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Senior Project based Educational Collaboration between Physics and Electrical Engineering

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Collaborative Advising of Capstone: a Project in the Development of Data Acquisition Systems for the CGA Plasma Lab

Abstract: This paper reports on the results of an educational collaboration between Physics and Electrical Engineering faculty at US Coast Guard Academy (CGA), to advise a senior capstone project. The Physics faculty is constructing a research grade plasma laboratory as a nexus for Project Based Learning (PBL), the development of magneto-hydrodynamic (MHD) physics theory applications to support organization missions, and investigations into plasma physics experiments that are vital to today's scientific challenges. The collaborative project was designed to setup an electronic system for the lab's command, control, and data collection from three plasma experiments being developed in house.

Two Electrical Engineering majors were selected to work on this project with supervision and advising responsibilities shared between Engineering and Physics faculty. Both students were simultaneously enrolled in an Electrical Engineering capstone course that introduced them to project management while simultaneously supplying them with some of the necessary tools to be applied in empirical research in the plasma lab. Unlike many traditional student driven projects, there was a strong emphasis on not only the high caliber research in the lab, but also in the student's development in inquiry based scientific methodology as it applies to the maturity of a comprehensively engineered product.

The collaboration yielded unexpected results. Because of the faculty collaboration on the capstone project, Electrical Engineering was able to develop a system that will become a vital building block for its data acquisition needs for several data acquisition and digital signal processing experiments. There are also further opportunities for Physics and Electrical Engineering to develop systems to support Physics research and teaching, as well as develop experiments for Electrical Engineering labs in Signals and Systems, Controls and Digital Signal Processing.

I. Literature Review

Capstone projects tend to fall into two distinct categories: single discipline faculty advising students from a single discipline (single/single) and faculty from multiple disciplines advising students from multiple disciplines (multi/multi). The single/single model has been the traditional approach to capstone design. Tougaw and Will described this single/single approach to capstones at Valparaiso University prior to 2000 [1]. In this model, students from an engineering department would be assigned a capstone project focused on designing a system that primarily centered on that department's discipline.

ABET and the National Academy of Engineering (NAE) began initiatives that changed how institutions, departments and programs thought about capstone design courses and projects. NAE launched its Engineer of 2020 initiative. The goal was to predict the needs of engineering professionals in the year 2020, and determine what changes in engineering education would be required to meet those needs. *Engineer of 2020* and *Educating the Engineer of 2020* were two NAE publications that signaled the changes and challenges Engineers and Engineering Education were to face [2,3]. Based on this report, global marketplace influence on our economy significantly affects the engineering services. There is a growing need for interdisciplinary and system-based approaches. Engineering will only be successful if it continues to adapt to new trends in providing education to the next generation of students that arms them with the necessary tools in an ever-changing world.

ABET and NAE continue to mandate that engineering programs prepare students to meet these anticipated curricular demands. ABET fundamentally changed the accreditation process with its EC2000 Criteria while Criteria 3 requires student outcomes to be documented. General Criteria 3(d) requires engineering programs to document student ability to function on multidisciplinary teams [4]. Each of these new requirements can be directly implemented and evaluated in a capstone course. Many capstone courses are now multidisciplinary in nature and utilize a multi/multi model approach [5,6,7,8]. Since this model includes faculty and students from multiple disciplines, diverse perspectives are brought to various design project subsystems.

U.S. Coast Guard Academy (CGA) attempted another approach to capstone design. The multi/single model, pairs faculty from multiple disciplines with students from a single discipline. Developed by necessity, the multi/single capstone project model grew organically from previous student and faculty interactions, with a highly technical plasma physics research lab as a catalyst. CGA is a service academy with no graduate programs and currently without a physics major. Capstone students and EE faculty provided an intra-institutional service to physics via the capstone project. In turn, the addition of the physics faculty in this multi/single model created a realistic project management experience. EE faculty roles were similar to those of the other concurrent single/single model projects in the capstone project course (described in section III). Physics faculty introduced an “educational mentor” construct dynamic, by serving as customer, providing subject matter and project management advice, and allowing the students to make genuine mistakes without high-stake consequences.

