1. Opening Remarks
Craig Stephens, Manager, Powertrain Control Research and Advanced Engineering Department, Ford R&A, Ford Motor Company, USA.

2. Optimization-based Control Strategy for Advanced Powertrains
Huei Peng, the University of Michigan, USA.

Abstract: In recent years, many new concepts and technologies were introduced to improve the efficiency of ground vehicle propulsions. When these techniques were integrated together, they were usually designed individually and the integrated system may not work as efficiently as it potentially could be. A joint research between the University of Michigan and the General Motors Powertrain over the last three years focused on the design of advanced powertrain control system, with the aim to find coordinated powertrain control strategy in a coordinated and systematic fashion. By using a dynamic programming design approach, the control of automatic transmission, electronic throttle, and active fuel management system can be obtained systematically. This design concept was verified through extension simulations and experimental studies. More importantly, the design approach was found to give great potential for significantly reduced development cycle time, while achieving overall vehicle performance and fuel economy comparable to those achieved through current calibration process.

3. Optimization of Advanced Automotive Engines
Mrdjan Jankovic, Ford Research and Advanced Engineering, Ford Motor Company, USA.

Abstract: To improve vehicle emissions, fuel economy, and performance, designers are adding multiple auxiliary devices to automotive engines. Each of these devices increases complexity, which makes the control system’s task of realizing expected benefit more difficult.

The aim of this talk is to present engine control system in a broader context and analyze to what extent is its structure imposed by the very control objectives for the added devices. One of the points worth emphasizing is that optimization, as a design objective for an actuator, requires a very different approach than the one traditionally used for set point regulation. Thus, the current control structure is dominated by the feedforward component in which the controller relies on look-up tables to determine desired settings for each engine optimization variable. These tables are populated through an elaborate process that includes mapping, optimization, and calibration. We shall describe methods to reduce the optimization effort and real time complexity, while preserving scheduling accuracy. The problem and the proposed solutions are illustrated by simulations and experiments.

4. Future Calibration Processes and Methodologies at Toyota
Satoru Watanabe, Akira Ohata, Masato Ehara: all with Toyota Motor Corporation, Higashifuji Technical Center, Susono, Shizuoka, JAPAN; and Ken Butts: Toyota Technical Center, Ann Arbor, Michigan, USA.

Abstract: Today’s automobile engines have reached the complexity level where their calibration can be on the critical-path for vehicle development. Given this situation, automobile manufacturer's product plans are constrained by their ability to deliver engine calibrations. In this paper, we present a vision for a modular, automated, and model-based engine calibration process that will help Toyota manage this constraint in the future. The process is tailored according to its application stage in the engine development process: rapid calibration is critical in earlier stages when targets, objectives, and even engine hardware are fluid while accuracy and optimality are more critical during the latter stages of development. A rapid calibration environment can be established by strictly defining an efficient process, reducing the number of
experiments, and employing rapid measurement and automation. "Model Based Calibration (MBC)" is essential to reduce the number of required experiments. Moreover, the integration of physical and statistical models results in fewer parameters for model identification.

5. Automotive Transmission Control and Driveline Dynamics
Zongxuan Sun and Kumar Hebbale, Research and Development Center, General Motors Corporation, USA.

Abstract: Driveline dynamics and control not only determine the driveability of a vehicle, but also affect its fuel economy. Automotive transmission is a key element in the driveline that connects the power source to the wheels of a vehicle. The basic function of any type of automotive transmission is to transfer the torque smoothly and efficiently. The most common torque transfer device used in transmissions is either a torque converter or a clutch or both. While a torque converter is effective in providing superior driveability, it negatively impacts the fuel economy. On the other hand, a starting clutch can improve the fuel economy, but can adversely affect the driveability of a vehicle. This talk first reviews some of the new technological developments in the engine and transmission areas that affect the driveline torsional dynamics. We then examine the unique control challenges associated with driveline dynamics and control. While addressing these challenges, potential research opportunities in the automotive transmission area are outlined. We will look at both control algorithm development and mechatronic actuation devices to meet those challenges.

6. Vehicle Dynamics Integrated Control for 4-wheel-distributed Steering and 4-wheel-Distributed Traction/Braking Systems
Eiichi Ono, Vehicle Dynamics Control Lab., Toyota Central R&D Labs., JAPAN.

Abstract: Vehicle dynamics integrated control algorithm using an on-line non-linear optimization method is proposed for 4-wheel-distributed steering and 4-wheel-distributed traction/braking systems. The proposed algorithm minimizes work load of each tire, which is controlled to become the same value. The proposed integrated control improves limited performance of the vehicle dynamics operated by driver. The future problem is how to design and realize the vehicle trajectory control for the system based on automatic operation in order to improve limited performance and active safety.

7. Recent Advancement and Challenges in Differentials-Based Vehicle Stability Control
Jae Lew and Damrongrit Piyabongkarn, Eaton Innovation Center, USA.

Abstract: Recent studies have shown that the active vehicle stability control (VSC) can actually reduce the rate of vehicle accidents. More and more passenger vehicles are becoming equipped with the VSC as a standard feature. Typically, the VSC is based on the anti-lock brake technology; it simply modulates individual brake forces to distribute wheel torque properly while maintaining the direction of the vehicle. However, the unintended braking slows down the vehicle and could be intrusive to the driver. An alternative to the braked based VSC that offers better handling is the differentials-based torque distribution, also known as "torque vectoring." In this presentation, we will discuss the advantages of differentials-based VSC, one that specifically utilizes electronically controlled limited slip differentials (ELSD), and we will focus on control challenges to realize the vehicle stability with the ELSD.

