# AC 2009-1589: A MECHATRONICS PROGRAM AS AN ALTERNATIVE TO SEPARATE PROGRAMS IN ELECTRICAL AND MECHANICAL IN DEVELOPING COUNTRIES

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# A Mechatronics Program as an Alternative to Separate Programs in Electrical and Mechanical in Developing Countries


## Abstract

Education is one of the key infrastructure components needed to sustain peaceful development and maintain security, so that the Islamic Republic of Afghanistan (Afghanistan) can meet the critical needs of its people as well as participate fully in the international community. Higher education, in particular engineering education, is at a crucial crossroads. A comprehensive and functional higher education system for engineering students will provide Afghanistan with the capacity to develop its infrastructure as well as expanding its role in the international community.

The partnership between University of Hartford, USA and Herat University in Afghanistan began in August 2007. This partnership strives to develop and implement a program to strengthen and modernize engineering education at Herat University. Phase I of the program includes a number of activities such as curriculum review and revision, faculty development, and laboratory upgrading. Currently we are midway in Phase I. Phase II focuses on expanding the current undergraduate engineering program to areas beyond civil engineering that are critical for the continued development of infrastructure and capabilities in Afghanistan.

While reviewing and planning to expand the current engineering program to areas beyond civil engineering, the focus evolved to adding two new undergraduate engineering programs, one in electrical and one in mechanical. However, after further evaluation of the needs, priorities, financial constraints and infrastructure support, it was obvious that two programs would create a burden that would not be feasible at this time. A program in Mechatronics emerged as the best fit to meet the current and near future needs and augments the current offerings in civil engineering. Approval has been received for a Mechatronics Engineering program from the Ministry of Higher Education in Afghanistan and the financial support from the World Bank.

This paper will focus on the needs, resources and plan to develop a program in Mechatronics at HERAT University. The paper will focus on the preparation for laboratories, equipment, curriculum, faculty, etc. including the difficulties in helping to start a new program in another country.


## Introduction

The College of Engineering, Technology and Architecture at University of Hartford offers several ABET accredited programs in engineering, technology and architecture. The University of Hartford is a small private institution located in West Hartford, CT. The relationship between University of Hartford, USA and Herat University in Afghanistan began in the summer of 2006 under the framework of the Strengthening Higher Education Program (SHEP). The program is supported by the Ministry of Higher Education, Islamic Republic of Afghanistan, and is funded through a grant from the World Bank. The steering committee for SHEP selected University of Hartford to assess the current situation at Herat University and propose ways to improve

engineering education. A team of faculty from University of Hartford traveled to Kabul and Herat (western part of the country), and assessed the conditions of the Faculty of Engineering at Herat University and proposed means of improving engineering education. Shortly after the visit, a partnership was proposed to University of Hartford to help in strengthen the engineering education at Heart in implementing the recommendations. During 2007, a University of Hartford faculty traveled to Herat University several times to work with professors, gathering information on lab equipment, proposing curriculums and finalizing the agreement. In 2008, a team of faculty from University of Hartford again traveled to Herat University to assess the progress and work with the faculty of engineering on Phase II. Currently, we are nearing the end of Phase I and working towards implementing Phase II.

Before the war, engineering education in Afghanistan was being delivered in two centers, Kabul University and Kabul Polytechnic Institute. The Faculty of Engineering at Herat was established as part of the Faculty of Science in 1956. At the end of 1959, the first group of graduates received their Bachelor of Science in Engineering degree from the Faculty of Engineering. Through a contract with the United States Agency for International Development (USAID) and the then Royal Government of Afghanistan, the University of Wyoming assumed the responsibility for guiding the new faculty. The University of Wyoming supplied the staff members and equipment and established a four-year "general" engineering program. In recent years, a number of universities have been established that deliver engineering education, mainly in the field of civil engineering. Five of these universities have the semblance of an engineering program, and the rest are engineering in name only.

Two systems of engineering education are followed in Afghanistan: the Russian model and the American model. Kabul University, Herat University, and Kandahar University follow the American model while Kabul Polytechnic, Balkh University, and Nangarhar University follow the Russian model. In the Russian model, students are trained to specialize in different fields of civil engineering. In the American model, students receive a broad background in different fields of civil engineering. Specialization is gained through on-the-job training or further education at the master's level. At this time, there is no equivalency or coordination between the two systems. If a student wishes to transfer from one university system to another, he/she may be facing an impossible task.