II. Coast Guard Academy Plasma Lab (CGAPL) Background and Initiatives

The Physics Section at the CGA continues to make steps toward developing our student undergraduate research in magneto-hydrodynamic (MHD) and Plasma Physics with the Coast Guard Academy Plasma Lab (CGAPL). The lab is in its mid stages of development with 8 active undergraduate students and 4 collaborating instructors and staff. CGAPL is a nexus for Project Based Learning (PBL) and undergraduate exploration. Here, MHD applications to Coast Guard missions and investigations into plasma physics experiments, vital for finding solutions to the scientific challenges of today and tomorrow are explored.

At CGAPL we have three main experiments:

MHD Thrusters - MHD is a well-studied area of science utilized in a multitude of disciplines, including fluid dynamics, fusion energy research, astrophysics and solar physics, and spacecraft/vessel propulsion. MHD uses currents that flow through electrically conducting fluids in force balance with magnetic fields to manipulate the flow of the collective fluid. MHD thrusters have been demonstrated in spacecraft and actual seagoing vessels like Japan’s Yamato[9].

CGAPL is exploring the feasibility of using MHD for buoy station-keeping in addition to the chain and sinker, currently used.

Demonstration Discharge Plasma - A Pyrex bell-jar vacuum chamber holds a discharge plasma will be utilized to familiarize new members with general plasma physics and high vacuum fundamentals in the lab. The chamber also doubles as a tool to explore open to air or standard temperature and pressure (STP) plasma properties.

Helicon Plasma Experiment (HPX) - This device is designed to create high-density plasmas (10^{13} cm^{-3} and higher) at low pressure (.01 Torr). Our goal for HPX is to develop high temperature and density diagnostics for future use in CGAPL and fusion laboratory investigations. HPX creates stable plasmas with Radio Frequency (RF) waves, in the 10 to 70

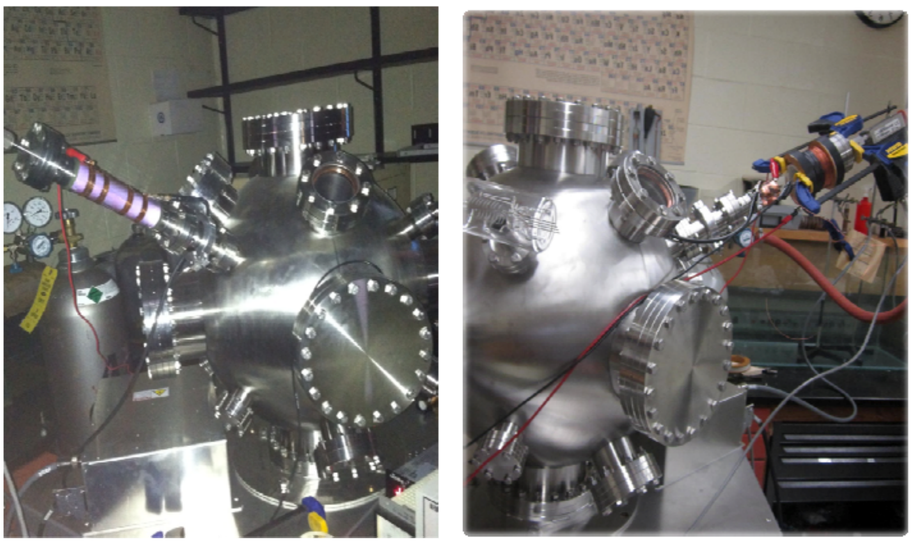


Figure 1. First plasmas in the vacuum chamber have been observed. The nature of the plasma will not be able to be properly determined until the probes amplifiers, and DAQ system is installed. (CGAPL)

MHz range. Argon gas is injected into a pyrex tube and ignited via an RF antenna driven by up to 200 W of pulsed or continuous wave (cw) power. HPX has achieved first plasmas and the initial machine construction and safety protocols are complete. HPX has repeatedly created plasmas with lifetimes exceeding 20 minutes. HPX utilizes an external electromagnet to provide additional energy to the plasma's internal magnetic field. It is the increased magnetic energy that provides the boosted plasma density required to support helicon wave propagation. Subsequently, the helicon wave resonance the plasma in turn produces the 10^{13} cm^{-3} and higher densities we require for our experiments.

