U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Advanced Propulsion with Onboard Power (APOP) Model Based Approach

6/10/15

OPSEC # 26836

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **10 JUL 2015**	2. REPORT TYPE	3. DATES COVERED **00-00-2015 to 00-00-2015**
4. TITLE AND SUBTITLE **Advanced Propulsion with Onboard Power (APOP) Model Based Approach**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army RDECOM-TARDEC,6501 E. 11 Mile Road,Warren,MI,48397-5000**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Briefing

14. ABSTRACT
None

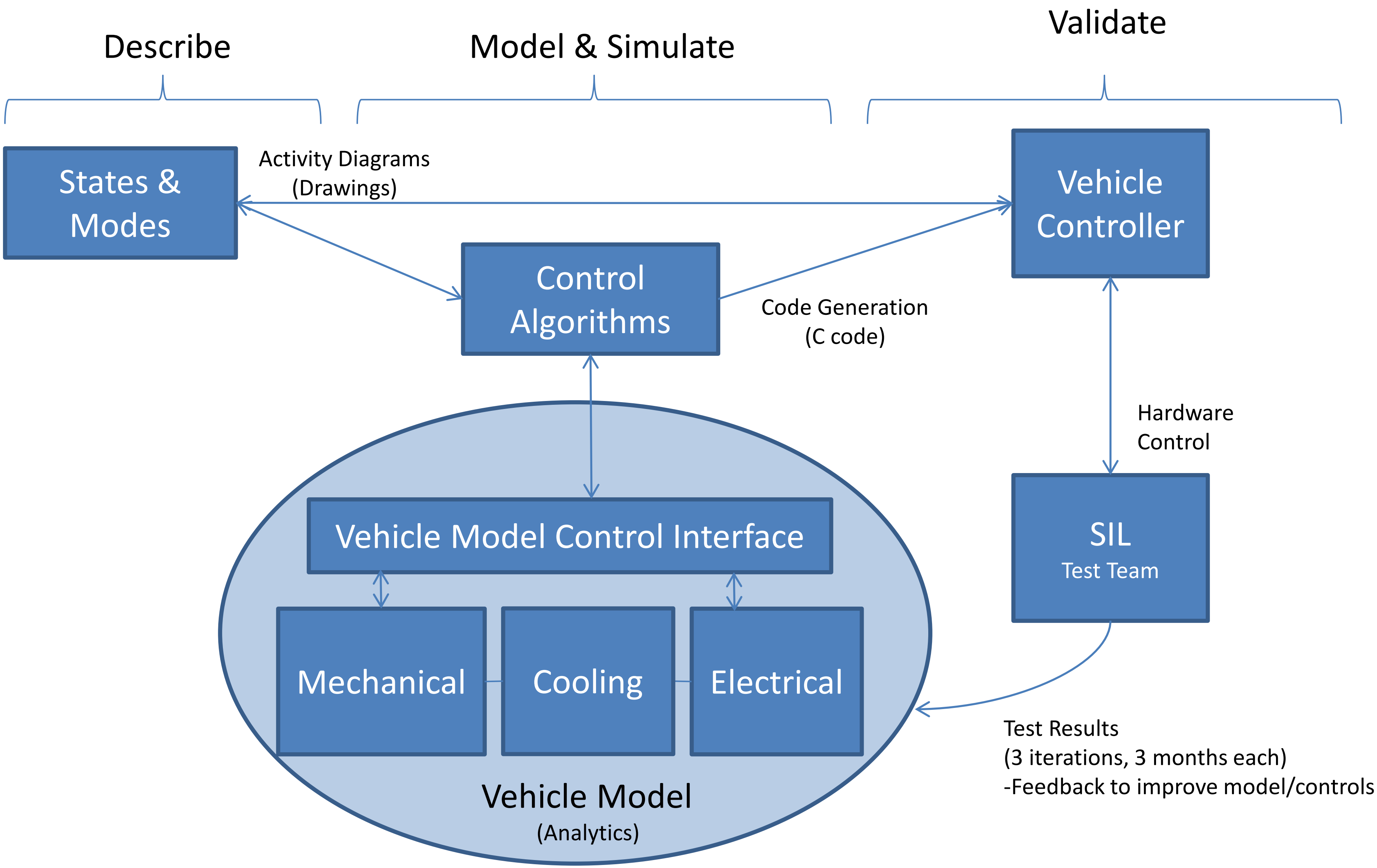
15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**20**	

