

Automotive Development Processes and Complete Vehicle Integration: An Intensive Course for Automotive Engineering Graduate Students

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ABSTRACT

Clemson University has recently partnered with the State of South Carolina, BMW, Michelin, Timken, and other partner companies to create new MS and PhD programs in Automotive Engineering. These academic programs are housed in a new 90,000 square foot facility located at the newly created Clemson University International Center for Automotive Research (CU-ICAR) in Greenville, SC. This paper describes a unique course, *Automotive Development Processes*, developed as a part of the Automotive Engineering curriculum by the authors, Dr. Julian Weber, Manager in BMW Electric/Electronics and Driver Environment development in Munich, Germany, and Dr. John Ziegert, a member of the Automotive Engineering Faculty at Clemson University. Due to geographic and time constraints for Dr. Weber, the course is offered as a 2 week intensive course during the university's Maymester term.

INTRODUCTION/BACKGROUND

Automotive Engineering research has been an historical area of strength within the Mechanical and Electrical Engineering Departments at Clemson University. The importance of this research was strengthened in the mid-1990's when BMW opened their first US manufacturing facility in Spartanburg, SC, about 40 miles from the Clemson campus and a few miles from

the US headquarters of Michelin. Over the next decade, Clemson faculty collaborated extensively with BMW, Michelin, and many of the hundreds of Tier 1 and 2 automotive suppliers located in the region. During these interactions, it became clear that these companies shared an interest in recruiting new engineering employees who were specifically trained in Automotive Engineering. To address this need, Clemson University partnered with the State of South Carolina, BMW, Michelin, Timken, and other partner companies to create new MS and PhD programs in Automotive Engineering. These academic programs are housed at the newly created Clemson University International Center for Automotive Research (CU-ICAR) in Greenville, SC. CU-ICAR is a 250 acre research campus open to companies performing research and development in all technological areas relevant to the automotive industry. The Automotive Engineering graduate programs are housed at CU-ICAR in a new 90,000 sq. ft building, the Carroll A. Campbell Graduate Engineering Center (CGEC), with offices for 10 newly hired faculty, including 4 Endowed Chairs in the areas of Automotive Systems Integration, Automotive Design and Development, Automotive Manufacturing, and Automotive Electronics. At steady-state, the program is expected to enroll approximately 75 MS and 35 PhD students. CGEC contains state-of-the-art facilities for automotive research, including:

- 580 HP hot-fired engine dynamometer
- 500 HP, 2WD/4WD chassis dynamometer in a anechoic chamber
- 7-post shaker/road simulator in environmental chamber (-40°C to +85°C)
- Dual-arm full vehicle coordinate measuring machine
- Precision dimensional metrology laboratory
- RF shielded chamber
- Manufacturing research laboratory

MS/PHD PROGRAMS IN AUTOMOTIVE ENGINEERING

The curriculum for the newly developed Automotive Engineering MS and PhD programs was developed in close collaboration between the Clemson faculty and the partner companies, and focuses on the theme of Automotive Systems Integration. The non-thesis MS program is designed to provide students with in-depth professional training that will give them unique technical and managerial skills, enabling them to quickly assume senior technical management roles in automobile manufacturers and suppliers. MS students must have at least 2 years of Post-BS professional experience prior to acceptance, and are required to complete 36 credit hours over a 2 year period. They must demonstrate proficiency in a foreign language, and complete a 6 month professional internship in a country other than their native country. The MS program has two stems. The curriculum of the Function Stem is designed primarily to meet the needs of Tier 1 and 2 suppliers, while the Systems Stem is designed to meet the needs of automotive OEMs for individuals having knowledge and skills to manage and integrate people, technologies, and suppliers at different stages of the vehicle development and production process chain.

Automotive Engineering PhD students must also have 2 years of post-BS professional experience prior to acceptance into the program, although a MS in a relevant discipline can be substituted. PhD students must complete 18 courses (54 credit hours) in addition to their dissertation. They must also demonstrate proficiency in a foreign language and complete a 6 month international internship. The objective of the PhD program is to produce highly trained individuals working at the cutting edge of disciplines critical to the automotive industry.