HPX has a three-phase project plan:

Phase I (current phase): In this stage we utilize the new triple and Mach particle probes to record baseline temperature and density profiles at the plasma's edge. The plasma's temperature and density change as a function of the power delivered to the plasma via the RF antenna. These measurements are the key indicators in classifying the RF Plasma's mode transitions. Phase I, will also include the completion of HPX's electromagnet to establish the helicon mode and the acceleration coil that will push the helicon plasma into a vacuum chamber where the optical and particle probes (currently under construction by students this Fall and scheduled for completion in early Spring 2013) will collect plasma property data.

Phase II: Once the helicon mode is verified with the direct particle probe and relative optical probe measurements, we will measure the plasma's internal temperature and density with a Thomson Scattering diagnostic. HPX has recently procured a 300 W continuous wave diode pumped YAG laser that will serve as crux of the Thomson Scattering diagnostic system. Once in operation, CGA will become one of the only (if not the single) 'exclusively four-year institutions' with an electromagnetic scattered radiation plasma diagnostic. Consequently, HPX will expand its data collection capability and take the initial steps in developing invaluable diagnostics that yield real-time, highly accurate simultaneous measurements of electron plasma temperature and density. It is the data collected by multiple diagnostics of various design and function, over such long timescales that mandate CGAPL's multidisciplinary collaboration with Electrical Engineering, where a 40-channel Data Acquisition (DAQ) system is currently in development. Once the full DAQ system is installed, scattered light data will be referenced with particle and optical probe data, to produce a comprehensive plasma profile, pinnacle to any future investigations.

Phase III: Once the diagnostics have been established on HPX, energy solution investigations can commence. Since it is such a small and easily reconfigurable device, HPX will be used to develop innovative 'intelligent' diagnostics for the fusion energy community. The versatile nature of HPX also makes it ideal for spacecraft propulsion design and engineering, capacitive energy studies that explore chemical laser cooling issues, and power transfer efficiencies.

CGAPL Initiatives

CGAPL is completely staffed by the undergraduate and faculty group members. Currently CGA, a teaching military academy, does not have a major, minor, or concentration (track) program in physics. Faculty research at a level outside of general physics student inquiry has historically been extremely difficult. CGAPL has been a venue for interested faculty and students to pool resources and interest towards relevant disciplined research. Interdisciplinary collaborations with other CGA departments have enabled the coalescence and persistent development of the lab. In this cross-discipline teaching lab (multi/single) model, senior students and their capstone advisors replace mid-level

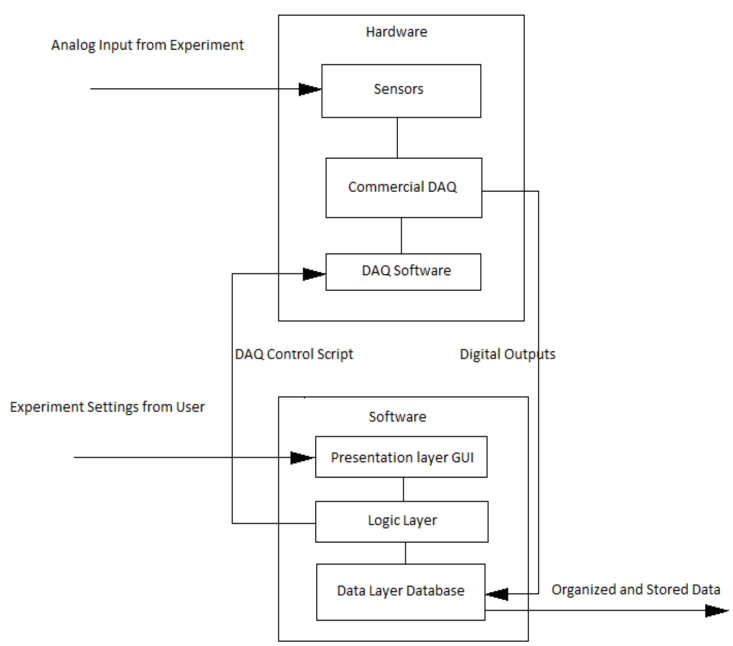


Figure2. Flow diagram for DAQ development

graduate students found in a typical research university.

Two first class (1/c) students and two EE faculty advisors joined with CGAPL do develop the lab's control DAQ system for data collection, system monitoring, and remote control. The system is required to simultaneously record data from 30 to 40 sensors with sampling frequencies between kilo to mega samples/s depending on the diagnostic input level and speed. During the preliminary planning of the project, students were responsible for developing the DAQ system from the probe (sensor) amplifier box to the GUI interface. A flow diagram was created with a "systems engineering" approach to constructing a timeline and procedure for development of the system.