In recent years, students are remaining in Afghanistan to attend high school and opting to attend on of the national universities. This increase has been noticeable in Civil Engineering, and students are now looking for other engineering options. This increased the urgency to offer additional programs such as electrical and mechanical engineering.

**Curriculum and faculty development**

Phase I of the program includes a number of activities such as review and revision of the Civil Engineering curriculum, faculty development, and laboratory upgrading. Faculty development is an essential part of this phase; of the twelve full-time engineering faculties, eleven have bachelor's degrees. A logical choice is to provide advanced degrees for the faculty by bringing them to University of Hartford to earn a Masters degree. The University of Hartford offers a Master's of Engineering degree with specializations in Civil, Electrical, Environmental and

Mechanical. Currently eleven faculty members are enrolled in this program with more to join soon. The majority, now, are enrolled in the civil track. However, those who are preparing to teach in the mechatronics program are taking a combination of mechanical and electrical courses. These graduates will be able to teach all the courses in the new Mechatronics program. To ensure the continuity of engineering education at Herat University, enrollment of faculty in the masters program was staggered.

A job-shadow experience for senior level faculty was developed. Two senior faculty members from Herat University will shadow the Associate Dean and other faculty members at University of Hartford over the course of one month. In September 2008, the Dean of the Faculty of Engineering spent a month at University of Hartford in the shadowing program. Another senior faculty will spend the month of June 2009 at University of Hartford as part of the shadowing program too. These activities include:

- Observe engineering classes at all levels;
- Assist in teaching courses to develop pedagogical models and options;
- Develop courses for Herat University, with emphasis on distance learning for future shared projects with University of Hartford;
- Observe, study, and practice administrative and management skills, including ongoing faculty and curriculum development and revision;
- Development and managing a course assessment process; and,
- Practice academic advising.

Currently, a new revised curriculum in Civil Engineering is being phased in at Herat University[1]. The civil engineering laboratories are being upgraded and developed to meet the needs of the new curriculum.

Phase II focuses on expanding the current undergraduate engineering offerings. These new offering are critical for continued development of Afghanistan. The undergraduate areas of interest for Herat University are: Architecture, Electrical, and Mechanical Engineering. While reviewing and planning to expand the current engineering program to include electrical and mechanical engineering, it was clear that this step would be difficult to achieve. Establishing two new engineering programs needing specialized laboratories would be a financial burden on a country struggling to rebuild its infrastructure and achieve security. Additionally, finding the financial support and expertise to hire new faculty would be nearly impossible. Hence, a program in Mechatronics emerged as the best solution to supplement the current offerings in civil engineering. The appropriate approvals from the Ministry of Higher Education in Afghanistan have been secured for the Mechatronics program with financial backing from the World Bank. The addition of an Architecture Engineering program is under consideration, since architectural and civil engineering would utilize similar facilities and some courses.

**Mechatronics Engineering, the curriculum**

According to Wikipedia, Mechatronics (or *Mechanical* and *Electronics Engineering*) is the "combination of mechanical, electronic and computer engineering. The purpose of this interdisciplinary engineering field is the study of automata from an engineering perspective and

serves the purposes of controlling advanced hybrid systems". Figure 1 below describes the various fields that make up Mechatronics[2].

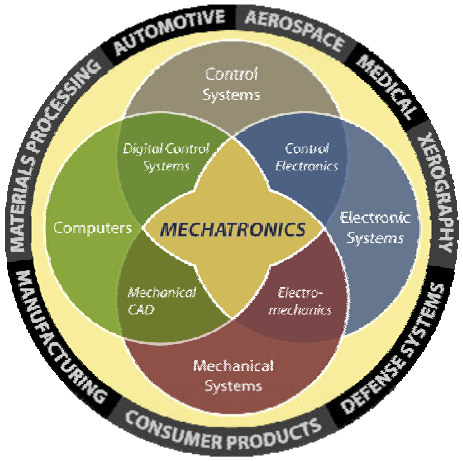


Figure 1 Aerial Venn diagram from RPI's website describes the various fields that make up Mechatronics

We consider it a multidisciplinary major that generates simpler, economical, reliable, and versatile systems. Such a major would serve developing countries, such Afghanistan, in several ways.

