical Logic



Challenges to a Model Based Design

- Estimating project cost
  - Functional based estimates
  - Calibrating SEER-SEM
  - Scaling for project size
- Reporting development progress
  - SLOC is meaningless metric
- Artifacts for independent test teams
  - Design can be performed with higher level requirements
  - Specific documents only for testing may be required

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