Project management eventualy became the most prominent hurddle for the collaboration. There were many competing demands on multiple key contributors to the collaboration and time on task was imperative for successful testing and eventual implementation. A list of milestones with an approprite associated timeframes was drafted by the students under guidelines provided by the physics faculty mentor/customer. The milestones were broken into five major categories; DAQ procurement, Software design, lab space allocation, DAQ setup, and software build. These milestones were then prioritized and subdivided in to measurable deliverables and associated timetables. Once the milestones were sifted by these requirements, they seemed quite intuitive:

1) Order the DAQ board(s)

2) Design the Software

3) Lab (Physical Plant) Setup

4) DAQ Hardware Intitilization

5) DAQ Software Initilization

With some significant nudging from faculty, the students created a project management tool to identify and assign their own deliverables with timetables for these five agreed upon milestones on their own.

It was imparritive that the milestones be comprehensive yet as selfcontained as possible so they could be independently assigned to the students and completed independent of order when possible.We decided to assign one student an area of responsibility (AOR) from the presentation

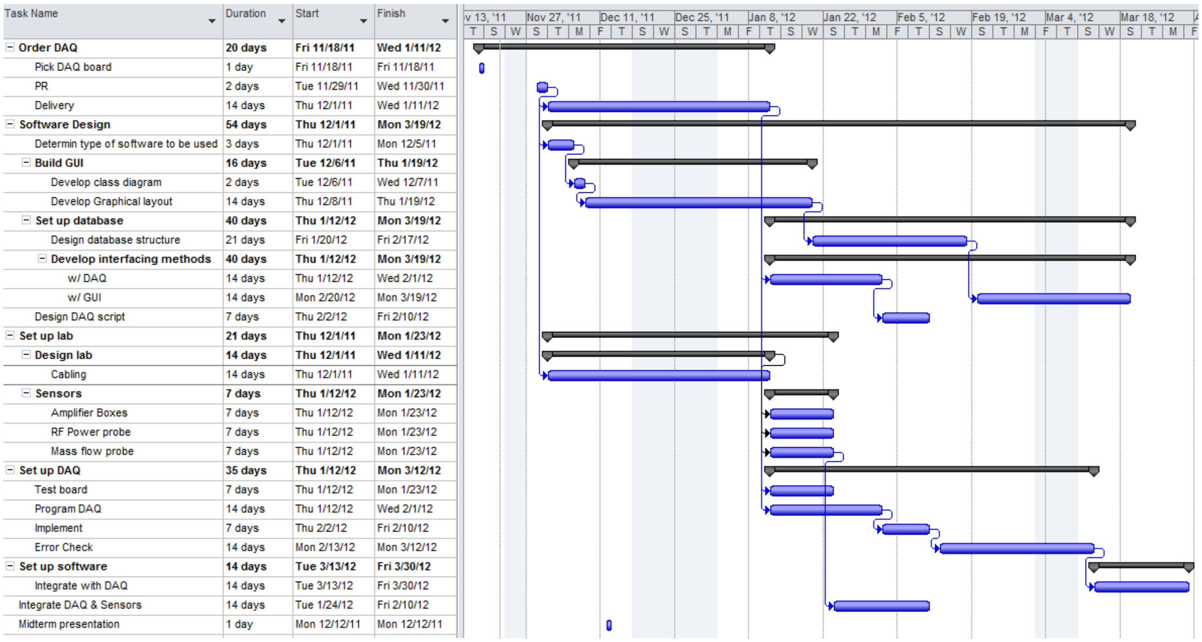


Figure 3. Student devised project milestones and deliverables timetable. Milestones are listed under "Task Name" in bold with their associated deliverables nested underneath. On the right, the black lines denote the student's time allotment for each milestone and subsequent deliverables in blue.

layer GUI (user interface) to the comercial DAQ board inputs; which at first glance is the bulk of the flow diagram! However, the flow diagram does not include documentation of the build, integration, and operation. Most of the documentation except for the user's manual that they both collaborated on, became the second student's AOR.in addition to the amplifiers and other hardware construction or procurements, their physical interfaces, and the lab/physical plant setup.