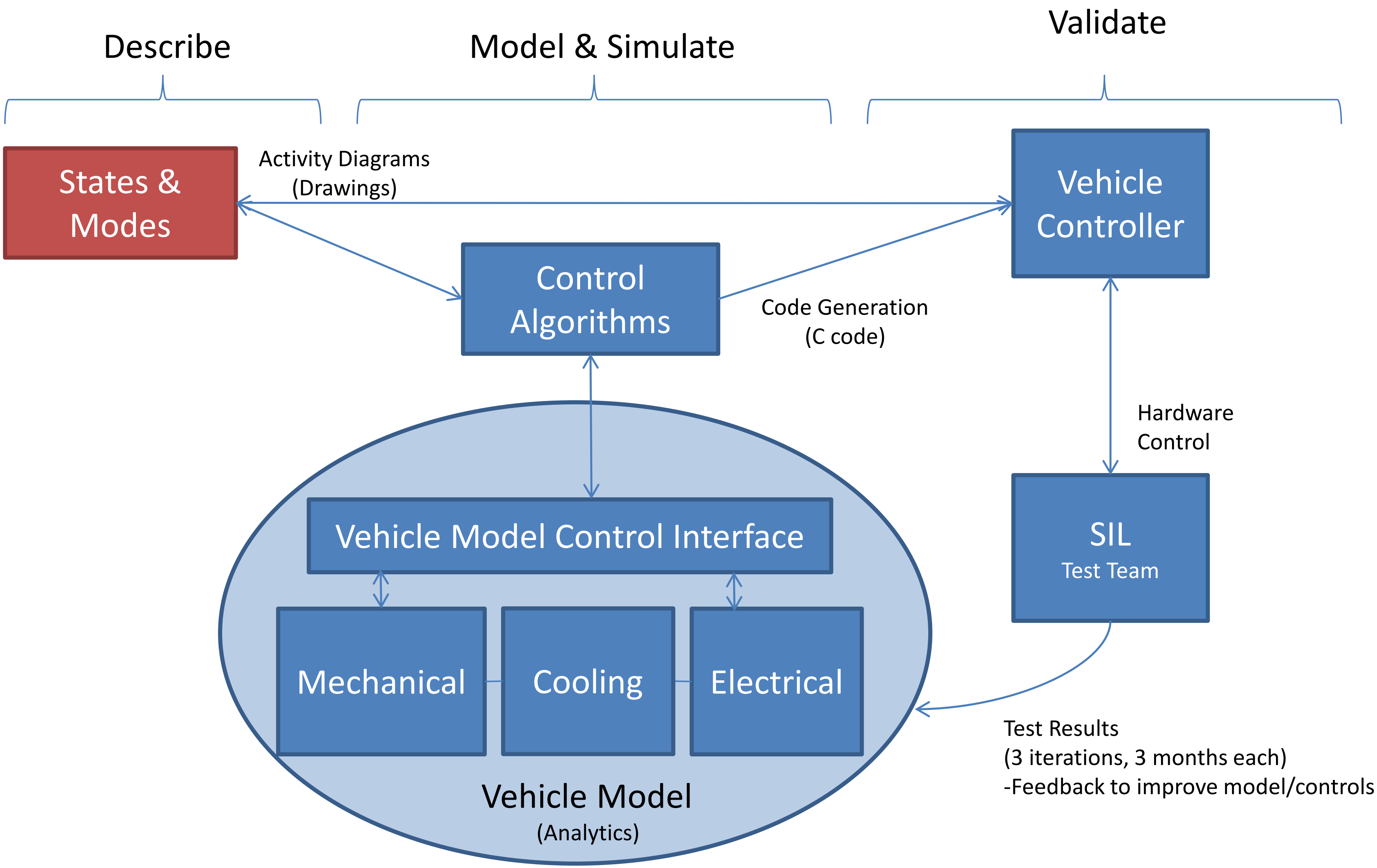
Agenda

- Overview of Approach
- Architecture
- Vehicle Model
- Controls Model
- Vehicle Controller
- System Integration Laboratory (SIL)

APOP Controls



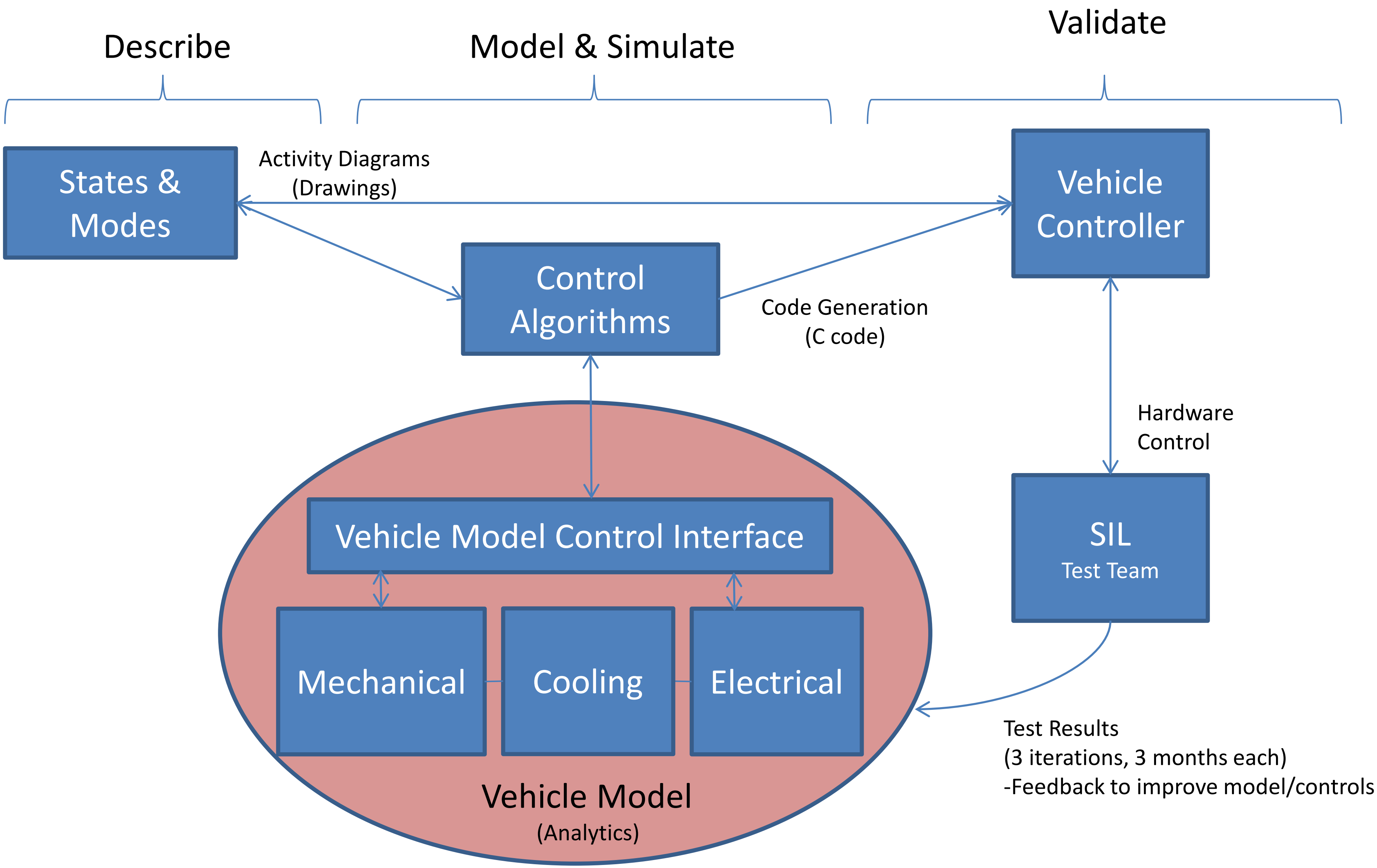
APOP Controls



VEA Power System Architecture

- The Next Generation Combat Vehicle Electrical Power Architecture (NGCVEPA) is the Vehicle Electronics and Architecture (VEA) Power System architecture and power management approach being developed as part of complete vehicle electrical architecture for the VEA Research SIL.
- NGCVEPA will meet the most difficult case, super-set of requirements derived from all combat vehicle requirements.
- VEA has decided to use a Systems Modeling Language (SYSML) tool to capture architecture, interface and functional design details.

