

Advanced Electric Vehicles Graduate Certificate Program

A Proposal of the College of Engineering and Science



November 25, 2009

Proposal for the UDM Graduate Certificate Program in Advanced Electric Vehicles

A. Summary

The College of Engineering and Science proposes a graduate certificate engineering program in Advanced Electric Vehicles (AEV) Engineering. The purpose of this program is to rapidly infuse important advanced electric vehicle (AEV) knowledge and capabilities into the technological team of the automotive and defense ground vehicle industries of the region. The delivery of courses that are part of this program will start in January 2010 as an undesignated program of studies with the first students being engineers from Ford Motor Company and its suppliers. It will be aimed at specific learning outcomes defined in direct collaboration with leaders in AEV development at Ford. Ford has committed to send 125 students to this program over the next five years. There is also significant potential to draw students from outside of Ford. Students successful in this program will learn to apply their engineering talents to the development of the next generation of advanced electric vehicles.

Engineers in this certificate program will select five of the seven newly created graduate courses that are designed by "competency teams" whose explicit purpose is to create curriculum that is directly responsive to Ford's needs, but also deploys the most current technology, strategies, methods and tools emerging from universities, corporations and national laboratories. These five courses will be completed in one calendar year. Most courses will be offered at the Ford Training and Development Center in Dearborn; a few courses and laboratory experiences will be provided at the McNichols campus.

Graduate Course (required core courses in bold)	Instructor
Introduction to Advanced Electric Vehicles (AEVs)	Dr. Abul Masrur –TARDEC Technical Leader and UDM Adjunct Prof. (experienced in similar courses at UDM and SAE)
Power Electronics for Electric Vehicles	Dr. Mohan Krishnan – UDM ECE Dept.
Controls for Electric Vehicles	Dr. Richard Hill – UDM ME Dept
E-drives	Dr. Shuvra Das – UDM ME Dept.
Energy Storage Systems/ Battery technologies	Dr. Mark Benvenuto – Chairperson, UDM Chemistry Dept.
Innovation and Systems Architecture in AEVs	Dr. Darrell Kleinke - UDM ME Dept.
Systems Engineering for AEVs	Dr. Jonathan Weaver – UDM ME Dept.

Ford Motor Company has also committed \$88,000 for faculty development in the focal areas of these courses, principally through support for off-term assignments in the AEV engineering and

research groups at Ford and for support for workshops and courses offered by universities with highly regarded programs in these areas.

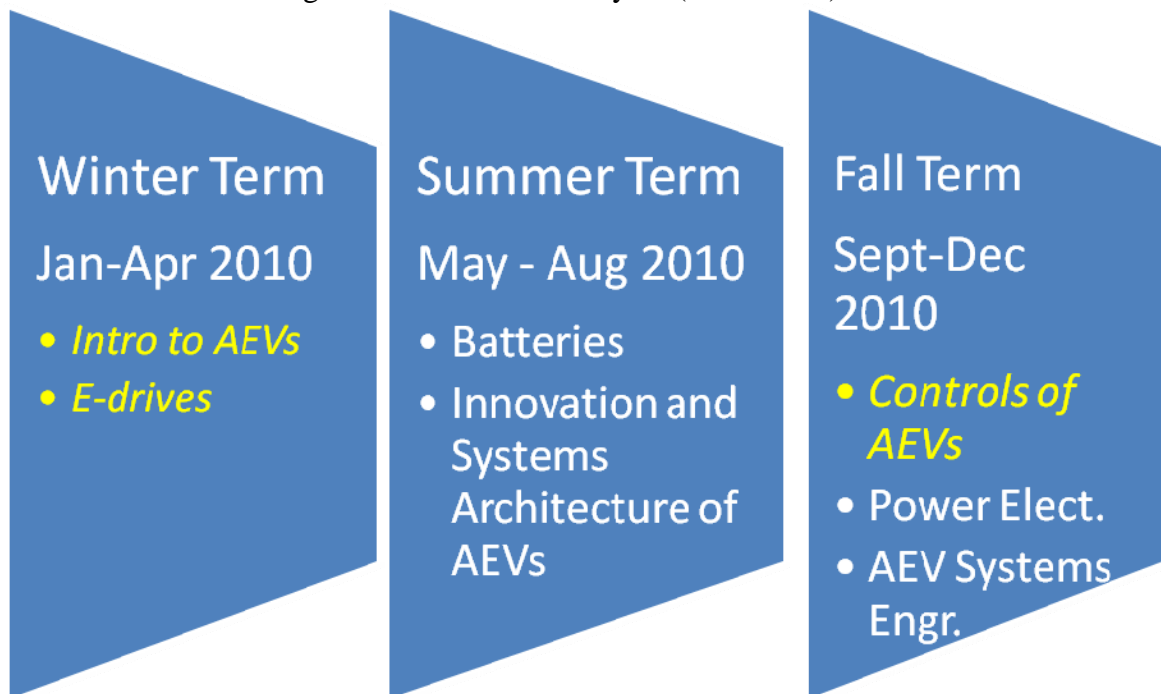
B. Description of the Certificate

1. Narrative description of the certificate as it would appear in the catalog.

The UDM Advanced Electric Vehicle Engineering (AEV) Program is a program to provide automotive engineers with the technical and systems knowledge needed to be effective contributors to the development of world-class advanced electric vehicles. The program requires students to complete five of the seven AEV courses, including three required courses, Introduction to AEVs, Electric Drives/Electromechanical Energy Conversion, and Control of AEVs. Their remaining two courses can be selected from courses that either focus on underlying AEV technologies (Energy Storage Systems [principally batteries] or Power Electronics for Electric Vehicles) or the unique systems issues of AEVs (Innovation and Systems Architecture for AEVs or Systems Engineering for AEVs). Student may transfer a maximum of one three-credit hour course into the AEV Certificate. Students must achieve a 3.0 overall GPA in the certificate courses to earn the AEV Certificate.

2. Provide a matrix that shows a typical course sequence, taken by a student.

Students will take five three-credit graduate courses to complete the AEV Certificate Program over one calendar year (three terms).



Yellow italics: required courses (students take a total of three)

White: elective courses (students take a total of two: one in each the summer and fall terms)

Typical Course Sequence – AEV Technology Focus

Winter Term	Summer Term	Fall Term
Introduction to Advanced Electric Vehicles (AEVs)	Batteries	Controls for Electric Vehicles
E-drives		Power Electronics for Electric Vehicles

Typical Course Sequence – AEV Systems Focus

Winter Term	Summer Term	Fall Term
Introduction to Advanced Electric Vehicles (AEVs)	Innovation and Systems Architecture in AEVs	Controls for Electric Vehicles
E-drives		Systems Engineering for AEVs

A student is free to mix and match across the two focal areas.

3. List all courses in the curriculum: catalog number, title, description, academic unit, and units of credit, as they would appear in the catalog. Indicate which courses are new (+) and which are already being offered and in which program (*). Proposals with fewer than 15 credit hours require a separate rationale. See Appendix I for course syllabi.

All seven of the courses below are new, although the two systems related courses are significant updates to existing courses.

- **AEV5010: Introduction to Advanced Electric Vehicles:** fundamentals of AEVs and key challenges and opportunities of AEV technologies. The course will explain the engineering philosophy of various AEVs (HEV, PHEV and BEV) and, the component selection and design, modeling, and control of AEVs. Some existing AEV models will be used as case studies. Initial Instructor Dr. Abul Masrur, US Army TARDEC and UDM Adjunct in the Department of Electrical and Computer Engineering; 3 credit hours
- **AEV5020: Controls Modeling and Design for AEV:** System and sub-systems, Modeling and design of AEVs as a system, principles of controls engineering for AEV. Significant use of software tools. Instructor: Dr. Richard Hill, Assistant Professor, Department of Mechanical and Manufacturing Engineering; 3 credit hours
- **AEV5030: Energy Storage Systems:** Energy storage systems used in electric vehicles, batteries. Battery electro-chemistry, battery design and construction, charging and discharging, power density, interaction of the batteries with other sub-systems.

