Session 1566

Building a Hands-on Mechatronics Lab

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Abstract

Practical hands-on experience is critical for the engineering student of the new millennium. The demand on the educators of today is to prepare students to meet the challenge that tomorrow's industry will bring.

This paper presents a methodology used to design and build a mechatronics laboratory. It can help those involved with the responsibility of designing and constructing a mechatronics laboratory. The paper provides the reader with an "out of the box" strategy to meet a shortened laboratory implementation requirement, while providing students with a hands-on educational experience.

This paper presents general guidelines for designing a modular laboratory experimental environment. The laboratory designer, reader, will be provided with a methodology to achieve a laboratory environment covering a breadth of electromechanical applications.

Industrial and scholastic benchmarking are a few tools used in identifying the goals of the laboratory experiments. Additional goals of increasing student involvement, student communication and technical skills are also defined. The paper will address methods of involving the students during the construction process. It offers ways to involve the students to work together in multi-disciplinary teams, similar to a real-life work experience.

In short, the paper offers an innovative approach to start-up a mechatronics laboratory. It provides an approach to increase the educational experience of the mechanical engineering student and provide them with the skills to meet the demands of a dynamic industry.

I. How would a hands-on mechatronics laboratory benefit the students?

The current demands on entry-level engineers, by prospective employers, are for the new hire to quickly transfer from the classroom student into a contributing team member. The graduating engineer should be well prepared to take on the new challenges in the work place.

"Employers have expressed strongly that our graduate students should be better prepared to relate concepts learned in system modeling and controls courses to real modeling and control applications"[1].

Previous roles of the mechanical engineer in industry have been in positions such as mechanical design, component, quality, manufacturing and heating ventilation and air conditioning. These roles have historically required that the mechanical engineer have a specific skill set.

The skill set required of the mechanical engineer has expanded with the increased utilization of automated data collection methods and manufacturing automation. Additional important skills now include the ability to embed a computational element into a mechanical product or process[2].

Corporate goals to increase product quality and performance can be obtained by implementing process changes based upon in-line data collection in the manufacturing and testing environment. A mechanical engineer operating in this environment is often required to implement electromechanical control systems for data acquisition and in-line process improvements.

The surge of industry implementing the concurrent engineering philosophy[3] has provided the fuel for an increasing formation of cross-functional teams. The cross-functional or multidisciplinary teams are formed to design new products, address quality issues etc. The team members, each representative of a different functional group within the organization, bring to the table a specific skill set.

The mechanical engineer should be well prepared to successfully operate within this mixed discipline environment. A mechatronic lab would help better prepare today's engineering students in this facility.

The entry level mechanical engineer would be well prepared to successfully adapt to the new work environment provided that he/she had hands-on experience of the fundamental components of the electromechancial system design and integration. Hands-on experience is obtained by involving the students heavily in building and preparing the modular laboratory workstations as well as their participation in the mechatronics class itself.

- Why an “out of the box” strategy?

Resources are normally limited and often present themselves as obstacles in achieving the laboratory development goals. It is the author’s intention to provide alternative methods of overcoming obstacles in the laboratory development and implementation process.

Some of the methods are considered “out of the box” as they present options “outside” of the standard operating procedures.

II. What is a modular laboratory?

Modularity refers to the separation of the sub-components of the mechatronic system into functioning modules.

For example, a mechatronics system consists of the fundamental mechatronic system building blocks such as: communication technology, controllers, programmed logic (Code), user interfaces, sensors and drivers.
The authors’ laboratory is being built utilizing the modular approach.

Why is it important to have a modular mechatronics laboratory?

<u>Any complex mechatronic system can be broken down into the fundamental components or building blocks</u>. These various independent building blocks can serve as tools for classroom student performed experiments.

The independent building blocks can be combined to build a larger system. In doing so, this increases the student practical knowledge of the individual building blocks as well as the larger assembled mechatronic system.

One could anticipate that a student would now be able to assemble many different building blocks into a unique larger mechatronic system.

There are seven building blocks / modular components: Controllers, Logic (Code), Sensors, Drivers, Integration, User Interface, Calibration, and Communication Protocol.

III. Planning Phase

To meet the shortened time schedule, it is critical to invest sufficient time in planning well. The typical planning cycle involves the following top-level steps:

1. Obtain a sponsor, faculty support and interdisciplinary faculty interest
2. Recruit Team members
3. Clearly define Mechatronics lab goals
4. Outline Work Breakdown Structure (WBS) to meet laboratory goals
5. Assign responsibility of WBS tasks to team members.

1. Obtain a sponsor, faculty support and interdisciplinary faculty interest.

The sponsor is typically the department head, whose role is to review, advise and validate decisions made during the laboratory development and implementation process.

Faculty from other schools and departments are encouraged to join as active participants. This provides additional student and instructional resources in the development and implementation phase of the project. Involving faculty of other departments and schools will facilitate delivering an interdisciplinary mechatronics laboratory.