APOP Controls

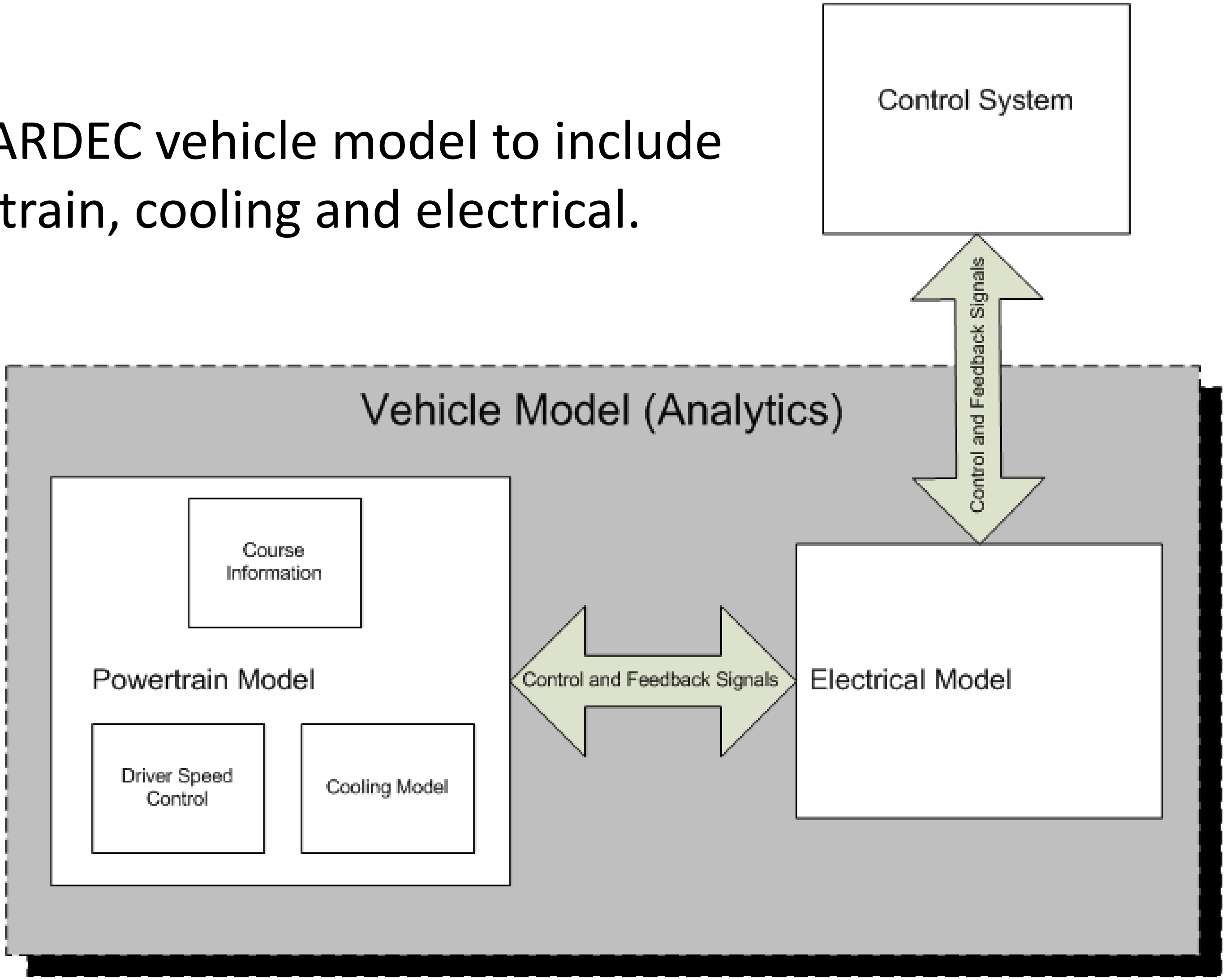


Vehicle Model Overview

- Create a fully integrated Advanced Propulsion On-Board Power (APOP) model that includes the powertrain, cooling and electrical system.
- This model will be used to predict system performance and serve as a test bed for the vehicle control development.

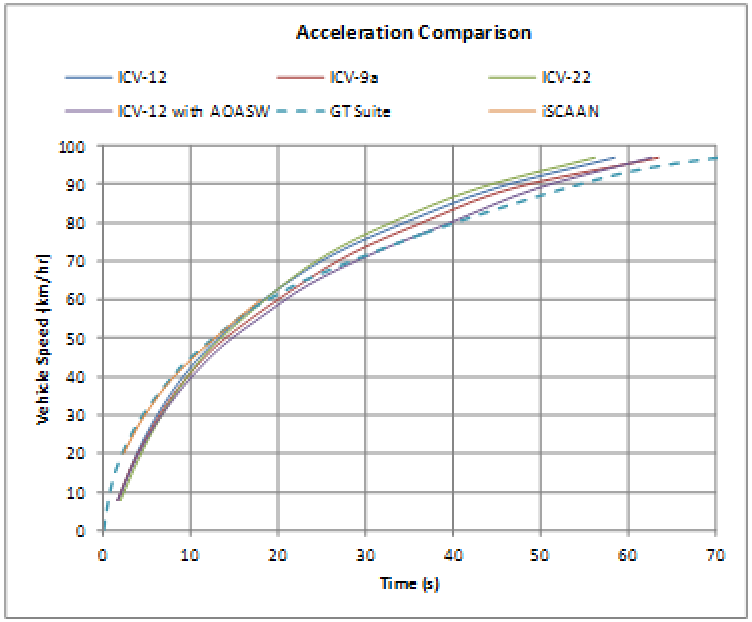
Model Schematic

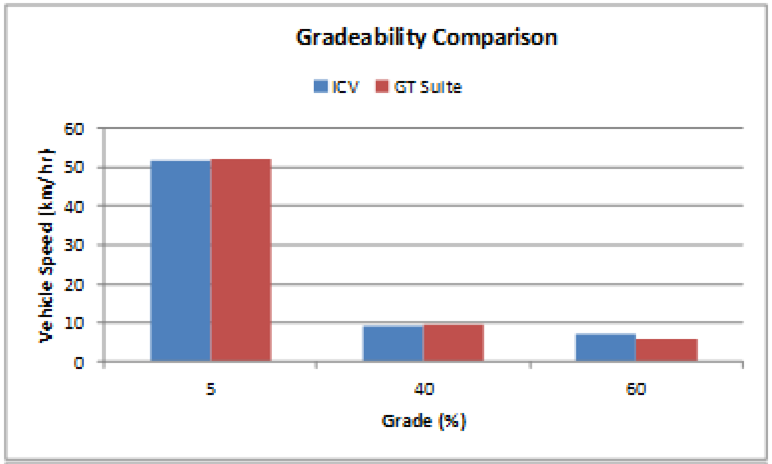
First TARDEC vehicle model to include powertrain, cooling and electrical.