Instructor: Dr. Mark Benvenuto, Professor, Department of Chemistry and BioChemistry (with support from electrical and mechanical engineering faculty) ; 3 credit hours

- **AEV 5040: Power Electronics for Electric Vehicles:** Applications of power electronic circuits, devices for power switching used in automotive applications – diodes, MOSFETs, IGBTs; conversion circuits - AC-DC (rectifiers), DC-DC (buck, boost, buck-boost), DC-AC (inverters); feedback controller circuit design; design of magnetics involved in switch-mode converter components. Instructor: Dr. Mohan Krishnan, Professor, Department of Electrical and Computer Engineering; 3 credit hours
- **AEV 5050: Electric Drives/Electromechanical Energy Conversion:** Variety of linear and rotary actuators, their characteristics, operating range and interactivity within power train system. Instructor: Dr. Shuvra Das, Professor, Department of Mechanical and Manufacturing Engineering; 3 credit hours
- **AEV 5060: Innovation and Systems Architecture for AEVs:** A variety of innovation techniques will be demonstrated and a methodical, proven approach to architecture development will be studied. Theory and a variety of case studies – some related to Advanced Electric Vehicles (AEV) - will be used to illustrate successful, and not so successful, practices. Instructors: Dr. Jonathan Weaver, Professor, and Dr. Darrell Kleinke, Assistant Professor, Department of Mechanical and Manufacturing Engineering; 3 credit hours
- **AEV 5070: Systems Engineering for AEVs:** Technologies which disrupt the way things have historically been done (such as a transition to Advanced Electric Vehicles (AEVs)) coupled with increasing use of digital tools in the design and validation processes warrant taking a very close look at the best tools and practices for executing the systems engineering process. The major activities of the systems engineering process will be explored with numerous examples and case studies focusing on Advanced Electric Vehicles (AEVs). A required project will be related to AEV development. Instructors: Dr. Jonathan Weaver, Professor, and Dr. Darrell Kleinke, Assistant Professor, Department of Mechanical and Manufacturing Engineering; 3 credit hours

4. Delivery Format

The AEV Certificate Courses will be delivered in the evening, with five technical courses offered at the Ford Motor Company's Fairlane Training and Development Center and the two systems courses offered on the McNichols Campus. Starting in the second year the program will be augmented by on-line delivery to serve students from outside of SE Michigan, especially those from distance sites of the partnering corporations who wish to infuse this knowledge throughout their corporation's global workforce.

5. Describe how the proposed certificate respects academic integrity and intellectual merit

All courses were designed to incorporate graduate level content, rigor and pedagogy. Six of the seven courses will be taught by full time faculty of the engineering and chemistry departments. Two of the faculty members are chairpersons and one is Dean of Research and Outreach.

All students in the program will be admitted as graduate students in engineering after completing undergraduate degrees in engineering (or a closely affiliated field such as engineering physics) earning at least a 3.0 GPA.

The content of these courses has been defined with the advice of highly regarded technical experts from the auto industry. It will be refined by our faculty studying the relevant fields and applying their deep competence to specific advanced electric vehicle systems. It will be continually improved through the process of assessment described below.

6. Indicate unusual or unique characteristics of the proposed certificate.

The AEV Program can be incorporate into the UDM Masters in Product Development Program as follows:

Masters of Product Development with a Concentration in Advance Electric Engineering

A. Product Development Foundational Courses		
<i>All required</i>		
Course Number	Course Name	
MPD 5200	System Project Management	MPD
MPD 5300	System Optimization	College of Bus. Admin.
MPD 5350	Organizational Processes	College of Bus. Admin.
MPD 5400	Financial & Managerial Management	College of Bus. Admin.
MPD 5450	Marketing Management	College of Bus. Admin.
MPD 5600	Product Planning & Development	MPD
MPD 5990	Capstone Thesis*	ENG
B. AEV Systems Engineering/Architecture/Innovation Courses		
<i>Select Either MPD5150 or both MPD5010 and MPD5020</i>		
MPD 5150	Systems Engineering and Architecture	MPD
MPD 5070	Systems Engineering for AEVs	MPD
MPD 5060	Innovation and Systems Architecture AEV	MPD

C. AEV Technologies Courses		
<i>Select 3 or 4 A.E.V. Course Electives of the Following Courses to Bring Total to 12 Courses</i>		
AEV_5040	AEV Power Electronics	ENG
AEV_5010	Intro to AEVs	ENG
AEV_5030	Batteries	ENG
AEV_5020	AEV Controls	ENG
AEV_5050	AEV E Drives	ENG
<i>Total 12 Courses (36 Credit Hours)</i>		

* Capstone Thesis can focus on AEV Product Development (encouraged for students in AEV concentration)
 In fact, many of the AEV courses can be applied toward three other graduate engineering degrees at UDM.

7. Describe how the proposed certificate affects related departments or fields of concentration.

The AEV program will directly strengthen the capabilities and the stature of the mechanical and electrical engineering programs and departments at UDM. Faculty will develop new knowledge by off-term assignments in the leading AEV groups at Ford Motor Company. In addition to the direct application of this new knowledge to the AEV graduate courses, they will be able to integrate examples of the application of many undergraduate knowledge areas to AEVs, thereby providing a better preparation to UDM's engineering graduates for their service to the auto industry. It will also provide the foundation for UDM's future movement into other important areas of energy, such as wind generation and "smart grid" distribution of electricity.

8. Indicate if the certificate is granted on a stand-alone basis or in conjunction with another academic degree.

While the certificate is offered on a stand-alone basis, most or all of the courses can be used towards a student's pursuit of four engineering degrees:

- Masters in Product Development (most likely focus for AEV certificate program graduates)
- Masters in Engineering Management
- Master of Engineering in Electrical Engineering
- Master of Engineering in Mechanical Engineering

9. Indicate the level of the certificate:

The AEV Certificate will be a graduate program at the Post-Baccalaureate level

C. Mission

1. Describe how the proposed certificate fulfills the mission of the University.

It is the mission of UDM to support the people of our region with quality academic programs. This program supports our region by educating engineers with competencies in advanced technical areas that are in great demand. Also, it provides their companies with the competencies to develop electric vehicles that will support the economy of our region, providing jobs for thousands of worker and will also provide environmentally friendly transportation systems. As such, the AEV certificate program is of service to God's children and God's world.

2. Describe how the proposed certificate fulfills the mission of the College or School.

The Mission of the College of Engineering and Science is as follows:

It is our mission to serve the Detroit area, the national and world communities through the education of professional engineers, scientists and mathematicians, through the discovery, application, and dissemination of knowledge.

That education will be personally focused on the needs of each student, value centered in the tradition of the Catholic Church, affordable, and unexcelled in quality of instruction and content. It will be characterized by a hands-on nature, which includes frequent laboratory experiences and an integrated cooperative experience for all students. It will be convenient to all students, whether full-time or part-time, on-campus or off-campus.

The College will discover an apply knowledge which effectively addresses the critical opportunities and challenges of the urban and industrial communities. It will do so in active and intimate partnerships with industry and government.

The elements that are highlighted are served directly by the AEV Certificate program.

D. Objectives, Learning Outcomes and Assessment

1. Certificate Objectives

- To educate engineers in the principles and performance of Electric and Hybrid Electric Vehicles, including its components, sub-systems and their interaction, power generation, storage, control aspects and system integration.
- To educate engineers who excel in the professional practice of innovating, designing and building Advanced Electric and Hybrid Electric Vehicles. This

will include the ability to identify, design and implement innovative solutions to technical problems associated with AEV systems.

- To educate engineers to be aware of how their roles as technical professionals change with the change of vehicular technology from gasoline driven to electric and hybrid electric vehicles.

2. Learning Outcomes

Students completing this certificate program will have the

- a. ability to apply knowledge of AEV vehicles to solve problems in AEV design and system integration.
- b. ability to design, develop and use validated system models for AEV components and systems to solve problems associated with AEVs.
- c. ability to choose and integrate proper E-drives for vehicle powertrain and other applications associated with AEVs.
- d. ability to implement optimum solutions for control problems associated with AEV systems.
- e. ability to function effectively on multi-disciplinary teams and interface effectively with engineers developing the AEV.

and two of the following four depending on the choice of electives

- f. ability to design and develop optimum power storage solutions by designing and developing battery systems. This includes all aspects of power storage such as battery chemistry, packaging and layout design, thermal management, manufacturing and charging process and life-cycle management.
- g. ability to implement proper electronic solutions for power conversion and management problems associated with AEVs.
- h. ability to use techniques of innovation in AEV system design
- i. ability to analyze as well as design an optimum architecture for AEVs systems, and engineer AEV systems

A mapping of courses to specific program outcomes

Outcomes	AEV5010	AEV5020	AEV5030	AEV5040	AEV5050	AEV5060	AEV 5070
a	X	X			X		X
b	X	X			X		
c							
d		X			X		
e	X	X			X		
f			X				
g				X			
h						X	
i						X	X

3. Assessment:

The learning outcomes and objectives will be assessed through a variety of assessment devices in individual courses such as assignments, projects and project reports, exams, pre- and post- lesson surveys. A mapping of individual course outcomes will be mapped to the certificate outcome (much the same way as ABET outcomes are done) so that multiple pieces of data from different courses can be used to assess each of the outcomes. Also, since the students taking the courses are expected to be employees in automotive companies and their suppliers their performance at the workplace or a feedback from employers' surveys will be also used in this assessment process.