III. Electrical Engineering Capstone Course Description

The Capstone course is a graduation requirement, two-semesters long, and is worth 4.0 credits. The current course format is two one-hour lectures and two 3-hour labs per week. The course spans two semesters. During the first semester, students are lectured on the basic Engineering Design Process (EDP), and general project management (PM) theory and practices. During the second semester, students are lectured on Coast Guard specific system development doctrines and other engineering topics.

For lab, students are divided into groups of 2 to 4, and assigned to a pre-selected project. Groups are expected to apply the engineering design process to their project. This includes performing the requisite background research, establishing a clear problem statement, a valid list of requirements and the associated test plans, identifying constraints, developing the appropriate functional decompositions or behavior models, and justifying major design choices via the decision-matrix method. In addition, students are expected to apply basic PM theory by developing a project plans, including a work breakdown structure (WBS), network diagram, and/or Gantt chart. Cost modeling and estimation are not required to be applied to the group projects, however are covered in the second semester curriculum. However, since the Academy is a U.S. Government entity, project groups are required to adhere the U.S. Federal Acquisition Rules (FAR) for all purchases. The EDP is not unique among capstone courses, however the PM concentration is not so typical.

The emphasis on project management stems from the skills required of a successful Coast Guard Officer in the "engineering community." The Coast Guard-specific term for the community that includes the electrical engineering discipline is: Command, Control, Communications, Computers and Information Technology (C4IT). The Coast Guard C4IT community requires skills in project management. Coast Guard directives governing who can run high-cost projects and C4IT-acquisition doctrine either explicitly require key personnel to have project management credentials, or heavily incorporate project management principles in key acquisition processes. The Project Management Professional (PMP), Professional Engineer (PE), and Department of Homeland Security (DHS) Project Manager certifications are common and popular among members of the C4IT community.

Under the single/single capstone model, the electrical engineering faculty attempt to create a framework for student projects that mimics that experienced in actual Coast Guard projects. For the most part, this is successful, however the exception involves the need to simultaneously teach the students both the engineering design process and project management prior to graduation. Normally in large projects, the engineering design teams and project management teams are separate groups of people, however in this course, the students are presented both simultaneously. The dual nature of the course can prove problematic for students. For students, it can be confusing to practice "managing" the design team of which you are a member.

Multiple faculty members fill the role of course instructors and technical advisors to avoid confusion in applying both project management and engineering design principles within the group. A single course instructor usually handles administrative and curriculum matters as well as course lectures on the engineering design process and project management. The students submit all graded deliverables to the course instructor. Additionally, each group also has a cadre of project "advisors" who they meet with and receive tasking from each week. The function of the technical advisor is to advise the student groups in technical matters and set major technical milestones and therefore expectations for the technical progress for each semester. Project groups usually have multiple project advisors, however a single advisor "lead advisor" is designated to make it clear to students who has the final say on technical milestone and other tasking. The advisor task completion percentages constitute 15% of the individual student course grades. The goal of the advisor tasking is to assess student performance in the areas of performance and schedule. The course instructor and technical advisors communicate throughout the semester to assess the overall progress of each project, the performance of each student, and help keep all parties "on the same page."

The above scheme is decidedly different from deadline-based homework normally given in undergraduate courses. Normal homework, if not completed, is not a concern for students after the due date. This scheme allows capstone groups to fall behind schedule the same manner as real-world project groups, but still need to complete the late tasks, just as in real world projects. This allows for more realistic project management experience.

Mitigating the potential disconnect between the lecture material and the project work: A potential disconnect exists between the lecture material and the project work. Successful project work requires a sufficient framework to attack the problem, which students do not generally have at the start of the semester. So the course instructor covers topics needed to complete administrative and technical deliverables prior to their due dates.

The instructor expects students to apply engineering design process and project management tools to their projects but does not explicitly require students to be ultimately successful in solving the underlying technical problems associated with their project. This allows for learning and mistakes to occur with unduly penalizing the student. So the student is not in danger of failing a required course simply because they were not an expert engineer or expert project manager on their first attempt. The student is guided using technical milestones and tasks from their technical advisors, which sets the expectation for technical progress and does affect grades. This allows us to choose open-ended and multi-year projects without negatively affecting students' grades. Therefore, the students receive directives from both their course instructor and technical advisors, but the directives affect different parts of their grades.