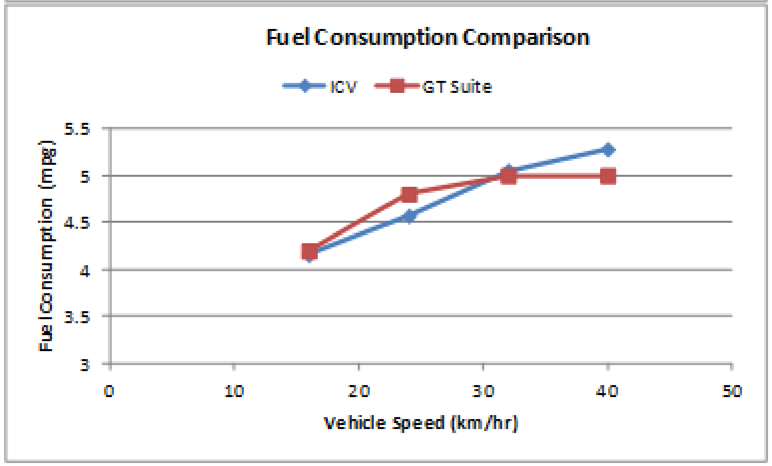


Powertrain Model Validation

Powertrain Model for the vehicle was compared with results from tests run at the government test site.



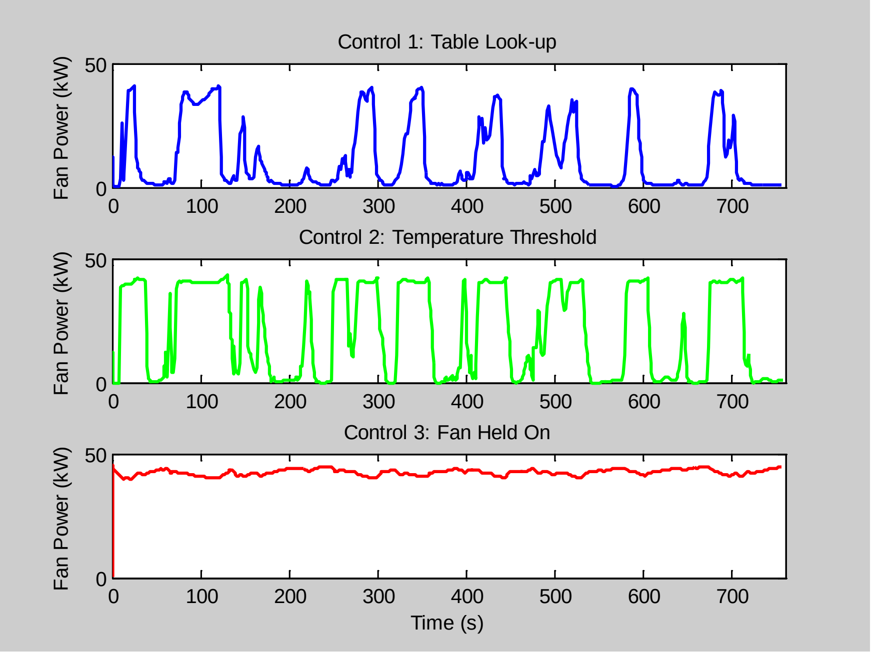


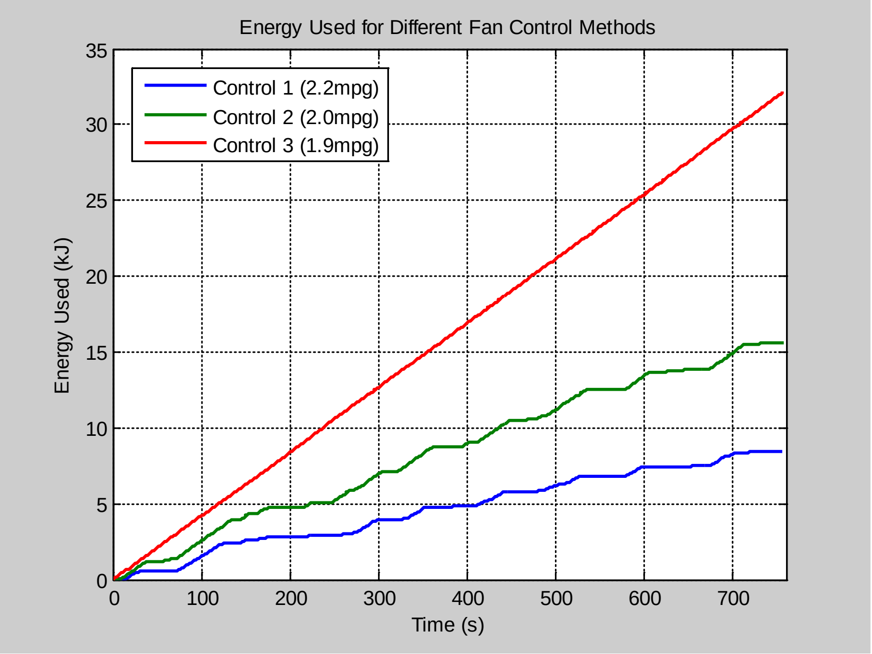


To date, APOP vehicle data does not exist, but as data becomes available it will be used to validate the model