E. Market and Need

1. Provide evidence of student demand

Ford Motor Company has formally committed to sending 125 students to this program in the next five years, including 30 students who will start taking these courses in January 2010. Over this five year period the average number of student credit hours per year will be 1,125 (25 x 15 x3).

This will not only provide ample enrollments to launch the program, but also will provide the foundation for growth by attracting engineers who are working at supplier companies, other auto companies and the US Army's Tank Automotive Research, Development and Engineering Center (TARDEC). In addition, the State of Michigan Department of Energy, Labor and Economic Growth (DELEG) has begun to support the tuition of students for courses in the area of electric vehicles through the newly formed Michigan Academy for Green Mobility (MAGM). UDM will seek to designation by MAGM as a program eligible for such tuition support from the state.

2. Describe the competition for the certificate. Are there similar certificates at other institutions in Michigan?

While other institutions in SE Michigan have begun to offer some courses related to AEVs, no other university has yet to announce a certificate program such as this and Ford has committed to providing students to this program.

3. For professional certificates indicate the job market for graduates including national or regional data on jobs available and job growth trends.

Southeastern Michigan remains a world center for automotive development, and vehicle electrification is one of the emerging trends of the auto industry. The MAGM (see E.1 above) has, through surveys of automotive companies, identified a number of high demand positions that are in great need in SE Michigan. Many of those engineering specialties will be directly served by the proposed AEV Program (e.g. – battery engineer, electric drive engineer, . . .).

4. Describe the market area of the certificate i.e. is it local, regional or national.

There is great interest in this area as indicated by the creation of the Michigan Academy of Green Mobility (MAGM) by the State of Michigan. This institute, with support from the Michigan Department of Labor and Economic Growth has begun to designate courses for direct tuition support. The first two were graduate courses in batteries and electric vehicles at Wayne State University and Michigan Tech. UDM will aggressively promote the designation of the AEV Certificate Program as a program endorsed by the MAGM for state support of tuition.

However, there is a national and even international demand for such education, and UDM will be able to serve students outside of this area after the program is transformed into a distance delivered mode in the second year.

5. Identify interest and potential partners in the certificate who can help make it successful e.g. students, alumni, local groups, industry leaders, etc.

Ford Motor Company has committed to sending 125 students to this program and providing over \$1.75 million in tuition and \$88,000 in faculty development. The College has also committed an additional \$80,000 from past alumni and corporate contributions to support the development of laboratory resources needed for this program. Ford has designated leaders in the AEV technologies as advisors for each course and will host six UDM faculty members for one to two month assignments in the AEV R&D areas of the company.

6. Describe how the certificate will be unique and attract market share.

The AEV Certificate Program will be unique in that it will be the first such program to be offered in SE Michigan. In fact, we know of no such program elsewhere in the world.

UDM has already attracted a good market share by proposing the program to Ford Motor Company and having the proposal accepted. Also, Ford will issue a joint press release with UDM and will write to leaders of twelve suppliers of AEV systems and components, recommending the UDM program to them.

On a broader basis, Duane Spytman and the E&S Dean's office will promote the through direct promotion at other companies and at the US Army's TARDEC in Warren.

Finally, the college, with support from the UDM Marketing and Public Affairs Office, will create a website that describes the program and how to apply to it.

F. Students

1. Describe a typical student of the certificate program including whether the student will be full-time or part-time.

Students in the AEV Certificate program will be part-time students who are working in the automotive and defense industries. They will all possess bachelor's degrees in engineering and a high undergraduate GPA to demonstrate their academic capability.

2. If the certificate is intended to provide an option for existing students in the University describe the enrollment impact on other programs.

The AEV certificate program can also serve as a concentration within the Masters in Product Development Program (see section B.6 above). As such, it will draw more students to a program that has had a drop in enrollments in recent years.

3. If the certificate will attract new students to the University describe who these students are and whether they have special needs or requirements not currently provided by the University.

The new students will be those engineers working in the auto industry who wish to expand or redirect their engineering talents into the emerging area of electric vehicles. There is no current program at UDM that serves that need. We have no knowledge of special needs for these students.

4. Describe how the certificate will attract a diverse student body.

For several decades the auto industry has sought to increase the ethnic and gender diversity of its engineering workforce in order to better serve the diverse world markets that it serves. As such, a program that appeals to the top engineers in the auto industry will naturally be more diverse. In fact, in the past, this has been the case in the MPD

program where the diversity of students is greater than that of other UDM engineering graduate programs.

5. If the proposed certificate is an expansion of existing program, or is new, list the number of majors and degrees in the related program for the past five years.

There is no UDM program that would provide valid data for this question.

G. Faculty

1. Provide a list of faculty who will be involved in the new certificate.

AEV5010 Introduction to AEVs	Dr. Abul Masrur –TARDEC Technical Leader and UDM Adjunct Prof. (experienced in similar courses at UDM and SAE)
AEV 5040 Power Electronics for Electric Vehicles	Dr. Mohan Krishnan – UDM ECE Dept.
AEV 5020 Controls for Electric Vehicles	Dr. Richard Hill – UDM ME Dept
AEV 5050 E-drives	Dr. Shuvra Das – UDM ME Dept.
AEV 5030 Energy Storage Systems or Battery technologies	Dr. Mark Benvenuto – Chairperson, UDM Chemistry Dept. (and Dr. Mark Schumack, UDM ME Dept)
AEV 5060 Innovation and Systems Architecture in AEVs	Dr. Darrell Kleinke - UDM ME Dept.
AEV 5070 Systems Engr. for AEVs	Dr. Jonathan Weaver – UDM ME Dept.

2. Indicate, with justification, whether new full-time, part-time, and/or adjunct faculty will be required to operate the certificate program.

No new faculty will be required to operate this certificate program.

3. Describe how the certificate may help the University attract a diverse faculty.

Not applicable since no new faculty will be hired.

4. Indicate what fields of specialization require new full-time or part-time faculty.

Not applicable since no new faculty will be hired.

H. Administration and Support

1. Indicate how the certificate will be administered.

The certificate will be administered by the Office of the Director of the Masters in Product Development and Master of Engineering Management Program, Duane Spytman. That office and its staff are experienced in serving the working engineering population and are well connected with a wide variety of industrial and governmental organizations that are possible sources for additional students.

2. Indicate, with justification, whether support personnel are required for the certificate including secretarial, information technology and lab support.

No additional staff positions are required for this program.

3. Indicate whether academic support will be required from existing certificates on campus such as UAS, Co-op, Writing Lab, etc.

Academic support from IDS will be needed late in year one and in two for the transformation of this program to on-line delivery.

I. Library Resources

1. University's library resources available in direct support of the proposed certificate: reference and periodical holdings, software, audiovisuals and other instructional materials.

The Dean of University Libraries in consultation with the librarians assigned to College of Engineering and Science confirm that UDM library has some holdings in this general area. The tables below provide information regarding the library books and full-text journal collections. While these are adequate at the moment, comparing the UDM collections to two other university AEV library collections shows that the UDM collections need to be augmented with more recent publications.

With the student ID card, registrants of this program will have remote access to the online full-text databases, the eBook collections, and reference assistant. The library's instant messaging, email a librarian, and telephone services are available to students taking courses off site.

Books

Keywords	Holdings Print and Electronic
Electric Machines	47 print; 607 eBooks
Control System	590 print; 1225 eBooks
Power Electronics	58 print; 700 eBooks

Battery	6 print; 408 eBooks
Innovation	684 print; 667 eBooks

Full Text Journals (including electronic access)

Keywords	Holdings
Control Engineering	10
Innovation	33
Electric Machines	1
Power Electronics	4
Battery	0

2. New library resources needed

As the field is evolving fast with new technological developments, continuous improvement of library resources will be necessary. A modest expenditure of \$1000-2000 per year along with input from relevant faculty as to what items should be bought will be more than sufficient to meet these needs.

J. Facilities

1. List the facilities which are currently available at the University for the certificate program including administrative office space, class room space, and the like.

- Administrative office space: already assigned to MPD/MEM Office
- Class room space: five of the seven courses will be offered at Ford Motor Company. The program will require the assignment of classroom for one course in the summer and one in the fall on the McNichols Campus.
- Laboratory: laboratory experiences will be limited and will be conducted in existing engineering laboratory spaces on Saturdays.

2. Indicate whether the Registrar has any concerns over provision of class room space for the certificate.

None have been expressed.

3. Indicate whether any facilities such as laboratories, classroom and office space have to be built, renovated or added to deliver the certificate and what the cost of same would be based upon a review and cost study by the University Facilities Management Department.

No laboratories need to be built. However, new equipment will be purchased and installed or fabricated by current E&S technical staff under the guidance of the responsible faculty members.