8. Title: Vehicle Dynamics State Estimation for Electronic Stability Control
H. E. Tseng, Ford Research and Advanced Engineering, Ford Motor Company, USA.

**Abstract:** Electronic Stability Control (ESC) systems which enhance vehicle lateral dynamics stability have gained substantial popularity and recognition in recent years. According to a recent NHTSA study [Dang, 2004], ESC reduces single vehicle crashes in passenger cars by 35 percent and in Sport Utility Vehicles (SUV) by 67 percent.

Vehicle lateral velocity, or the corresponding vehicle/tire side slip angle, can indicate the lateral dynamic state of a vehicle and is important for an ESC system. The estimation of this vehicle state has therefore been widely discussed in the literature.

In the literature, the majority of model based observers for lateral velocity either involve a model combining a vehicle model with nonlinear tire functions or a vehicle model with effective/linear cornering stiffness. The effective cornering stiffness is defined as the linear gain between tire slip angle and tire force. While the approach with nonlinear tire models could provide a better correlation with the actual tire forces under a nominal road surface/condition, the specific and usually more complex tire function may not be valid under other road surface/conditions. Therefore a switching logic is usually required with this approach during its implementation. For example, switching logic was used in the work of Tseng et.al. [1999], Fukada [1998], van Zanten et. al. [2000], Hac and Simpson [2000], and Nishio et. al.[2001]. The other approach, which usually includes a linear bicycle model, assumes the tire force can be represented as the product of the tire slip angle and an effective cornering stiffness. The resulted effective cornering stiffness, therefore, needs to be adapted to reflect any tire non-linearity. This approach with effective cornering stiffness and linear bicycle model can utilize modern control theory for its stability and convergence proof. For example, stability proof has been shown in the work of Liu and Peng [1998], Tseng [2002], Kaminaga and Naito [1998]. The performance of this approach, however, is highly dependent on the rate of convergence in their parameter adaptations because the true parameter, as defined, can change rapidly in a dynamic maneuver, even on a road surface with constant and uniform friction.

In this talk, we will discuss several lateral velocity estimation methodologies mentioned above. We will focus on a lateral velocity sliding mode observer that has high potential for field implementation.

References:
9. Control Challenges in the Vehicle Infrastructure Integration (VII) Initiative

Hemant M. Sardar, TRW Automotive, USA.

Abstract: Vehicle Infrastructure Integration (VII) is an initiative co-funded by M-DOT, to address future challenges to how vehicles communicate and respond to real-time information from other vehicles and/or from road transmitters or other highway infrastructure. The expectation is that VII will deliver enhanced levels of safety and infrastructure maintenance capability, in addition to pushing the boundary on automotive technologies. Similar activities are underway under the European Union’s e-Safety initiative.

At a very high level, VII involves real-time or near real-time sensing of information and definition of responses to/from multiple agents. These include vehicle-to-infrastructure, and vehicle-to-vehicle communications. Some of the issues that need to be addressed are:

- What information should be sensed from vehicles and stationary infrastructure? This includes infrastructure information such as road conditions, hazards, traffic patterns; vehicle information such as speed, appropriate stability parameters, speed; and perhaps driver information such as alertness in conjunction with vehicle information.

- How should the sensed information be processed and transmitted? This covers aspects of the problem such as prioritization of information, data clean-up to minimize effects of noisy environment, and deciding what information should/needs to be transmitted and to whom.

- How should the responses be defined? This aspect of the problem really covers the definition of the control action in response to all the inputs and desired outcomes. This includes how/what should be the vehicle responses, how/what should be responses from the infrastructure, and time constraints for the system responses.

This abbreviated list of requirements translates into some rather substantial technical challenges in sensor fusion, control systems development, and large-scale systems integration that need to be addressed in order for VII to become a reality. The technical challenges can be further categorized into technical areas such as sensor & data fusion, system & process identification and modeling, controller development and simulation. This discussion will focus explore some of the controls issues involved in the VII initiative.

For example, one of the control problems in this scenario is that of discrete event simulation and control. Consider a situation in which a vehicle moving in traffic starts sending out an error code. In the controls context, this can be viewed as the disturbance input signal for the traffic system. The controls problem can then be stated as:

Develop an automated system that can respond to this disturbance signal, such that

i) The final “system” reaches a steady state with minimal impact from the disturbance signal (maximize disturbance rejection), and

ii) There is appropriate corrective action triggered to fix the cause of the disturbance.

The solution needs to account for the range of potential noises that exist in such a system and to ensure that the appropriate level of sensor signal processing is done so that the inputs to the
controller are a reasonably good indicator of the actual situation. It is useful to note that in this scenario, multiple responses are possible that could all be correct & valid. There is therefore a decision tree that a controller would have to navigate in order to arrive at the appropriate balance of actions that result in the situation described in (i) above. This discussion will explore the range of issues involved in synthesizing solutions for this and allied challenges in the VII initiative.

10. User-Friendly Warning System Using the Driver Behavioral Information

Akira Hattori, Higashifuji Technical Center, Toyota Motor Corporation, USA.

Abstract: The technology for detecting driver behavior is essential for extrapolating and judging driver mistakes, which are the main cause of accidents, and will, at the same time, form technology that leads to reductions in the number of accidents. As the first step towards the realization of the application systems using these technology, we discusses the development of a warning system that utilizes driver movement to control the timing of warning emission when it detects that the driver is not facing the vicinity of straight ahead, based on information from a facial imaging camera gained through the use of facial image processing.