Model-Based Development: Realizing Fully Integrated Algorithm & Software Development for Production Automotive Electronic Control Units

www.aam.com
AAM Introduction

• American Axle & Manufacturing (AAM) is a tier 1 global automotive supplier with design, engineering, testing, validation and manufacturing capabilities. Traded at NYSE as AXL.

• AAM core competencies are in driveline, drivetrain and chassis systems for light trucks and buses, sport utility vehicles, crossover vehicles, and passenger cars.

• Established in 1994 from purchase of 5 plants in USA from GM. Today, it has 23 plants/offices in 10 countries and growing.

• Electronic Systems were introduced in 2001. Software development started in 2002. Currently, AAM is working on 7 customer programs involving software algorithms.
Production Development with Hand-Coding - 2002

1. Determine objectives

2. Identify and resolve risks

3. Development and Test

4. Plan the next iteration

Source: wikipedia
Rapid Prototyping

1. Requirements
2. Code Repository
   - Hand-Code
   - Auto-Code Algorithms
3. Hand Integrate Code
4. Vehicle Test & Calibration

Code Line
Proposed AAM R&D
Model-Based Development Sequence

1. REQUIREMENTS
2. ALGORITHM MODELS (Simulink)
3. PLANT MODELS (Simulink)
4. ALGORITHM INTEGRATION MODEL (Simulink)
5. SCHEDULER (Simulink)
6. AUTOCODE INDIVIDUAL ALGORITHM MODELS (RTW Embedded Coder)
7. DEVICE-DRIVERS ABSTRACTION LAYER, etc. (Hand-Code)
8. SCHEDULER (Hand-Code)
9. INTEGRATE & TEST (Hand-Code & Hand-Test)

DEVELOPMENT SEQUENCE
Revised Model-Based Development Process

- REQUIREMENTS
  - ALGORITHM MODELS (Simulink)
  - PLANT MODELS (Simulink)
  - ALGORITHM INTEGRATION MODEL (Simulink/UniPhi)
  - SCHEDULER (Simulink/UniPhi)
- SYSTEM INTEGRATION (Simulink/QuantiPhi/UniPhi)
- DEVICE-DRIVERS ABSTRACTION LAYER, etc. (QuantiPhi)
- AUTOCODE INTEGRATED SYSTEM SOFTWARE (RTW Embedded Coder/QuantiPhi)

DEVELOPMENT SEQUENCE
System Architecture Model for Simulation Testing
BIOS Software Integration
Moving from a Code Centric to a Model Centric Process

- Requirements
- Code Repository
- Rapid Prototype
- Integrate for RP
- Model Repository
- Integrate Pre-Cal Test Models
- HIL/Vehicle Test & Calibration
- Algorithms Hand-Code
- Drivers, OS Auto-Code
- Algorithms Auto-Code
- Rapid Prototype
Productivity Improvement

<table>
<thead>
<tr>
<th>Effort [man-months]</th>
<th>HAND-CODING ONLY</th>
<th>MATHWORKS TOOLS (HAND-CODE BIOS &amp; HAND INTEGRATION)</th>
<th>MATHWORKS + SimuQuest TOOLS (ZERO HAND-CODE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost [$millions]</th>
<th>0.6</th>
<th>1.2</th>
<th>1.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results from Customer Production Programs</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Focus Changes

- FOCUS ON INTELLECTUAL PROPERTY
- HANDLE MORE COMPLEXITY
- MUCH FASTER TIME TO MARKET!
- ACCOMPLISH MORE WITH LESS
Key Aspects of the Model-Based Development Solution

- Simulation Testing of Controls, State Machine, Diagnostic handler
- Integration and Test of Controls within Simulink
- Configuration of Micro within Simulink
- Integration and Debugging of BIOS within Simulink
- Full CAN Configuration within Simulink
- All Integration and Testing Performed before Code Generation
- Validation Testing on Hardware
  - Not Integration and Debugging