Equipment

The curriculum proposed here will not be complete without the inclusion of both simulation-based and hands-on laboratory activities. The following table provides the details of all equipment and supplies necessary for the labs. The supplies have been so chosen as to be scaled down items that can be used mostly in a flexible setting to illustrate the basic principles.

Item	Price	Quantity	Total	Source
Matlab/Simulink	250	4	1,000	UDM previous gifts
Power Electronic Lab station	3,000	4	12,000	UDM previous gifts
Electric Drive Lab Station	10,500	4	42,000	UDM previous gifts
Electric and Electric Drive train components	10,000 per set	2	NA	Ford In Kind Contribution
Computers	1,500	4	6,000	UDM previous gifts
Miscellaneous			2,000	UDM previous gifts
Lab and Vehicle Networking software			10,000	UDM previous gifts
Misc. equipment TBD			9,000	UDM previous gifts
Total			80,000	

The Power electronics lab station and the electric drive lab station are described in more details below.

Power Electronics Lab station

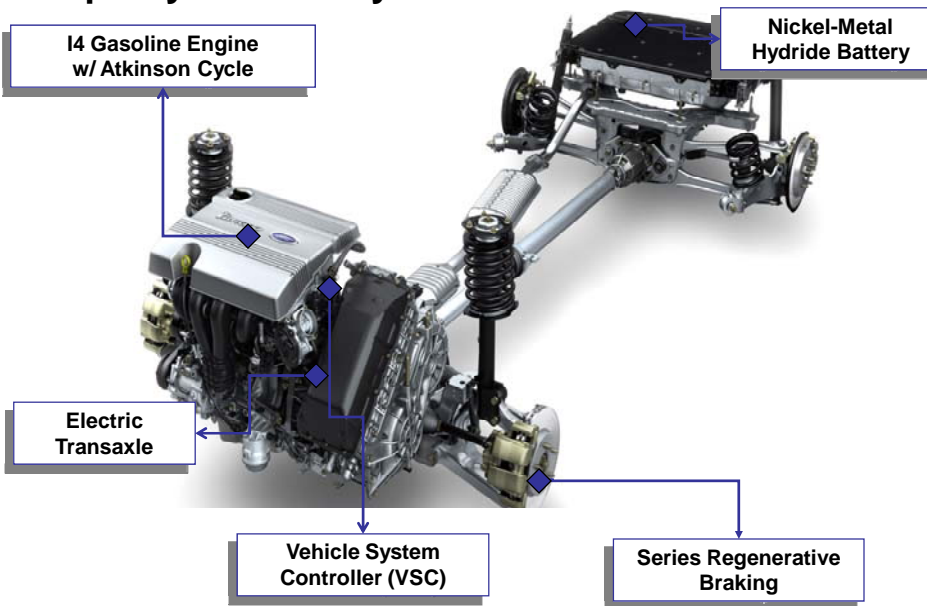
Item	Distributor	Cost
Power Pole board	HiRel Systems	1145
Power Supply	DIGIKEY	319
Signal Power Supply	Newark	41
External Device Module	Newark	258.58
Differential Probe	Newark	609.38
Function Generator	DIGIKEY	250
Digital Multimeter	DIGIKEY	167
Plug in board	DIGIKEY	6.62
Crimp Connectors	DIGIKEY	3.2
BNC Cable	Newark	48.96
BNC Graber	Newark	11.76
Rheostat	Newark	60.11
Rheostat Knob	Newark	2.99
Banana Wire(red)	Newark	30.76
Banana Wire(black)		30.76
Total		2985.12

Electric Drives Lab Station

Item	Manufacturer	Cost
Motor sets	Motor Solver Inc	2500
Electric Drives Board	HiRel Systems	1570
DSP Board Kit	DSPACE	5300
Signal Power Supply	Newark	41
Function Generator	DIGIKEY	250
Digital Multimeter	DiGiKEY	167
BNC Cable(2)	NEWARK	48.96
BNC Cable(2)	NEWARK	33.04
Power Supply	TestMart	429
Banana Wire(4)	NEWARK	30.76
Banana Wire (4)	NEWARK	30.76
		10,400.52

The drive trains to be provided by Ford are depicted below:

Escape Hybrid Sub-systems



K. External Support

1. Describe any accreditation available in the field and recommend whether such accreditation should be sought.

There is no accreditation for certificates in advanced electric vehicle engineering.

2. If the certificate has been reviewed by an external consultant, professional organization, employers, etc. include a copy of their report in the appendix.

The certificate has been reviewed by Ford Motor Company and they decided to send 125 of their engineers to the program.

3. Describe any external funding that has been received or can be expected to be received to support the certificate. Include the duration of any grants or any continuing commitments that have future budget implications.

Ford has committed to sending 125 students to this program over the next five years, and to providing \$88,000 for the development of faculty knowledge in the areas of these courses. The College of Engineering and Science has committed \$80,000 of previous gifts from alumni and corporations (restricted funds) to support the development of laboratory equipment and software needed for this program.

4. Describe whether any resources are to be reallocated from existing certificates to support this new certificate.

None.

L. Operating Revenue and Costs

1. Provide a five year projection of revenue and expenses for the certificate utilizing the projected number of students from the market study and the projected credit hours taken per year.

See Appendix II for the revenue and expenses for developing and offering the courses from which the certificate is derived. This plan has been reviewed by the UDM budget office and approved by the UDM administration. While this spreadsheet does not follow the prescribed format, it clearly demonstrates that the commitment of tuition from Ford provides the funds needed for the personnel costs to develop and deliver the program, while retaining over \$1.5 million of net direct surplus to support other needs of UDM. The budget in Appendix III has been approved by the UDM administration and includes funding for course

development, transformation to on-line delivery and stipends to instructors for the first five years of the program.

M. Approval Process

1. Indicate any other University support that has been obtained. Include support letters from internal or external sources.

In addition to the tuition (projected at \$1.75 million over five years) and the development funds (\$88,000) from Ford, they have committed to provide a complete Ford Escape Hybrid Electric Vehicle and another drive from an Escape Hybrid for use in laboratory experiences that will be part of the program. (copy of email appended)

This proposal has been reviewed and approved by both the Curriculum and Standards Committee and the Leadership Team of the College of Engineering and Science.

N. Appendices

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|---|-------|
| I. AEV Course Syllabi | p. 20 |
| II. Cost-income analysis for AEV Course Offerings | p. 38 |
| III. Approved UDM AEV 5-Year Budget | p. 39 |
| IV. Ford Approved Plan | p. 41 |

AEV 5010: Fundamentals of Advanced Electric & Hybrid Vehicles

Instructor: Dr. M. Abul Masrur, Adjunct Professor, Department of Electrical and Computer Engineering

3 credit hours

One of the fastest growing automotive fields, advanced electric and hybrid vehicles presents both opportunities and challenges. These vehicles are more fuel-efficient and environmentally friendly compared to conventional vehicles. Optimizing the power intake in AEVs allows the vehicles operation to be kept within the range designed for best fuel economy and lowest emission, while the motor/generator system either provides additional power input, generates electricity using the excessive power from the engine, or, in the case of battery electric vehicles is the sole source of propulsion. In the case of hybrid electric vehicles (HEVs) the motor/generators system also recovers the kinetic energy during braking or coasting. During braking or coasting, it is also possible to recover kinetic energy for a battery electric vehicle by introducing additional generator/s mounted either in the hub or in the axle of the vehicle. These advantages have attracted worldwide development interests for such vehicles and has created a need for many automotive engineers to quickly learn about these systems as they contribute to their design and manufacture.

The challenges and emerging technologies present in electric and hybrid electric vehicles include power electronics, electric motors and generators, batteries, power management, thermal management, and system integration. Additional challenges related to after-sales issues include reliability, gracefully degradable operation, and maintenance/servicing.

This graduate level course will provide an overview and fundamentals of AEVs (HEV, EV, BEV) and key challenges and opportunities of AEV technologies. The course will explain the engineering philosophy of various AEVs (HEV, PHEV and BEV). It will also give an overview of electric drives, power electronics, regenerative braking system, power management, and battery management (more details of some of which will follow in later companion courses by other instructors). Sample problems involving modeling and simulation using Matlab-Simulink (and/or Advisor) will be assigned and discussed to cover some of the above topic areas with a view to making design decisions in terms of size and performance. Some existing commercial HEV architecture will be discussed. HEV application areas for other than passenger vehicles, namely heavy vehicles, will also be discussed. Reliability issues, and other potential problem areas will be discussed.

AEV 5020 CONTROLS MODELING AND DESIGN FOR AEV
Term XXX Fall 20XX-20XX
Lecture: TBD

- **DRAFT 20091116 – Subject to Change**

Instructor: Richard C. Hill, Assistant Professor, Mechanical Engineering Department
Office: E274
Phone: (313) 578 - 0428
Fax: (313) 993 - 1187
E-mail: hillrc@udmercy.edu

Office Hours: TBD

Prerequisites: AEV 5010 Introduction to AEVs. Acceptance into the MPD Program and/or an engineering graduate program to pursue the AEV Certificate.