- Professionally, it would prepare graduates with a background in more than one area, electrical and mechanical, that function well in both electrical and mechanical engineering job markets.
- Financially, it is easier to support one program than to support two distinct programs for a country that is trying to build its infrastructure. and,
- Educationally, an interdisciplinary program is an excellent step toward preparing young engineers for jobs that are more operational than research, design, or manufacturing oriented.

Afghanistan is in need of engineers who have a diverse background and who could work in different environments. The coursework can be drawn from typical electrical and mechanical engineering related courses; with additional courses added to the depth and range of current offerings.

The guidelines for establishing the curriculum for the Bachelors of Science in Mechatronics were:

- the ability of Herat University to sustain the offering and the support for such a curriculum;
- the curriculum should serve the country of Afghanistan in its effort to rebuild its infrastructure;
- the graduates should have the ability to function in both mechanical and electrical engineering jobs; and
- The students should have the ability to focus on certain topics if desired.

Several universities in the United States offer undergraduate program in Mechatronics and several international universities do the same. A review of several existing Mechatronics programs, domestically and internationally, was conducted by a team of faculty including an expert in Mechatronics and an author of a Mechatronics book. The offerings at Southern Polytechnic State University and California State University, Chico[3, 4, 5, and 6] are examples of such programs. While some programs offer a concentration in Mechatronics or a minor (like our college), we believe that a distinct program is an excellent fit for Afghanistan. Keeping in mind the mission of the Faculty of Engineering at Herat University to educate a generation of engineers with the technical backgrounds needed to address the countries advancement, a draft curriculum was established. The curriculum was presented to the Faculty of Engineering at Herat University in June 2008 in Herat. The two teams worked to finalize the curriculum see Table 1.

Laboratories are integrated into the curriculum in various levels of the curriculum and are associated with the following courses: Tech Drawing I, Physics I and II, Digital Systems, Chemistry I, Strength of Materials, Circuit Analysis, Elements of Machine Design, Mechatronics I and II, and Machinery. Technical Elective courses in Safety Engineering, Renewable Energy, Construction Management, and Quality Control Concepts will be offered.

The curriculum includes the core courses of engineering: mathematics, basic sciences and engineering sciences. Although not typically considered humanities/social sciences electives, religion courses include cultural and ethical content. In combination with the history and non-technical courses, the curriculum satisfies the humanities/social sciences requirement of the bachelor's degree. The technical courses are a combination of sophomore and junior level courses in electrical & mechanical engineering such as circuits, electronics, digital design, statics, dynamics, strength-of-materials, thermo-fluids and machine design. Instrumentation, microprocessor, control systems, Mechatronics I and II, and real-time robotics courses provide the students with the background and the skills in electrical engineering. On the other hand, elements of machine design, manufacturing processes, machinery, and solid modeling courses provide the necessary background for mechanical engineering. During the senior year, students choose courses that fit their individual interests and prepare them for a professional career. Students, however, may select a combination of courses from both specialties. Students, as mentioned above, will have to select two courses as technical elective, one as non technical elective, take a course in engineering economy and do a required senior design project.

It is our vision that the proposed Mechatronics Engineering program, due to its diversity in electrical and mechanical courses, will better prepare students for the job market that is available in Afghanistan.

**FRESHMAN YEAR**

| **FIRST SEMESTER** | | | | **SECOND SEMESTER** | | |
|---|---|---|---|---|---|---|
| IS 101 | Islamic Studies | 1 | | IS 102 | Islamic Studies | 1 |
| M 144 | Calculus I | 4 | | M 145 | Calculus II | 4 |
| ES 220 | Technical Drawing I | 3 | | ES 115 | Computer Prog. | 3 |
| ES 141 | Intro to Engineering | 4 | | PHY 112 | Physics I | 4 |
| ENG 110 | English I | 4 | | ENG 111 | English II | 3 |
| HIS 110 | History of Afghanistan | 1 | | ES 122 | Technical Drawing II | 3 |
| | Total: | 17 | | | Total: | 18 |