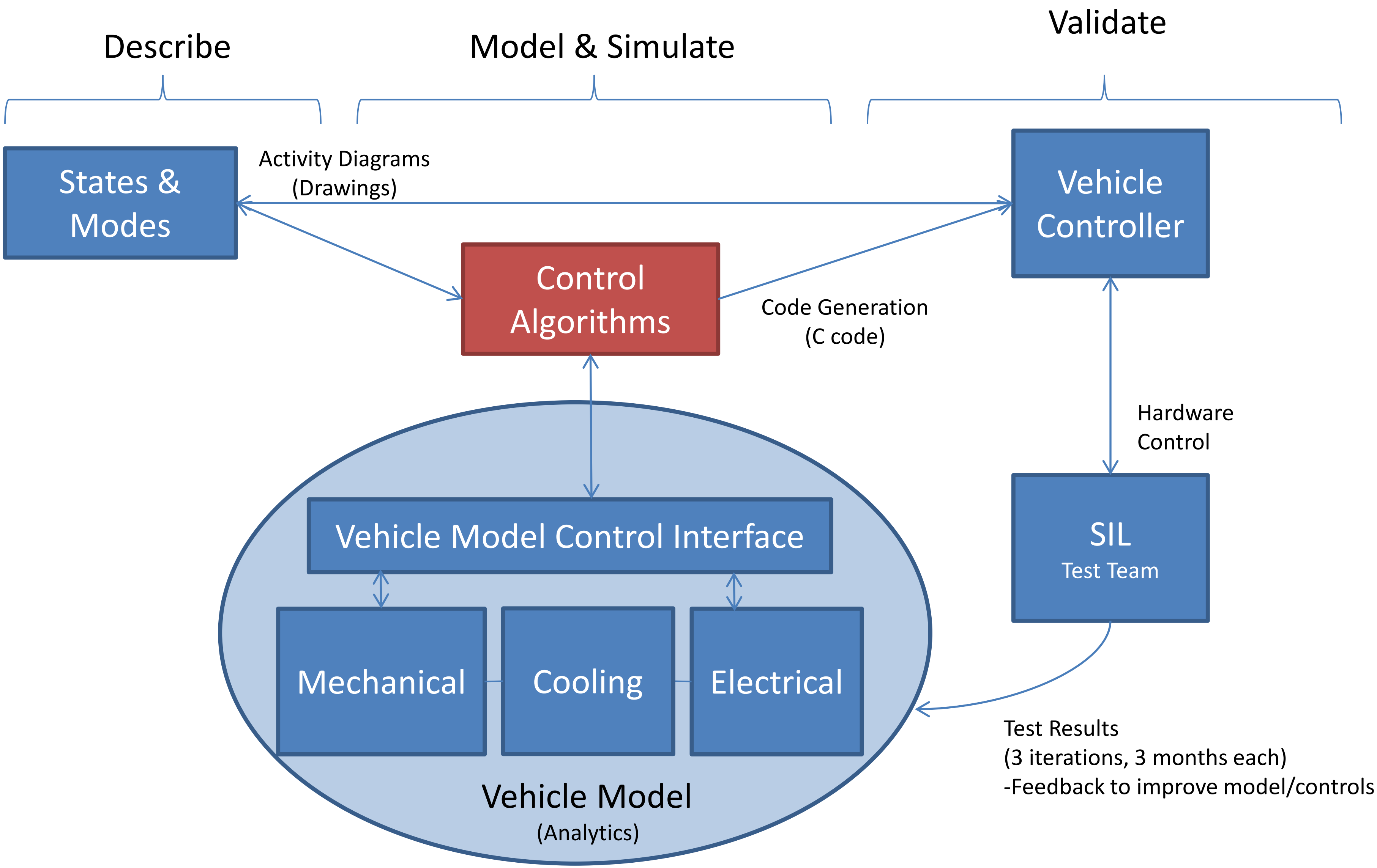
Example: Fan Control Comparison Results

- Results from the government test site:
  1. Control 1: 2.2 mpg (Lookup table)
  2. Control 2: 2.0 mpg (Temperature threshold)
  3. Control 3: 1.9 mpg (Always on)
- Conclusion: Control Method 1 produces the most energy efficient results.