The individuals from various departments such as Computer Science, Electronic, Electrical, Mechanical, Manufacturing Engineering and/or Industrial Engineering are recommended to actively participate. Other engineering and scientific disciplines offer potential significant contributions.

2. Recruit core team members.

The initial pass at assembling the team members should involve those individuals representing various functional areas. The core team members are those individuals who are responsible for completion of those items listed in the work breakdown structure.

A bi-weekly status meeting with recorded minutes is strongly recommended to track the progress of the project. The minutes along with the WBS can be displayed on project specific web pages.

The core team organized in this project consisted of a Mechanical Engineering (ME) faculty advisor and two ME graduate students. Each member brought to the table a myriad of professional experiences and technical skills. Key responsibilities of these core team members are to meet the schedule and organize activities that are involved with completion of the tasks. Some of these tasks include recruiting supporting team members to accomplish various lower level tasks as listed in the WBS.

3. Clearly define the laboratory objective statement and project scope.

It is the responsibility of the core team and sponsor to define the laboratory objective and project scope.

An illustrative example helps in defining the laboratory objective statement and project scope.

Let’s step back and inspect our long-term goals and short-term laboratory goals. The long-term goals are to have a full functioning multidisciplinary mechatronics lab. The laboratory will provide a breadth of industry applications spanning industries such as: agriculture, biomedical, space exploration and manufacturing.

- The scope of this paper pertains to the short-term goals. The following statement defines the author's short-term goal. "To deliver a functioning modular mechatronics laboratory with sufficient experiments for a semester class by September 2000 at a cost not to exceed $1,000 in material costs".

The objective statement offers specific manageable initiatives, which accumulate to achieve the goals[4] and address the aspects of the project Cost, Schedule & Performance (CSP). The objective statement should be in line with departmental goals.

- The scope of the laboratory development project has been divided into three areas: Deliverables, Measures and Exclusions. The scope organizes the laboratory goals into a useable framework to establish the WBS.

The WBS, as shown in Table 2, is a detailed list of outlined tasks to meet the Deliverables and measures as defined in the short-term project scope. Table 1 presents a defined list of the project scope.

4. Outline Work Breakdown Structure (WBS) to meet laboratory goals

The WBS outlines the tasks required to accomplish the goals defined in step three which is shown in Table 2 for illustrative purposes.

The WBS consists of task definitions, responsible task owner's name and a target completion date. It is the responsibility of the core team to develop the WBS.

Deliverables:
Documentation of university mechatronics lab benchmarking results
Documentation of industry feedback on expectations of new graduates.
A minimum of (4) modular laboratory experiments built, exhibiting fundamentals of mechatronics
Brief summaries of (4) experiments built for student laboratory manual.
Establish a plan for donations of materials/equipment from industry.
A documentation package of learned technical information relevant to specs etc.
List of Trade Shows and Expositions etc.
Measures:
Involve engineering student teams in the lab development process
Materials purchased for the build process of the laboratory are NTE $1,000.
Meet the standards / requirements for the engineering curriculum class requirements
Establish a laboratory environment to prepare students to meet industry needs.
Exclusions:
Does not include accrediting process for the class.

Table 1. Results of Scope Definition

The WBS provides a global status overview of the project. A time scheduling tools, Such as a Ghant chart, can be used concurrently to facilitate tracking against proposed schedule.

5. Assign responsibility of WBS tasks to team members.

Once the WBS is established, ownership of various tasks and subtasks needs to be assigned. The task owner coordinates efforts to complete the assigned task by the target date. The core team member will obtain additional support and sub team members as needed.

It is beneficial to encourage additional undergraduate and graduate students in completing the tasks of designing and building the laboratory. Table 2 shows the various activities required in this process. Involving additional students promotes student technical and professional growth. In doing so, the mechatronic multidisciplinary laboratory environment is promoted at the development stage.

IV. WBS Elaboration

The distinctive aspect of this paper is that it offers an “out of the box” strategy in designing a modular mechatronics laboratory.

Observing the ‘Sensors workstation’ can see an example of a modular laboratory experiment. A Sensors Workstation is a compilation of various linear and non-linear sensors, which are installed into a panel. The panel contains components such as the appropriate power supplies and assorted digital and analog displays.

The experiment requires the student to investigate the functionality of the provided sensors, identify the sensor limitations and recommended applications. The Sensors workstation provides a hands-on experience for the student in the sensor selection process.

Similarly, the other building blocks can be presented in a modular fashion. The ultimate laboratory goal is to provide the student with the fundamental knowledge of mechatronic system design and system integration.

The task of educational and industrial benchmarking establishes a reference from which the educational laboratory efforts can be directed. Some of the benchmarking activities involve attending trade shows and researching current industry related mechatronic technologies.