**SOPHOMORE YEAR**

| **THIRD SEMESTER** | | | | **FOURTH SEMESTER** | | |
|---|---|---|---|---|---|---|
| | Islamic Studies | 1 | | | Islamic Studies | 1 |
| CH 110 | Chemistry I | 4 | | | Digital Systems | 4 |
| M 240 | Calculus III (Calculus of Several Variables) | 4 | | M 242 | Differential Equations | 3 |
| PHY 113 | Physics II | 4 | | EE 210 | Circuit Analysis | 3 |
| ENG 112 | English III | 3 | | ES 212 | Strength of Materials | 4 |
| ES 110 | Engineering Mech. I (Statics) | 3 | | ES 211 | Engineering Mech. II (Dynamics) | 4 |
| | Total: | 19 | | | Total: | 19 |

**JUNIOR YEAR**

| **FIFTH SEMESTER** | | | | **SIXTH SEMESTER** | | |
|---|---|---|---|---|---|---|
| | Islamic Studies | 1 | | | Islamic Studies | 1 |
| | Probability and Statistics | 4 | | | Microprocessors | 3 |
| | Thermo-Fluids | 4 | | | Mechatronics I | 4 |
| | Electronics Circuits | 3 | | | Control Systems | 3 |
| | Elem. of Machine Design | 4 | | | Manufacturing Processes | 3 |
| | Instrumentation | 3 | | | Machinery | 4 |
| | Total: | 19 | | | Total: | 18 |

**SENIOR YEAR**

| **SEVENTH SEMESTER** | | | | **EIGHTH SEMESTER** | | |
|---|---|---|---|---|---|---|
| IS 103 | Islamic Studies | 1 | | IS 104 | Islamic Studies | 1 |
| | Mechatronics II | 4 | | | Technical Elective | 3 |
| | Real Time Robotics | 3 | | | Non Technical Elective | 3 |
| | Power Systems | 3 | | | Technical Writing | 3 |
| | Solid Modeling | 3 | | | Engineering Economy | 3 |
| | Technical Elective | 3 | | | Design Project | 4 |
| | Total: | 17 | | | Total: | 17 |

**Total Number of Credits: 144**

Table 1 The Approved Mechatronics Engineering Curriculum

**Implementation and Obstacles**

Designing a curriculum is a relatively easy task compared to implementation. It is easy since it was a team effort with members who are experts in designing new programs. However, designing and executing the support facility for such program in a foreign land is extremely challenging; especially given the location of Herat University, and the security conditions in a war torn country.

We, the University of Hartford team, concluded that in order to support such a program in Mechatronics Engineering, several laboratories needed to be established in addition to the existing laboratories:

- a Circuit/Electronics/Digital Laboratory
- a Mechatronics Laboratory
- a Computer Laboratory for teaching
- a Distance Learning Facility to provide real-time support for faculty.

A detailed design for each of the laboratories was developed and all specifications were provided, including cost estimate and quantities of each item including furniture. For example, how many function generators, oscilloscopes, computers, etc. were provided, with a blueprint of the layout for each laboratory (see Table 2 for a list of proposed equipment). All the laboratories will be housed in the Faculty of Engineering building, part of a new campus, which also houses the Computer Science Department.

In addition to the typical obstacles, language and Academic Calendar[7], we faced several other issues that were not expected. In Summer 2008 when the team visited Herat University to follow up on the progress, it discovered that nothing was accomplished except for a few equipment bids. While looking for a quick action plan, we discovered that furniture was the main problem. The lack of reliable suppliers and the luxury of ordering from a catalog do not exist. The market is saturated with personal computer desks that are fancy and expensive; however, they are totally useless in a computer laboratory. After further investigation, visiting the market several times, and talking with a carpenter and blacksmith, we decided to design our own computer desks, laboratory benches, and library tables. Detailed blueprints of furniture were developed, and within few days the tables were delivered for a fraction of the cost. A sample of the layout of labs and the design of furniture will be presented at the conference.

While reviewing the bidding contracts for equipment, price hiking was obvious; each item was two to three times the typical price in the United States. In reality, the bids came from local offices that solicited information from foreign sales representatives from the surrounding countries. After each sales office added its share, the price was doubled or tripled and the concept of "Educational Discount" simply does not exist. At the time of editing this paper, we are still trying to find ways to purchase some of the equipment for a reasonable price.