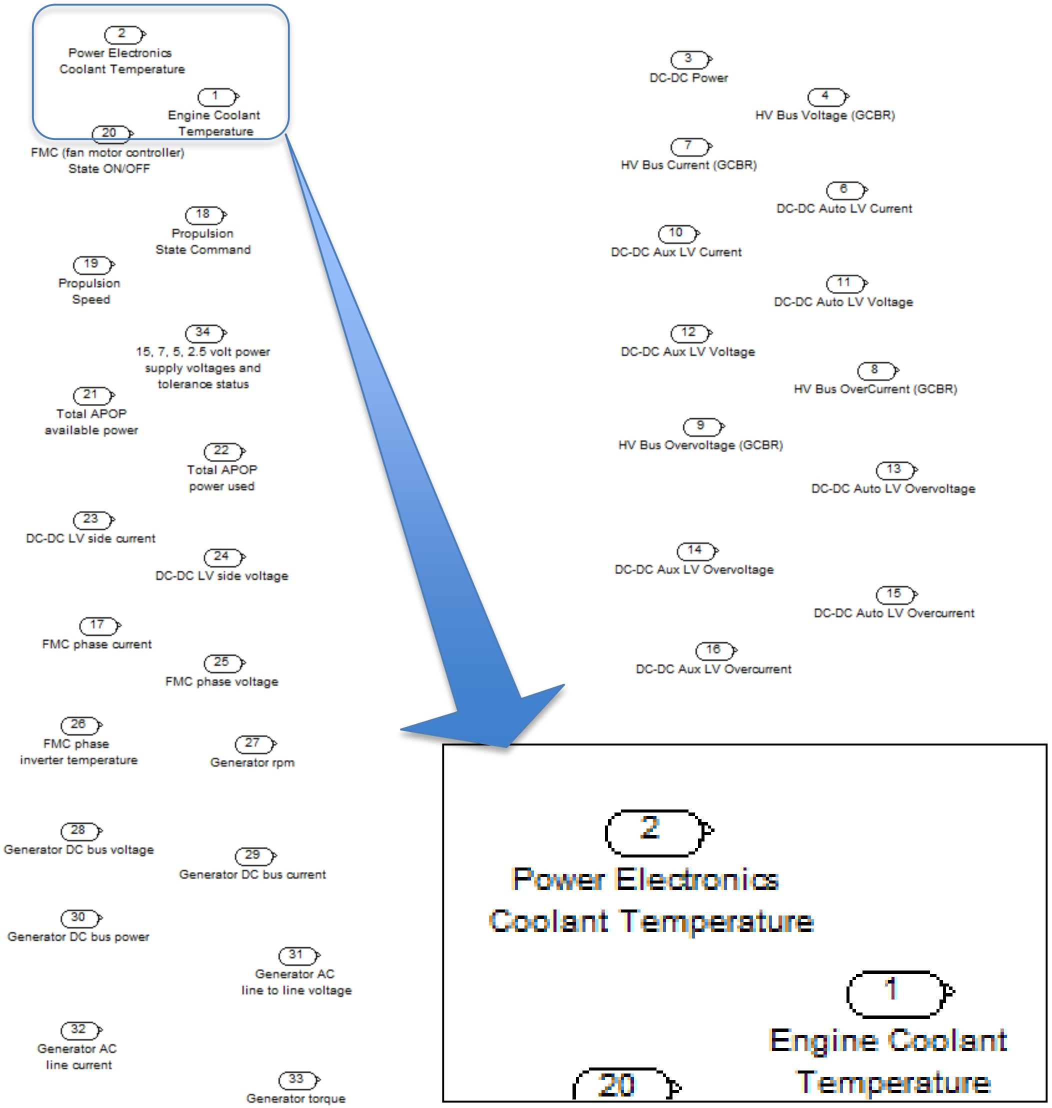
APOP Controls

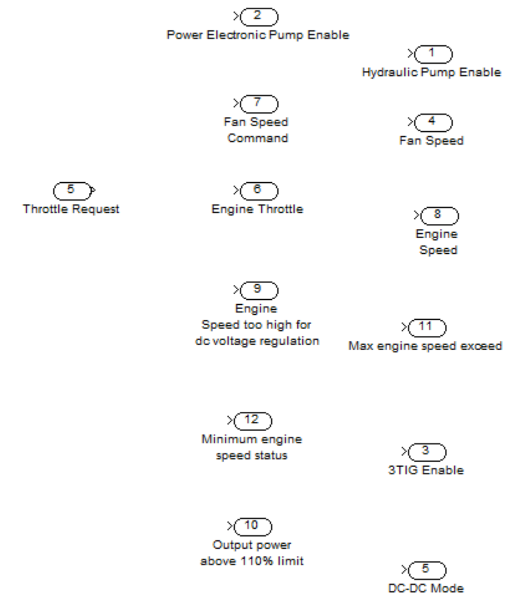


Why, what, how

- Need to control the overall APOP based vehicle (containing the ISG) in the most efficient manner to achieve desired performance
- Overall vehicle has mobility demand and also higher electrical load demand (in the APOP system) --- some higher electrical load demand being due to electrification of previously mechanical loads
- Controller involves real time control of various devices in the APOP based vehicle system in the most efficient manner
- Modeling and Simulation (M&S) allows developing the control algorithm in software and then exercise it completely in software to ensure its proper functionality and correct any errors or issues while in software phase
- M&S allows trying alternative control strategies for best efficiency and performance, before implementing in hardware, thus saving cost, avoid errors, and ensure successful operation
- Upon validation of the control algorithm in software, it can then be converted to C programming language code and then to executable code by compiling appropriately
- Controller code in C can be generated by software tools and then can be touched up if needed and then compiled prior to uploading the executable code to hardware based controller board (presently the Controller box), which can be used to drive one or more hardware component or subsystems to validate the control algorithm
- Once the hardware validation is complete, the algorithm can be burned in an embedded controller board for eventual production level APOP vehicle development