Work Breakdown Structure (WBS) for the Development Of The Mechatronics Laboratory Development Process:

Task No:	Target Date:	Status:	Name:	Task Definition:
1				I. Collect laboratory materials
2				A. Collect inventory of materials & resources currently available
9				B. Collect scrapped material from
10			All	1 Organizations/Industry scrapping old manufacturing equipment
11			SK/SMO	2 Organize student teams to dismantle equipment
12				C. Collect Test & Measurement Instrumentation
15				D. Collect Experimentation / Modular Lab equipment
16				1 Collect Sensors
17				2 Collect drivers
18				3 Communication: wireless, RS232 etc, Optical,.
19				4 micro controllers
20				5 PLCs
21				6 PC control H/W and S/W
22				7 Coordinate guest speakers to come to campus re: educate the lab team on application
25				E. Educate lab developers per hdw
28				II. Establish Laboratory requirements/expectations
29				A. Identify curriculum requirements to satisfy engineering lab accreditation r requirements
30				B. Identify Engineering school goals or mission statement
31		Support Needed		C. Perform scholastic benchmarking from other accredited respectable universities (lab specs):
32		Support Needed		D. Perform benchmarking of industries needs (university customer input):
33		Support Needed		1 Technical group industry/education group to carve out curriculum focus
34		Support Needed		2 Perform audit of industries needs: call various industries to discuss
38			SK/SMO	E. Collect student input (customer input) [SWE, ASME]
39			SK/SMO	1 Attend student engineering meetings and spread interest
40			SK/SMO	2 Perform a group discussion braisnst. on fun project for students
41			SK/SMO	3 Promote studnt involvement: need student support and activities they are a val resource and benefit greatly from hands-on experience
42				F. Establish Faculty support
46				G. Identify outside resources (faculty who are interested to promote cross fxnl)
47				III. Establish Laboratory scope
48				A. Establish Laboratory expectations / goals
49				1 Based upon the results of section II educational goals s/b established.
50			SMO	B. Build demo experiments and review Lab goals against demo experiments with faculty/advisors/dean

Table 2. Work Break Down Structure (WBS) Example

V. Obtaining Resources

Funding a mechatronic laboratory and developing a budget is a critical component in the starting of a new mechatronics laboratory.

It is recommended to acquire funding via the ’shotgun effect’ while concurrently developing a systematic yet creative approach to acquire money, equipment, and other capital. An example of a creative approach is salvaging scrapped materials from local industries that might be in the process of upgrading their facilities.

The salvaged material can be used in stocking equipment for the newly formed laboratory. The remaining scrapped materials that are not utilized can be sold to local scrap buyers to cover the tooling expenses.

Generally, funding a laboratory comes under either of two categories: academia or research.

Upon completion of establishing the laboratory goals, the next step is to identify which avenues of funding to pursue. For example, if building a research lab were the objective, one would pursue funding from the research allocated funds.

In identifying potential local donors, it is suggested to pursue different avenues. Some leads to start your funding search are the following: the local chamber of commerce, local newspaper, the college career office and the R&D department at the school.

In some cases the donations from industry may be less then desirable. However, it is recommended to accept these donations. There are several unrecognized benefits to used equipment donations such as: a learning experience is provided by the salvaging process (re-engineering) to those students or staff disassembling, the lab acquires salvaged materials, and a relationship is developed with the industry donor.

Limited resources such as time and man-hours often present themselves as obstacles. To address this issue, it may be advantageous to use the local resources available, students. In acquiring student involvement and interest, it is recommended to get the local student professional clubs and future mechatronic students involved. Table 3 lists incentives.

1	Money
2	Units / Credits
3	Master’s Thesis / Senior Project opportunity
4	Department sponsored Technical competitions
5	Extra-credit / Bonus points
6	Job Prospects / Job experiences
7	School involvement
8	Industry sponsored projects

Table 3. Table of incentives to increase student involvement

After students begin using the laboratory, it might be possible to find additional creative approaches in acquiring funding and materials for the laboratory. As the students are developing their understanding of the fundamentals of mechatronics via modular blocks, they will progress to utilizing the fundamentals in increasingly complex systems. During this time the students should be encouraged to find new uses for the laboratory by developing projects that could be funded by industry, government or research organizations.

While the funding is being acquired for the laboratory it is suggested to start slow, plan well, prepare for the unexpected and keep the long-term goal in mind.

VI. Conclusions / Closing

It is the author's belief that this paper offers a practical tool in organizing the events required to design and build a first-pass modular mechatronics laboratory.

The authors are currently waiting for the delivery of materials from donators and are currently in the process of recruiting additional students.

Additionally, they are in the steps of finalizing the relationships between the ME department, other related university departments and local industry.

Implementing the processes established in this paper, the authors would expect a successful multi-disciplined hands-on mechatronics laboratory.

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