In order to promote program improvement and modernization, a workshop on assessment that covers topics such as program objectives, expected outcomes, and course outcomes was conducted at Herat University. The workshop was to encourage faculty to start thinking about establishing clear and achievable objectives and outcomes based on the vision that was provided

at the start of this partnership. Currently, we are working with the faculty, who are pursuing graduate degrees at University of Hartford, to finalize the objectives and outcomes and establish an assessment plan for the new program.

Additionally, to promote collaboration between the faculty at University of Hartford and Herat University, a distance learning facility is being implemented at Herat University. Soon, faculty and students from both universities will be able to collaborate and work on projects together.

**Herat University**
**Faculty of Engineering**

**Mechatronics Laboratories**
**(Needs and Specifications for the additional laboratories)**

**1. Computer Teaching Lab**

| Item | Quantity | details |
|---|---|---|
| Computer Desk (Model A) | 9 | |
| Computer Desk (Model B) | 9 | |
| White Board | 1 | |
| Computer Screen | 1 | |
| Computers | 21 | |
| LCD Projector | 1 | |
| Printer | 1 | |
| Safety Power Extension Cord Cover (with 2 tracks) | 25 ft |  |
| Chairs | 21 | |
| VGA Cable 25ft | 1 | From PC to projector |
| Power Extension Cord 25 ft | 1 | From power to projector |
| Power Extension Cord 20 | 3 | |
| Power Extension Cord 15 | 4 | |
| Power Extension Cord 10 | 5 | |
| Power Strip | 6 | 4 outlets each |
| Network Cable | ? | Ask the IT group |
| Hubs | ? | Ask the IT group 2 (16 each jacks) or 3 (8 each jacks) |
| UPS (if needed) | 12 | |
| Clean Slate | 21 | |

**2. Distance Learning Lab**

| Item | Quantity | Note |
|---|---|---|
| Conference Table | 1 | |
| Computer Desk | 1 | |
| Chair | 11 | |

| | | |
|---|---|---|
| PC | 1 | |
| Webcam (best available) | 1 | |
| Electronics White Board | 1 | |
| Safety Power Extension Cord Cover (with 2 tracks) | 20 ft |  |
| VGA Cable (M-M) 25ft | 1 | From PC to projector |
| Power Extension Cord 25 ft | 1 | From power to projector |
| Power Strip | 6 | 4 outlets each |
| USB Cable | 10ft | |
| Projector | 1 | |
| Set of Speakers | 1 | |

**3. Mechatronics Lab**

| **Item** | **Quantity** | **Note** |
|---|---|---|
| Lab bench | 8 | |
| Computer Desk | 1 | |
| Computers | 9 | |
| LCD Projector | 1 | |
| Data Acquisition Cards | 9 | |
| Stools | 16 | |
| White Board | 1 | |
| Chairs | 1 | |
| VGA Cable 25ft | 1 | From PC to projector |
| Power Extension Cord 25 ft | 1 | From power to projector |
| Power Strip | 9 | 8 outlets each |
| Power Extension Cord 10 | 4 | |
| UPS (if needed) | 9 | |
| Printer | 1 | |

**4. Circuit/Electronic/Digital Lab**

| **Item** | **Quantity** | **Note** |
|---|---|---|
| Lab Bench | 8 | |
| Stools | 16 | |
| White Board | 1 | |
| Power Strip | 8 | 8 outlets each |
| Power Supplies | 8 | |
| Oscilloscopes | 8 | |
| Multimeters | 8 | |
| Function Generators | 8 | |
| Circuit/Electronic/Digital Board | 8 | |
| Power Extension Cord 10 | 4 | |

Table 2 List of Proposed Equipment

## Conclusion

A comprehensive and functional higher education system for engineering students will provide Afghanistan with the capacity to build and develop its infrastructure as well as expand its role in the international community. The partnership between University of Hartford and Herat University resulted in strengthening and modernizing the current Civil Engineering program, and the establishment of a Mechatronics Engineering curriculum. The development of an Architecture Engineering is in the planning phase. This paper discussed the needs, the resources and the plan to offer a program in Mechatronics. It also discussed the challenges and the obstacles faced while planning and implementing this program. Enrollment in the Mechatronics program is slated to begin in 2010. While there are issues to resolve, we are confident that the facility will be in place and operational in time for students to use.

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