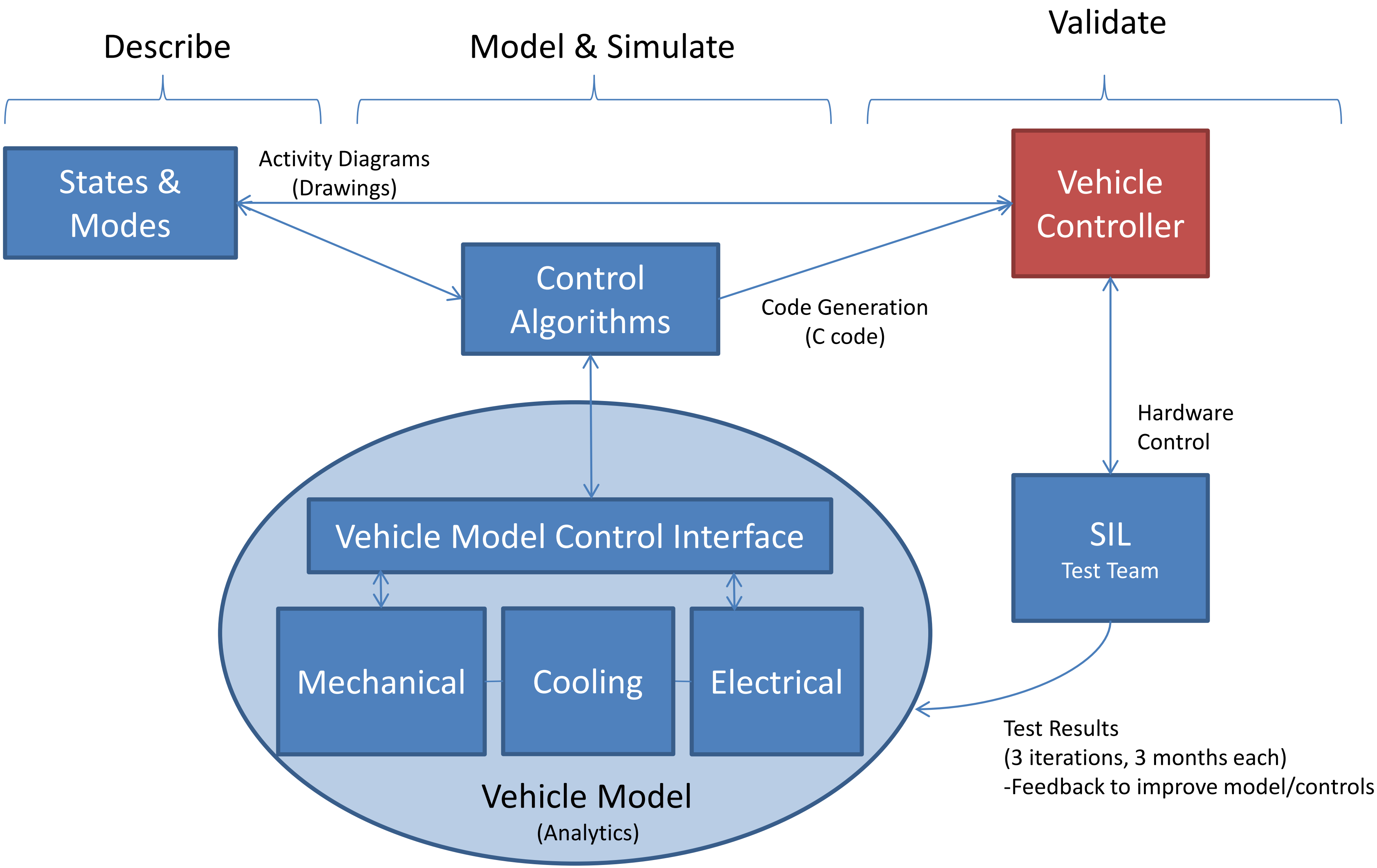
APOP Controller Signals for M&S





Various signal input/output needed for APOP controller M&S

APOP Controls



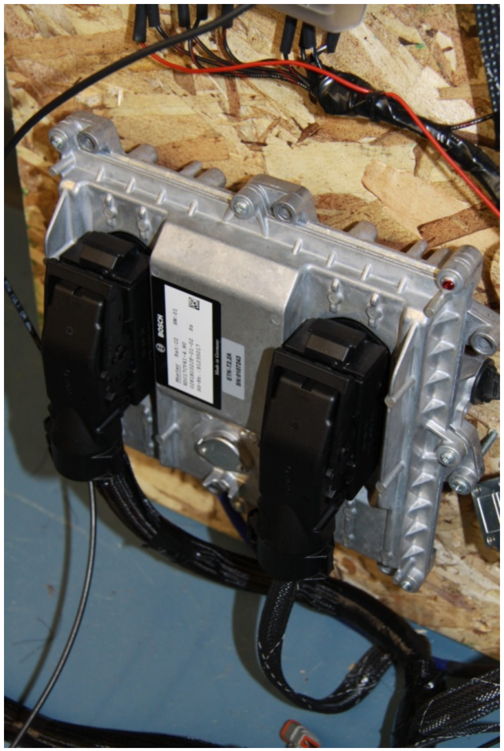
Vehicle Controller

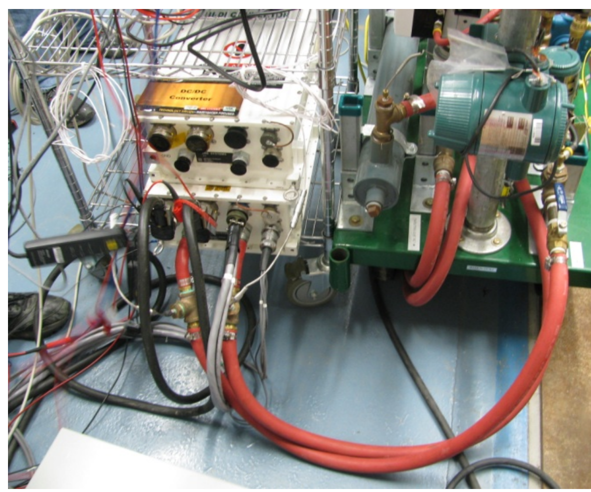
- Controls Development
  - Programming in C
  - Flashed to controller
  - User interface software on control computer
- Integration Strategy
  - Component level code and CAN control (Fan, DC/DC converters, etc.)
  - Adaptation of VEA state machine diagrams into system
  - SIL/Vehicle integration of controls including throttle control
  - Optimization of controls leveraging feedback from Analytics, experiences in integrated testing
- The controller allows physical control of the system at various stages of development and in the vehicle

