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## **System Architecture Optimization of Advanced Propulsion Systems**

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We present key results from several recent studies that we have completed on the architectural optimization of advanced propulsion systems. The challenge of improving the efficiency and fuel economy of a propulsion system by augmenting it with a single electric machine and a battery has been investigated by numerous researchers. We begin with a recap of our main findings on this topic, wherein we estimate the regenerative brake energy potential of vehicles of various masses as they are driven on the certification cycles. This enables an optimal selection of the power and voltage levels for the motor and battery, depending on the vehicle application. After completing this phase of the study, we sweep the electric motor through all possible candidate attachment points on the propulsion system and compute the resulting fuel economy. This helps to focus the next phase of our work, wherein we investigate all possible loss mechanisms to help identify further opportunities for efficiency improvement. This approach suggests the judicious use of an engine disconnect clutch to split the propulsion system. Such an arrangement allows “sailing” or “coasting” operation which further improves fuel economy. The use of this clutch, in turn, creates drive quality challenges that we must tackle in order to provide a responsive vehicle that satisfies customers. To this end we investigate the dynamics of the tip-in response problem and explore several novel mechatronic schemes to address it. We conclude the presentation with experimental results from our hardware set up that confirms the various simulation results.

### **Experience:**

Dr. Madhusudan Raghavan received his Bachelor of Technology degree in Mechanical Engineering from the Indian Institute of Technology, Bombay, in 1985. He then received his M.S. (1987) and Ph.D. (1989) degrees in Mechanical Engineering from Stanford University. He also received an MBA from the University of Michigan, Ann Arbor, in 2001. Since 1989 he has been employed at the General Motors Research & Development Center in Warren, Michigan, where he is currently a GM Technical Fellow as well as Lab Group Manager of the System Architecture Group. He leads research projects on electrified propulsion systems, mechatronic systems and alternative energy systems. He holds 278 patents and has co-authored 7 book chapters and 57 papers. He is a past Chair of the IFToMM Technical Committee on Transportation Machinery. He is a Fellow of ASME as well as SAE.