Textbook: TBD

Course homepage: <http://knowledge.udmercy.edu>

Course Description:

Introduction to modeling and simulation of various elements of the powertrain of Advanced Electric Vehicles (AEV), time and frequency domain analysis techniques, introduction to classical controller design techniques for Single Input Single Output (SISO) Linear Time-Invariant (LTI) systems with an emphasis on PID controller design, advanced topics pertinent to AEVs will be addressed as time allows

Prerequisites by Topic:

1. Basic dynamic modeling for mechanical systems (Newton's laws) and electrical systems (Kirchoff's laws)
2. Basic understanding of control systems

Course Content:

1. Modeling and Simulation: Modeling of the dynamics of the various elements of the powertrain of AEVs. Possible elements include IC engines, DC motors, AC motors (induction machines), power electronics and batteries, and sensors. Forms for the mathematical models will include differential equation and transfer function models. Only a high level understanding of the underlying dynamics will be required with detailed instruction left to more specific courses on E-drives, Power Electronics, and Batteries. Emphasis will be placed on identifying the proper level of model detail for analysis and design as compared to simulation. MATLAB/Simulink will be used for the

simulation exercises in the course. Techniques for achieving reduced order and linearized models will also be presented.

2. Time and Frequency Domain Analysis: Time and frequency domain analysis techniques will be covered. Bode plots will be employed for the frequency response analysis. Understanding dynamic systems in terms of their transient performance, steady-state performance, and robustness characteristics will be taught.
3. Controller Design: Pole placement and frequency domain design techniques will be introduced for SISO LTI systems. The effect of the three terms of the traditional PID controller will be taught. Different control architectures and their effect on performance will also be investigated.
4. Advanced Topics: Possibilities include how to design control systems with multiple loops, how to design control for systems with multiple inputs and/or multiple outputs, how to design for robustness, understanding the effect of specific nonlinearities like actuator saturation and coulomb friction, integrator anti-windup, and switching between different power plants in the control system.

Course Outcomes:

After taking this course, students will be able to:

1. Derive mathematical models for the various elements of the powertrain of AEVs (differential equations and transfer functions).
2. Describe the principles of the operation of sensors necessary for the feedback control of AEVs and will be able to model the relevant dynamics.
3. Describe and evaluate simplifying assumptions made in the modeling process (nonlinearities, higher order dynamics).
4. Determine and describe quantitatively the time response of systems based on the pole locations of their models (transient and steady state).
5. Model a system of components by block diagram and determine the input/output behavior of the system based on such a model (reduction of multiple loops, effect of inputs entering at different places in the feedback loop).
6. Generate the linear approximation of a nonlinear model.
7. Determine and describe the robustness properties of a system based on its frequency response (stability margins).
8. Use frequency domain techniques (Bode plots) to analyze and design control systems.
9. Describe and tune the effect of the three terms of a PID controller.
10. Evaluate the trade-offs inherent in the design of a controller (different gains, different architectures).
11. Design the torque and speed control of a DC motor with mechanical load (cascade control structure).
12. Design the speed control of an AC motor (induction machine) in an energy efficient manner.
13. Qualitatively describe and heuristically design necessary nonlinear elements of an AEV control system like switching between system components and limiting signal magnitudes.
14. Use MATLAB/Simulink for the analysis and design of control systems.

Class Elements:

Homework - Problem sets will be assigned approximately every one to two weeks over the course of the semester.

Exams - Two cumulative midterms will be given during the semester in addition to a cumulative final.

Class Policies:

Late work - Homework must be turned in at the beginning of class. Late homework is not accepted.

Exams - Exams will in general be closed book and closed note.

Academic Integrity - Any suspected cheating will be dealt with according to the College policy - see the Engineering Science Student Handbook. In the case of homework, working together is encouraged, but you must write your own solutions that reflect your own understanding of the material.

Grading:

Homework	20%
2 Midterm Exams	50% (25% each)
Final exam	30%

Grading Scale:

Grade:	A	A-	B+	B	B-	C+	C	D	F
Average (%):	93	90	87	83	80	77	70	60	<60

AEV5030: Batteries and Battery Systems for Advanced Electric Vehicles

Instructor: Dr. Mark Benvenuto, Professor, Department of Chemistry and Biochemistry

Co-instructor: Dr. Mark Schumack, Professor, Department of Mechanical and Manufacturing Engineering

3 credit hours

Overview: In this course, students will be exposed to the chemistry of batteries in a wide variety of redox couples, and will explore the numerous applications of battery chemistry, with an emphasis on batteries as a transportation power source. The following will be presented in the course:

1. Voltage capabilities of various couples, which include the established:
 - lead – lead sulfate (*still used as 12v SLI but little future in traction (except historical milk floats, fork lifts and other industrial apps)*)
 - zinc – manganese dioxide (*common primary electrochem for small apps - low cost, low voltage*)
 - nickel – cadmium (*no longer used due to toxicity of cadmium but interesting app in utility load leveling*)
 - silver oxide (*good primary reference as high energy target*)
 - nickel – metal hydride cells (*NiMH for current HEVs*)But will also include novel, light element couples such as:
 - lithium – manganese dioxide
 - zinc, magnesium – air batteries
 - rechargeable lithium ion – metal hydrides (*layered oxides, olivines and spinel cathodes in combination with two types of anodes*)
 - sodium family - NaS and NaMCl₂
2. Battery capacities, and comparisons of the capacities available among established couples as well as emerging materials couples.
3. The role of active, nano-structured materials in battery composition, and how particle size and morphology affect battery capacity and power delivery and absorption
4. Battery lifetimes (calendar and cyclic) , life-cycles, and the re-chargeable nature of certain couples
5. Material availability and economic feasibility in battery construction and mass production.
6. The industrial, ecological footprint of battery production will also be addressed.
7. A look at the cost and time scale of development of some relevant electrochemistries
 - ‘S’ curves and the various technologies and skill sets required at each stage

8. Assessment of the 'customer wants and needs' for a battery application as guidance for the focused development of individual electrochemistries/packs
9. Relationship of the product development process and particular attention to DV requirements
10. Role of regulations and standards
11. Warranty and Safety (product liability) as drivers of battery product development
12. Cell size and electric circuit design for power and energy
13. Battery requirements as determined by HEV, PHEV, REEV and EV vehicle requirements

Thus, the course will reinforce the student's basic knowledge of battery redox chemistry, but will also include an emphasis on new and emerging areas of battery chemistry and redox coupling, inclusive of organic and nano-structured materials. The subject matter will be connected to the use of batteries and energy storage systems for automotive propulsion whenever feasible.

Outcomes:

- Students will gain a thorough understanding of established battery redox chemistry, as well as a thorough knowledge of emerging battery materials.
- Students will be familiar with different battery voltages, capabilities, lifetimes, and how these affect battery performance.
- Students will gain a full understanding of how batteries are constructed, and of the sources of the materials which are used as redox couples.

AEV 5040: Power Electronics for Electric Vehicles
Term I, 2010
Course Syllabus

Catalog course description:

AEV 5040: Power Electronics for Electric Vehicles (3 cr)

Applications of power electronic circuits; devices for power switching used in automotive applications – diodes, MOSFETs, IGBTs; conversion circuits - AC-DC (rectifiers), DC-DC (buck, boost, buck-boost), DC-AC (inverters); feedback controller circuit design; design of the magnetics involved in switch-mode converter components.

Overview:

The course will deal with electronic devices and circuits used in the conversion, control, and distribution of electric power as they relate to applications in electric vehicles. The focus will be on switch-mode power converters that are predominant in the electric drives of today.

Instructor: Dr. Mohan Krishnan, Professor, ECE Dept.

Office: Room E328

Contact info: 313-993-3367, mohank@udmercy.edu

Office hours: As posted outside office. Other hours by appointment.

Lecture hours: XX

Course web site:

A web site for the course is available at <http://knowledge.udmercy.edu/>. Through this site you can participate in discussions, access announcements pertaining to the course such as hints on homework assignments, new information on projects, last minute information on quizzes and tests, etc. It is very important for you to periodically access and check the web site for new information, as often this might be the only way in which such information is disseminated! Make sure that your correct email address is listed on the site so that I am able to communicate with you in a timely manner!

Learning Outcomes:

Upon completion of this course the students should be able to:

- a) Understand the role of power electronics in the context of their use in electric drives; this will also involve a broad understanding of common electromagnetic actuators and the overall control philosophy.
- b) Understand the behavior of various power electronic circuits and be able to specifically identify their roles in Hybrid Electric Vehicle applications.
- c) Understand the DC and AC characteristics of electronic devices used in hybrid electric vehicle applications and demonstrate this through an ability to theoretically analyze and simulate circuits containing these devices.
- d) Understand common switch-mode power conversion topologies used in hybrid electric vehicles and demonstrate this through an ability to theoretically analyze and simulate circuits containing these circuits.