Component Testing in GSPEL-ECL

Fan Testing

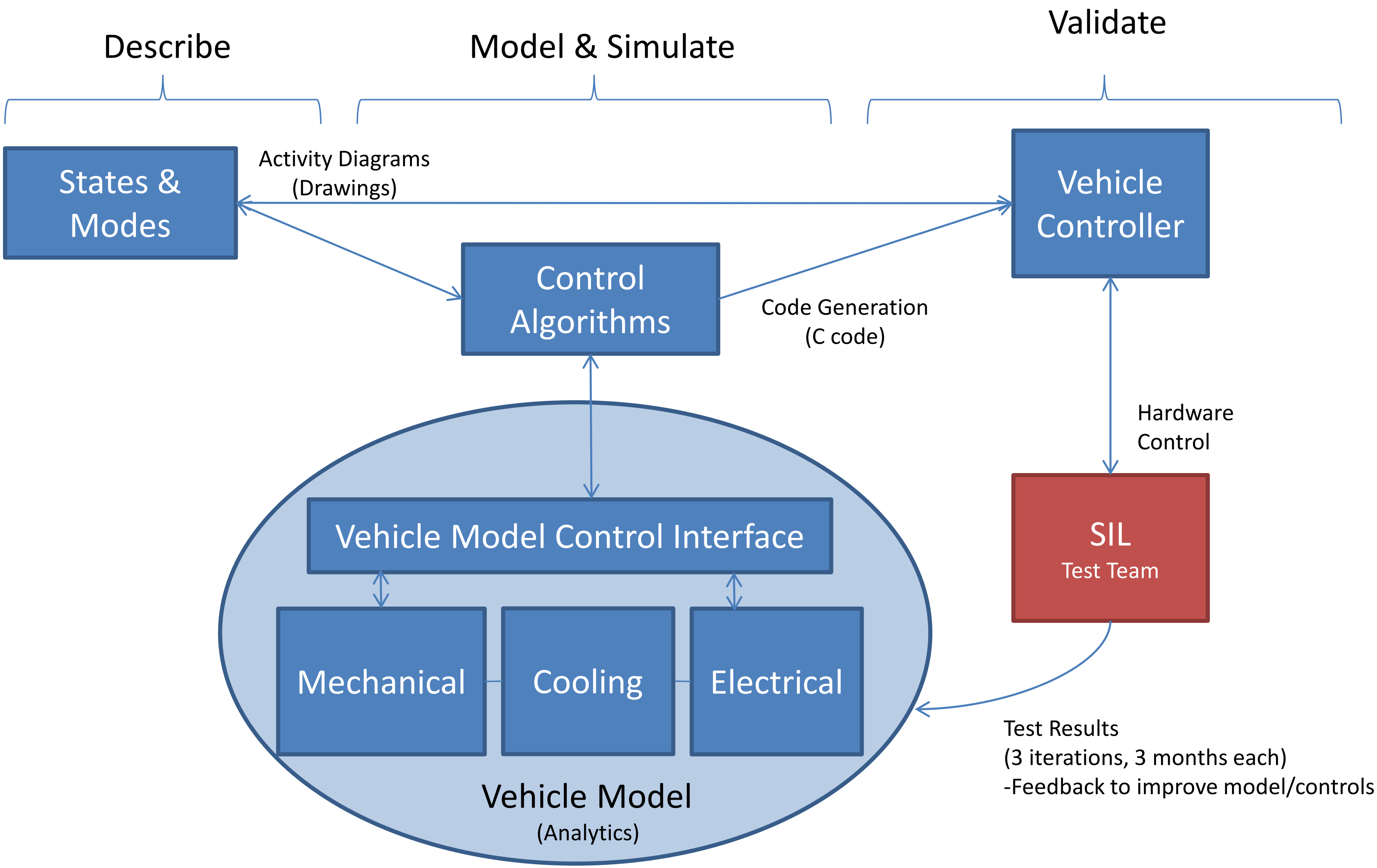
Controller box





DC/DC Testing

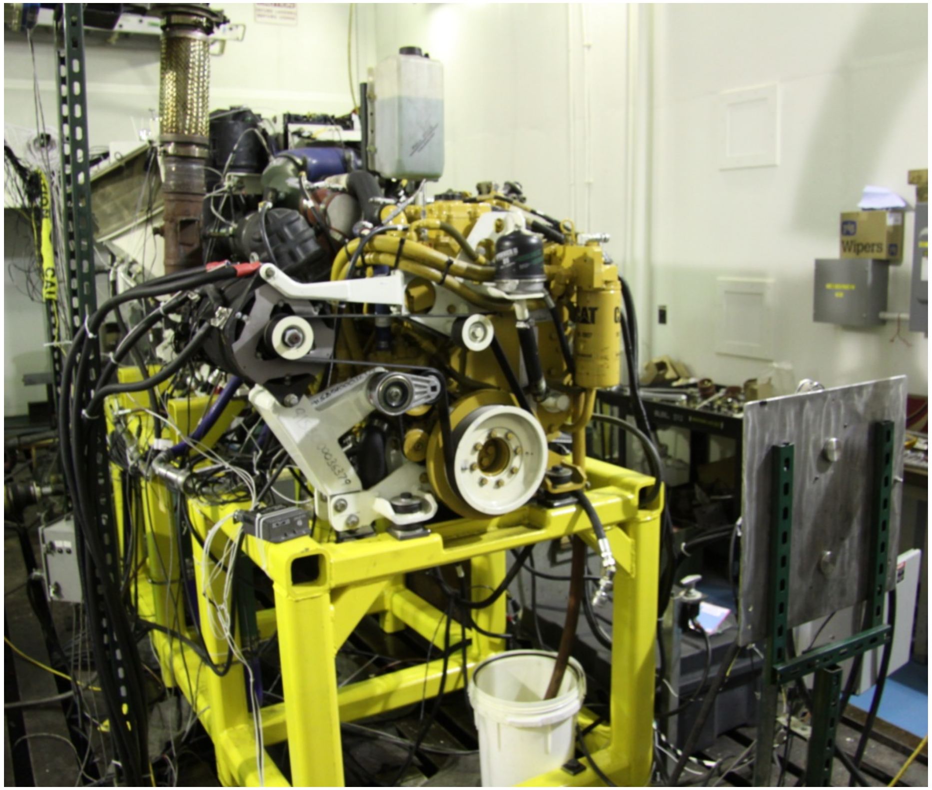
APOP Controls



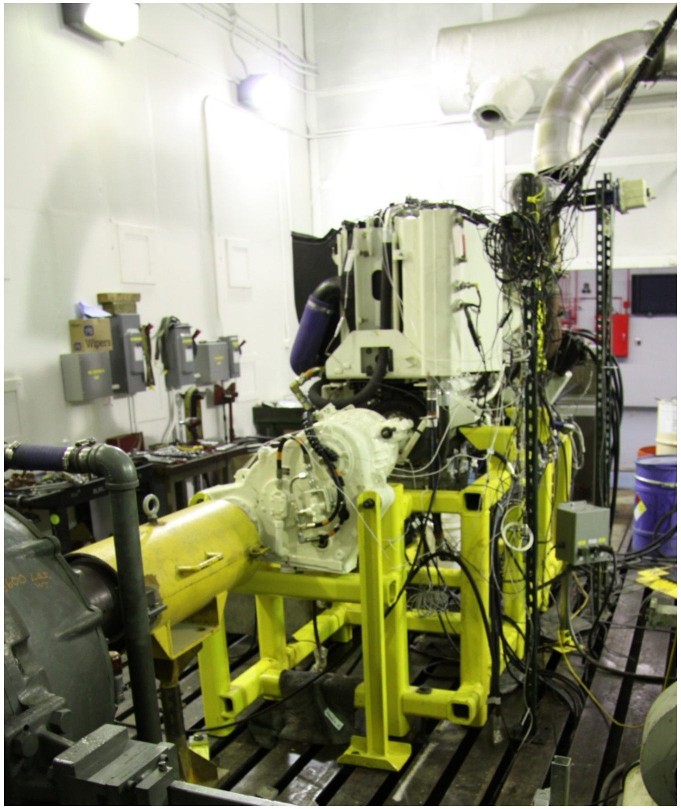
SIL Overview

- Baseline and APOP tests will be performed
- Allows checkout of system and controls prior to vehicle demonstration
- Results feed back into better models

APOP SIL Setup in Bldg. 212 Cell 2



- Fully instrumented Powerpack and Transfer Case
- Low voltage load bank



- Design of Experiments test points executed
- Elevated temperature testing
- Collected data given to Analytics for controls modeling

APOP Controls