All Automotive Engineering graduate students are required to complete 4 core courses in the areas of Automotive Design/Manufacture & Project Management, Overview of Automotive Systems, Automotive Systems

Integration Concepts and Methods, and Applied Automotive Systems Integration. Students specialize by selecting courses from one of 6 Tracks:

- Vehicle Materials, Structures, and Mechanics
- Vehicle Electronics, Mechatronics, and Computer Systems
- Vehicle Design and Integration Methods and Tools
- Vehicle Manufacturing and Production
- Vehicle Performance (Vehicle Physics)
- Vehicle Power Systems and Transmissions

One of the courses that supports the Vehicle Design Track is AuE 832 – Vehicle Development and Integration Methods, Processes, and Tools. While some authors have described the automotive design process, e.g Braess & Seifert [2005] and Happian-Smith [2002], we are unaware of any text or academic course that addresses the complete scope of the development process from the point of view of the automotive OEM. This paper describes this course in detail, and summarizes lessons learned during the first 2 offerings. The course was co-taught by the authors; Dr. Julian Weber, Manager in BMWs E/E and Driver's Environment development in Munich, Germany, and Dr. John Ziegert, a member of the Automotive Engineering Faculty at Clemson University. Due to geographic and time constraints for Dr. Weber, the course was offered as a 2 week intensive course during May, 2007 and May, 2008. The balance of this paper describes the objectives and content of the course.

COURSE OBJECTIVES AND STRUCTURE

The objective of this course is to provide students with a system level understanding of OEM vehicle development processes including:

- Organization of vehicle development projects
- Cost structures
- Product specification and target setting
- Concept development and vehicle architecture
- Vehicle Platforms
- Component development
- Development tools
- Quality methods and tools applied to design
- Prototype development
- Systems integration methods

- Vehicle testing
- Lifecycle product management

While students learn about the broad variety of processes that are necessary on different levels to develop a vehicle, the course focuses in-depth on the processes of functional integration that contribute to the realization of important customer-relevant vehicle characteristics, e.g. design appearance, agility, cabin comfort, passive safety, theft deterrence, or reliability.

The course is structured as a series of lectures, guest speakers from automotive industry, plant tours, and project activities. It meets for approximately 6 hours/day for 2 weeks during the period in May between Spring and Summer terms. The topical schedule is:

Automobiles and the Automotive Industry

- Course introduction
- Automotive industry today
 - BMW Group – a portrait
 - Auto industry in the USA
 - Auto customers: US vs. Europe
 - Social aspects of autos
 - Sustainability

Vehicle Development Projects

- Categories of vehicle projects
- The Product Evolution Process (PEP)
- Vehicle project management
- International development projects
- Product Strategy
 - Winners and losers
 - Worldwide market presence
 - Product portfolio
 - Product positioning
 - Product properties

Phases of Vehicle Development

- OEM Design CoCs (power train, chassis, body and exterior, interior)
- CAD and CAE systems
- Release processes
- Component Design
 - Component specification
 - Design CoCs
 - Methods, tool, and processes
 - Materials
- Virtual Car Process
 - Building virtual cars

- System requirements
- Geometrical integration
- Functional clearance
- Further functional evaluation

Complete Vehicle Development

- Customer requirements
- Target management
- Problem management
- Engineering change management
- Building and testing prototypes
- Complete vehicle quality
- Sign-off process
- Complete vehicle testing

Functional Design and Integration

- Vehicle dynamics
- Operational strength
- Performance, fuel efficiency, and emissions
- Vehicle acoustics
- Registration approval
- Passive safety
- Thermal comfort
- Value Perceived Interior

Electronic System Design and Integration

- Electronic system design and integration
- Electro-magnetic compatibility

Supplier Integration

- Automotive suppliers
- Cooperation models
- Responsibility levels
- International purchasing; wages, currency, natural hedging
- Supplier management
- ISO/TS 16949
- Guest Speaker: A Suppliers View: benefits and challenges of developing and producing for an OEM from a suppliers point of view

Production Integration

- Production systems
- Core automotive production processes
- Product launch
- Manufacturability assessment of virtual and real cars
- Measuring production-related maturity
- Functional dimensions, cubing