- e) Understand the factors involved in the design of the magnetics-based components in switch mode power conversion circuits.

Computer usage:

SPICE-based simulation will be extensively used to support theoretical coverage and in homework and laboratory exercises. The particular commercial product used for simulation activities at UDM is Multisim® (owned by National Instruments).

Homework assignments:

There will be several homework assignments involving analysis and design that require the use of the Multisim® circuit simulator.

Important policy issues:

1. Normally no make-up examinations will be conducted. Exceptions will only be made under compelling circumstances. Students must check with the instructor *before* absenting themselves from the scheduled examination. Even if a make-up exam is granted, it will be of a greater level of difficulty than the regularly scheduled exam.
2. It is expected that work submitted by students in quizzes, assignments, projects, etc., is a product of the student's own efforts (or that of the student team in the case of a design project). Cheating on tests, homework assignments, or design projects will not be tolerated and will result in a grade of zero for that particular exercise for all parties involved, as well as additional penalties as prescribed in the *Student Handbook of Policies and Procedures* for the College of E & S. Please also note the policy forbidding plagiarism in the compilation of your reports.

Important dates:

Last day to delete a course without a 'W' – September XX, 2010

Last day to withdraw from a class – November XX, 2010

AEV 5050: Electric Drives/Electromechanical Energy Conversion

Instructor information:

Dr. Shuvra Das, Department of Mechanical and Manufacturing Engineering, E130, 993-3380
(phone), dass@udmercy.edu (e-mail)

3 credit hours

Catalog Description: Introduction to magnetic circuits and induction, principles of electro-mechanical energy conversion, basic concepts of electromechanical actuators-rotational and linear, DC Machines, Synchronous machines, Induction Machines, Steppers and Servos.

COURSE OUTLINE

1. Magnetic Circuits and Induction

Magnetic Circuits, Magnetic Induction, AC operation of Magnetic circuits, Magnetic materials, Magnetically induced emf and Force, Hysteresis and eddy losses, Applications

2. Principles of Electro-Mechanical Energy Conversion

Basic Physics of Electromagnetics, Energy, Force and Torque in Magnetic Systems, Energy Conversion via electric field, Dynamic of Electromechanical Systems

3. Basic concepts of electromechanical actuators-rotational and linear

Elementary linear and rotational actuators, solenoids, AC DC motors, phasors and phase circuits, operations, leakage, ratings, efficiency, machine characteristics vs. load matching

4. DC Machines

Permanent magnet DC motors, Series, shunt and separately excited DC motors, models of motors, characteristics, efficiency, applications, etc.

5. Synchronous Machines

Construction and principles of operation, Basic Models, synchronous reactance, power and torque output, power flow equations, machine dynamics, characteristics, efficiency, etc.

6. Induction Machines

Construction and principles of operation, Basic Models, synchronous reactance, power and torque output, power flow equations, machine dynamics, characteristics, efficiency, etc.

This course will take a model based approach, i.e. extensive use of MATLAB/Simulink based and other models will be made throughout the course to teach concepts discussed in this course. Since there will be two other courses on Power electronics and Controls the Power electronics aspects in this course will be treated as “black boxes” and the Controls aspects of e-drives will be left for discussion in the controls course.

Learning Outcomes: Upon completion of this course the students will be able to:

1. Describe the structure of Electric Drive systems and their role in various applications associated with Electric and Hybrid Electric Vehicles.
2. Determine the basic requirements placed by mechanical systems on electric drives.
3. Use the basic concepts of magnetic circuits to understand the principles of operation of electric machines.
4. Use the two basic principles (generation of force and emf) that govern electromechanical energy conversion.
5. Use the principles of operation of linear electro-magnetic actuators.
6. Use the operation of dc motor drives to satisfy four-quadrant operation to meet mechanical load requirements.
7. Clearly learn to use space vectors presented on a physical basis to describe the operation of an ac machine.
8. Apply the basic principles of AC Synchronous machines in modeling them.
9. Describe the operation of induction machines in steady state that allows them to be controlled in induction-motor drives.
10. Implement speed control of induction motor drives in an energy efficient manner using power electronics.
11. Learn the basic operation of stepper motors and switched-reluctance motor drives.
12. Get an appreciation of power quality issues in powering electric drives.
13. Apply space vectors to explain vector control of ac drives.
14. Model the dynamics of an induction machine.

Office Hours: Specific office hours will be maintained at the following times: **T, R 2-4 pm**. Outside of these hours you can see the instructor any other time that he is available. Use email to get most of your questions answered. The instructor will be accessing his email everyday, several times during the day.

Class Meetings: TBD

Required Text and Software Tools:

- **Access to software tools: MATLAB /Simulink.** Students are required to have a licensed copy of this software. A student version may be purchased from the software company.
- **Text book to be determined.**

Reference Texts and other materials:

1. **Propulsion Systems for Hybrid Vehicles**, John Miller, Instituton of Engineering and Technology.
2. **Electric Motors and Drives: Fundamentals, Types and Applicatios**, Austin Hughes, Elsevier.
3. **Electric Motors and Control Techniques**, Irvin Gottlieb, McGraw-Hill.
4. **Electric Machinery**, Fitzgerald, Kingsley, Umans, M-Graw-Hill

Computer Simulation Projects: Details about the computer problems will be provided in separate documents.

Grading Policy: The following components contribute to the grade for this class:

Mid-term Exam:	20%
Final Exam:	30%
Homework and Computer Simulation exercises:	30%
Laboratory reports:	20%

The tentative grading scale for the course is as follows:

% Average	93-100	90-92	87-89	83-86	80-82	77-79
Letter Grade	A	A-	B+	B	B-	C+

% Average	73-76%	70-72	60-69%	<60
Letter Grade	C	C-	D	F

Other Policies:

Academic Integrity: Academic dishonesty will not be tolerated. Working together on individual assignments is different than copying. Plagiarism will not be tolerated either. See the UDM Student Handbook for more about this. Students are expected to perform to a high standard of honesty and integrity in this course.

Attendance: While not computed as a direct part of your grade for this course, we want to emphasize the importance of attending class. Since no single text books are being used, failure to attend class will cause you to miss out on important aspects of the course.

Exams: A mid-term and a final exam will test your level of mastery of important theoretical concepts associated with the course. Approximate exam dates are listed in the weekly lesson plan and will be announced during class as well.

Homework and Projects: These assignments will be individual assignments. When an assignment is assigned its nature and due date will also be announced. Late assignments will not be accepted.

MPD 5060 INNOVATION AND SYSTEMS ARCHITECTURE
Term XXX Summer 20XX
Lecture: TBD

Instructor:

Darrell Kleinke
Dept. of Mechanical Engineering
Cell Phone (313) 993-1140
kleinked@udmercy.edu
Office E275, Hours: TBD,
or by appointment

Prerequisites: AEV 5010 Introduction to AEVs. Acceptance into the MPD Program and/or an engineering graduate program to pursue the AEV Certificate. Industrial experience with general awareness of corporate systems engineering practices.

Textbook: *The Art of Systems Architecting*
M. Maier and E. Rechtin, 3rd Edition, CRC Press, 2009.
ISBN 978-1-4200-7913-5

Goals:

To develop a fundamental skill set to apply the principles of system architecture such that the student will be able to: (1) Structure and lead the early, conceptual phases of the system development process, (2) Contribute ideas which strategically lead ongoing systems development, (3) Offer independent and holistic evaluations of product architecture, and (4) Challenge, critically evaluate, and contribute to the evolution of methods of architecting.

Prerequisites by Topic:

General understanding of a typical corporate product development process.

Topics:

It is planned to cover most material in the textbook with supplemental material, case studies and examples/case studies related to AEVs. Individual and team projects are required. Key topics will include:

1. What is the Art of System Architecture?
2. Overview of Innovation Practices and the Architecting Process.

3. Architecting Heuristics.
4. Architecting Principles and Innovation Techniques.
5. Builder-Architected Systems.
6. Manufacturing Systems.
7. Other Systems.
8. The Innovation Culture
9. Models and Modeling.
10. Architecting as a Profession and Innovation as a Norm.

Computer Usage:

All students must have (and regularly read) an email account. You will be automatically enrolled in the course’s Blackboard site when you are officially enrolled in the course. The Blackboard site will be used to post lecture notes, grades, assignments, etc., and should be used for class related questions and discussions. Certain assignments must be web submitted as Word and/or PowerPoint documents if requested. Failure to provide documents by the required process and in the required format will result in no credit given.

Grading:

Grade:	A	A-	B+	B	B-	C+	C	D	F
Average (%):	93	90	87	83	80	77	70	60	<60

Grade Weighting:

Projects50%
 Homework30%
 Quizzes (low 1 of 6 will be dropped)20%

Quizzes are Closed book and closed notes (approx. 15 minutes time)

Quiz Topics:

- Part I The Art of Architecting and Innovating
- (2) Part II New Domains, New Insights
- (2) Part III Models and Modeling
- Part IV The Systems Architecting Profession and Innovation Practice

Academic Integrity:

Students are expected to perform to a high standard of honesty and integrity in this course. All work submitted by individuals or teams must be the original work of the individual or team submitting the work. Direct usage of reference material is generally discouraged, but if used must be clearly and fully referenced. See also the UDM Catalog and E&S Student Handbook.

Descriptions of Assignments:

The team and individual assignments may require research, innovative thinking, write-ups, and presentation with appropriate visual aids. Attempts will be made to allow some of the assignments to be directly relevant to students' interests and work. All submitted work be the original work of the student(s) submitting it and have been done during the timeframe of the course. Each assignment will be given a point value.

Lecture Format:

Technology permitting, most of the lecture material will be projected from a laptop computer. PDF versions of the presentation materials will be available on the course website (main lecture notes will generally be posted before each lecture, lead-in slides will generally be posted after lecture).

Other Policies:

1. There will be no makeup quizzes. If you miss one, that will be the one which is dropped.
2. Late homework, reports, and projects will be penalized 20% per 24 hour past due period.
3. If a student does not participate in an active and approximately equal fashion in the completion of a homework, report, or project that was carried out in teams, his/her name must not appear on the cover page of that assignment. If this rule has been violated, all the team members will receive a grade of zero for that particular assignment.
4. Grading of all materials will be strongly influenced by readability, grammar, and overall quality of presentation.
5. Requests for re-grades on homework, reports, or projects must be submitted in writing (such as via email) within one week of the return of (or notification thereof) the item on which you question the grade. In this event, the entire homework/report/project will be re-graded with possible adjustment in either direction.
6. Class Cancellation Policy: If a class is missed for any reason, anything originally planned for that class will occur during the next class session.

AEV 5070 SYSTEMS ENGINEERING FOR AEVS
Term XXX Fall 20XX-20XX
Lecture: TBD

- **DRAFT 20091119** -

- **Subject to Change Based on Planned Internship at Ford in May/June 2010** -

Instructors: Jonathan M. Weaver, Professor and Chair, Mechanical Engineering Department

Office: E 214

Phone: (313) 993 - 3372

Fax: (313) 993 - 1187

E-mail: weaverjm@udmercy.edu

Office Hours: TBD

Prerequisites: AEV 5010 Introduction to AEVs. Acceptance into the MPD Program and/or an engineering graduate program to pursue the AEV Certificate. Industrial experience with general awareness of corporate systems engineering practices.

Textbook: Systems Engineering Principles and Practice, A. Kossiakoff and W. Sweet, Wiley Series in Systems Engineering and Management, Wiley Interscience, 2003.

INCOSE: All students must join INCOSE (International Council on Systems Engineering). You can join at www.incose.org. The *Systems Engineering Handbook* and other resources available to members will be utilized.

Catalog Description:

Technologies which disrupt the way things have historically been done (such as a transition to Advanced Electric Vehicles (AEVs)) coupled with increasing use of digital tools in the design and validation processes warrant taking a very close look at the best tools and practices for executing the systems engineering process. The major activities of the systems engineering process will be explored with numerous examples and case studies focusing on Advanced Electric Vehicles (AEVs). A required project will be related to AEV development. 3 credit hours

Goals:

The primary goal of this course is to provide an understanding of key elements of Systems Engineering. Within this framework, elements of good systems engineering processes, requirements analysis, interface definition and management, trade-off studies, decision-making tools, system models, and design validation techniques are

addressed. A particular focus on AEVs will be achieved through examples, case studies, and a required project.

Outcomes:

- Students will be able to describe the major activities of the systems engineering process and be able to execute those activities to realize complex architectures – including AEVs.
- Students will be able to apply the system engineering “vee’ as a model of the systems engineering process including needs identification, requirements development and cascading, interface definition, and planning and execution of verification and validation activities.

Prerequisites by Topic:

1. General understanding of a typical corporate product development process.
2. Systems Architecture

Topics:

It is planned to cover much of the material in the textbook with substantial supplemental material and examples/case studies introduced as appropriate – many of those related to AEVs. New content may be developed during the term, but a tentative list of topics is given in Table 1.

Table 1. Tentative Topics

<ol style="list-style-type: none"> 1. Introduction to Systems Engineering (SE) <ol style="list-style-type: none"> a. What is SE? <ol style="list-style-type: none"> i. Origin and evolution ii. Definitions of systems, SE, etc. iii. Objectives of SE iv. Importance b. Relation of SE to architecture <ol style="list-style-type: none"> i. Where one ends, other starts ii. Implications of architecture on SE c. Importance/role of standards <ol style="list-style-type: none"> i. MIL-STD, IEEE, Etc. d. Examples of SE done poorly e. Examples of SE done well
<ol style="list-style-type: none"> 2. Introduction to the Systems Engineering Process <ol style="list-style-type: none"> a. SE relationship to the U&E generic PD Process b. SE models <ol style="list-style-type: none"> i. V ii. Spiral c. Process considerations
<ol style="list-style-type: none"> 3. Requirements/Attributes <ol style="list-style-type: none"> a. Attributes vs requirements b. Sources c. How to write good requirements

<ul style="list-style-type: none"> d. Cascading requirements e. Quality Functional Deployment (QFD) f. Traceability
<ul style="list-style-type: none"> 4. Partitions and Interfaces <ul style="list-style-type: none"> a. Partitioning the system b. Interface definition and management c. Boundary diagrams <ul style="list-style-type: none"> i. Information flow
<ul style="list-style-type: none"> 5. System Analysis and Decision Making <ul style="list-style-type: none"> a. Trade studies b. Order/timing of decisions <ul style="list-style-type: none"> i. Design Structure Matrix (DSM)
<ul style="list-style-type: none"> 6. Validation <ul style="list-style-type: none"> a. System integration <ul style="list-style-type: none"> i. Design reviews b. Analytical vs physical validation c. Role of prototypes d. Tooling e. Verifying process capability <ul style="list-style-type: none"> i. Gage R&R, SPC f. Design validation plan <ul style="list-style-type: none"> i. Test design ii. Execution iii. Interpretation g. Reliability h. Empirical testing
<ul style="list-style-type: none"> 7. Managing the SE process <ul style="list-style-type: none"> a. Work breakdown structure b. Managing PD data <ul style="list-style-type: none"> i. Change control c. Metrics d. Risk/uncertainty management
<ul style="list-style-type: none"> 8. SE applied in various industries (tailoring the process) <ul style="list-style-type: none"> a. Automotive Industry b. Department of Defense (DOD) c. National Aeronautics and Space Administration (NASA) d. Projects involving hardware and software e. AEV specific considerations
<ul style="list-style-type: none"> 9. Project closure/learning from experience (Knowledge Management) <ul style="list-style-type: none"> a. Integrating it upstream b. Subsequent usability
<ul style="list-style-type: none"> 10. Other Assignments / Topics <ul style="list-style-type: none"> a. Numerous case studies and examples related to AEVs b. Other computer aided SE tools c. Individual and team assignments d. Term project related to AEVs

Computer Usage:

All students must in frequent contact with our Blackboard course site and their email. Many projects and assignments must be submitted via the Blackboard Digital Drop Box.

Grading:

Grade:	A	A-	B+	B	B-	C+	C	D	F
Average (%):	93	90	87	83	80	77	70	60	<60

Grade Weighting:

Individual Assignments.....	25%
Team Assignments.....	50%
Quizzes (lowest of first 4 dropped).....	25%

Important Dates:

- Quizzes (20 minutes each) ...
- Last day to drop without a “W” ...
- Project proposal due ...
- Last day to withdraw from class ...
- Holidays ...
- Project reports due ...
- Project presentations ...

Academic Integrity:

Students are expected to perform to a high standard of honesty and integrity in this course. All work submitted by individuals or teams must be the original work of the individual or team submitting the work. Direct usage of reference material is generally discouraged, but if used must be clearly and fully referenced. See also the UDM Catalog and E&S Student Handbook.

Assignment Descriptions:

The team and individual assignments may require research, innovative thinking, write-ups, and presentation with appropriate visual aids. Attempts will be made to allow some of the projects to be directly relevant to students’ interests and work. All projects must be the original work of the student(s) submitting it and have been done during the timeframe of the course.

Lecture Format:

Technology permitting, lectures will be delivered via PowerPoint projected from a laptop. The lectures will be videotaped for subsequent viewing by anyone who misses a lecture. Contact the MPD Program office to obtain the videos.

Other Policies:

7. Quizzes are closed book, closed notes. There will be no makeup quizzes. If you miss one of the first four, that will be the one which is dropped. If you must miss more than one quiz or the last quiz, then an advance arrangement must be made with the instructor.
8. Late homework, reports, and projects will not be accepted.
9. If a student does not participate in an active fashion in the completion of a homework, report, or project that was carried out in teams, his/her name must not appear on the cover page of that assignment. If this rule has been violated, all the team members will receive a grade of zero for that particular assignment.
10. Grading of all materials will be strongly influenced by readability, grammar, and overall quality of presentation.
11. Requests for re-grades on homework, reports, or projects must be submitted in writing within one week of the class in which we return the item on which you question the grade. In this event, the entire homework/report/project will be re-graded with possible adjustment in either direction.
12. Items not claimed the first time we return them to the class must be picked up in the prof's office within two weeks of the class in which return was attempted. Items not picked up after two weeks may be disposed of.
13. Class Cancellation Policy: If a class is missed due to weather or instructors' absence, anything originally planned for that class will occur during the next class session.

Lecture Format:

Technology permitting, lectures will be delivered via PowerPoint projected from a laptop. The lectures will be videotaped for subsequent viewing by anyone who misses a lecture. Contact the MPD Program office to obtain the videos.

Other Policies:

3. Quizzes are closed book, closed notes. There will be no makeup quizzes. If you miss one of the first four, that will be the one which is dropped. If you must miss more than one quiz or the last quiz, then an advance arrangement must be made with the instructor.
4. Late homework, reports, and projects will not be accepted.
5. If a student does not participate in an active fashion in the completion of a homework, report, or project that was carried out in teams, his/her name must not appear on the cover page of that assignment. If this rule has been violated, all the team members will receive a grade of zero for that particular assignment.
6. Grading of all materials will be strongly influenced by readability, grammar, and overall quality of presentation.
7. Requests for re-grades on homework, reports, or projects must be submitted in writing within one week of the class in which we return the item on which you question the grade. In this event, the entire homework/report/project will be re-graded with possible adjustment in either direction.
8. Items not claimed the first time we return them to the class must be picked up in the prof's office within two weeks of the class in which return was attempted. Items not picked up after two weeks may be disposed of.
9. Class Cancellation Policy: If a class is missed due to weather or instructors' absence, anything originally planned for that class will occur during the next class session.

Appendix II

AEV Program Cost and Income - minimum enrollments - just Ford employees																
	Term II	Term III	Term I	Term II	Term III	Term I	Term II	Term III	Term I	Term II	Term III	Term I	Term II	Term III	Term I	5YR TOTALS
FY	2010	2010	2011	2011	2011	2012	2012	2012	2013	2013	2013	2014	2014	2014	2015	
cohort	30	30	30	25	25	25	20	20	20	25	25	25	25	25	25	
Tuition Rate per Cr Hr	\$ 565	\$ 565	\$ 565	\$ 831	\$ 831	\$ 831	\$ 1,121	\$ 1,121	\$ 1,121	\$ 1,177	\$ 1,177	\$ 1,177	\$ 1,236	\$ 1,236	\$ 1,236	
Courses taught per term	1	3	3	2	2	3	2	2	3	2	2	3	2	2	3	35
Courses taken per student per term	1	1.5	2	2	1	2	2	1	2	2	1	2	2	1	2	25
tuition paid by term	\$ 50,850	\$ 81,360	\$ 101,700	\$ 124,583	\$ 62,251	\$ 124,583	\$ 134,549	\$ 67,275	\$ 134,549	\$ 176,595	\$ 88,298	\$ 176,595	\$ 185,425	\$ 92,713	\$ 185,425	\$ 1,786,792
cost of instruction (instructor stipend)	\$ 5,000	\$ 12,420	\$ 12,780	\$ 9,260	\$ 8,520	\$ 13,230	\$ 9,410	\$ 8,820	\$ 13,770	\$ 9,450	\$ 9,180	\$ 14,400	\$ 9,800	\$ 9,500	\$ 15,120	\$ 160,800
course development packages (total 7) stipends or course releases	\$ 10,000	\$ 20,000	\$ 5,000													\$ 35,000
travel - out of town	\$ 2,000	\$ 2,000	\$ 2,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 18,000
travel - to Ford	\$ 200	\$ 600	\$ 600	\$ 400	\$ 400	\$ 600	\$ 400	\$ 400	\$ 600	\$ 400	\$ 400	\$ 600	\$ 400	\$ 400	\$ 600	\$ 7,000
transformation to on-line delivery				\$ 15,000	\$ 20,000	\$ -										\$ 35,000
total budget	\$ 17,200	\$ 35,020	\$ 20,380	\$ 25,560	\$ 29,920	\$ 14,830	\$ 10,810	\$ 10,220	\$ 15,370	\$ 10,890	\$ 10,580	\$ 16,000	\$ 11,200	\$ 11,000	\$ 16,720	\$ 255,800
net direct income	\$ 33,650	\$ 46,340	\$ 81,320	\$ 98,923	\$ 32,371	\$ 109,753	\$ 123,739	\$ 57,055	\$ 119,179	\$ 165,706	\$ 77,718	\$ 160,596	\$ 174,225	\$ 81,713	\$ 168,705	\$ 1,530,992
total net per academic year		\$ 79,990		\$ 212,614			\$ 290,546			\$ 362,603		\$ 416,534	\$ 168,705	\$ 1,530,992		

Appendix III – Approved UDM AEV 5-Year Budget

UNIVERSITY OF DETROIT MERCY
UNRESTRICTED
BUDGET SUMMARY

PROGRAM:

Advanced Electric Vehicles (AEV) Graduate Program

ACCT CODE	LINE ITEM DESCRIPTIONS	Proposed
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6120	ADMIN SALARIES	0
6130	F/T FACULTY SALARIES	
6131	F/T FACULTY OVERLOAD	190,800
6133	PART TIME FACULTY	15,500
6132	OFF TERM STIPEND	13,825
6135	SUMMER INSTRUCTION	
6136	SUMMER INSTRUCTION	
6145	FULL TIME STAFF	0
6146	PART TIME STAFF	
6117	WORK STUDY STUDENTS	
6119	NON WORK STUDY STUDENTS	5,000

PERSONNEL SUB-TOTAL:	225,125
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7100	GENERAL SUPPLIES
7113	XEROX
7114	PRINTING
7120	DUES, MEMBERSHIPS
7130	BULLETINS, CATALOGS
7140	POSTAGE
7150	TELEPHONE
7175	FUEL
7176	SMALL TOOLS & EQUIP
7160	MAINTENANCE CONTRACTS
7165	REPAIRS

SUPPLIES SUB-TOTAL:	0
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POSN#	POSITION TITLE	INCUMBENT	NOTE	FTE	SALARY
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ADMIN SALARIES

0.00	0
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FULL TIME STAFF

0.00	0
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7230	CONFERENCE/SEMINAR FEES	
7210	OUT OF TOWN TRAVEL	18,000
7220	LODGING & MEALS	
7223	RECEPTIONS	
7234	LOCAL TRAVEL	7,000
7235	AUTO EXPENSE	

TRAVEL SUB-TOTAL: 25,000

7310	ADVERTISING	
7374	MEDICAL EXP	
7339	RENTALS AND LEASING	
7372	PROFESSIONAL SERVICES	
7371	HONORARIUMS	

CONTRACT SERVICES SUB-TOTAL: 0

7930	BOARD	
7931	ROOM	
6410	FRINGE BENEFITS	18,711
7913	COST RECOVERY	

OTHER SUB-TOTAL 18,711

7821	BUILDING IMPROVEMENTS	
7831	EQUIPMENT	
7835	COMPUTERS	4,500

PROPERTY SUB-TOTAL: 4,500

GRAND TOTAL: 273,336

NOTES:

Estimated Revenue:

Tuition	1,786,790
Fees	
Other	
Gross Revenue	<u>1,786,790</u>
Net Revenue	<u>1,513,454</u>

Appendix IV – Ford Approved Plan



Engineering Core Competencies/ Ford Design Institute



University of Detroit Mercy

Program Name: Advanced Electric Vehicles Graduate Certificate Program
or AEV concentration in Masters in Product Development Program

Program Type: Graduate Certificate or concentration in Masters Program

Required Courses:

- Fundamentals of Advanced Electric Vehicles (AEVs)
- Controls Modeling and Design for AEV
- Electric Drives/Electromechanical Energy Conversion

Elective Courses:

- Power Electronics for Electric Vehicles
- Energy Storage Systems
- Innovation and System Architecture for AEVs
- System Engineering for AEVs