How are projects chosen? Project selection actually starts at the end of the second semester. It is at this point when faculty review the projects and take a first cut at whether or not it is desired to continue a project or not.

Prior to the start of the first semester, new project proposals are solicited from Coast Guard engineering centers and operational units, current and past faculty, and other interested parties. Information contained in project proposals includes a description of need, desired deliverables, description of the design component, and opportunities for student site visits/travel, available budget if applicable. Projects are chosen that allow students the chance to exercise their skills in both project management and the engineering design process. Additionally, projects that have a focus on operational Coast Guard missions are an added bonus. Projects that do not have a design component are usually not selected. The course instructor leads the faculty review and ranking of project proposals. Finally, faculty evaluates the previous year's projects (i.e.: the projects from the second semester of the previous academic year) and decides which projects to continue and discontinue. Given the number of continued project, new projects are added to fill the gap up to the number of available students. The final project list is also a function of student and faculty interests and expertise, respectively.

The following are some key project selection guidelines used at CGA. Generally, a project should:

1) Be strongly focused on subject matter present in the electrical engineering program of study.
2) Have a C4IT operational context linked to Coast Guard mission execution or mission support applications.
3) Be strongly oriented towards design and development with an end state resulting in a tangible product.
4) Be oriented towards designated areas of emphasis for the electrical engineering section and in an area for which there is ample electrical engineering faculty expertise. The

current areas of emphasis are: signal processing, communications, controls, electronic navigation, electromagnetic theory and antennas, computer networking and information assurance.

5) Not be strongly oriented towards research or analysis without a design/build component.

IV. Lead Advisor Student Management

Two senior students selected to work on this project based on their own interests. One of the students had previous experience working in the CGAPL as part of a series of directed study (special topic) courses. The work plan on this particular project was to have regular meetings between the two EE advisers and one CGAPL adviser in order to properly coordinate and monitor the progress of the students in the project; the multi/single capstone model.

Initial faculty expectations centered on the establishment of specific project requirements that would facilitate efficient cross campus collaboration between the EE and CGAPL cohort. These project requirements eventually evolved in to the milestones described in section II, yet they were initially simply to develop a user-friendly computer instrumentation for control and data collection/presentation of experiments done with the plasma chamber from the sensors to the user interface and data storage. The objective of this system was to service CGAPL over a long lifetime, accommodating as vast of a selection of plasmas as possible. Versatility was key in developing the data acquisition scheme for the lab even in it's current state with three different experiments (detailed in section II). Therefore, the expectation was to gather data from different kinds of sensors each representing a particular physical characteristic of very different time scales and physical properties; from fill pressure to magnetic field strength of the plasma. Initially, the plan for the project was outlined as follows:

1) Select a suitable data acquisition system/board (DAQ) that can sample sensors' signals as versatile as possible (some of the intended experiments may deal with very short lived plasmas in the order of micro seconds, while others on the order of seconds).

2) The DAQ board should have multiple (minimum of 8) analog inputs, at least two analog outputs and several digital inputs and outputs for various experimental control requirements.

3) Computer interface with the DAQ should be flexible and user friendly.

4) The interface software should facilitate a trigger signal to start an experiment, collect and store received signals, and finally to provide a graphical means to examine the collected data.

5) Design the necessary electronics for sensor signal conditioning and amplification.

Figure 5: The National Instruments interface, BNC-2090A

At first, there was a very slow progress on making some of the critical decisions. After some initial searching and discussions, to include price considerations, it was decided that EE section proceeds with a DAQ board that can be acquired as soon as possible so that students can get on with their projects in a timely fashion. We acquired a high end National Instrument (NI) DAQ board with the maximum sampling rate of 2 MHz. This board came up with 32 input channels, 4 output channels and 16 Digital I/O channels. While the maximum sampling rate was less than optimum, however, it was in the range that could be used for many longed-lived plasma experiments.

CGAPL decided to proceed with two different DAQ boards, one exactly like the one bought by the EE section and the second one was a Gage Applied Technologies DAQ board that had the maximum of 125 MHz sampling rate for 8 channels. While the acquisition of these two boards took so much time, due to unforeseen reasons, students were able to proceed with a modified work plan using the board acquired by the EE section.

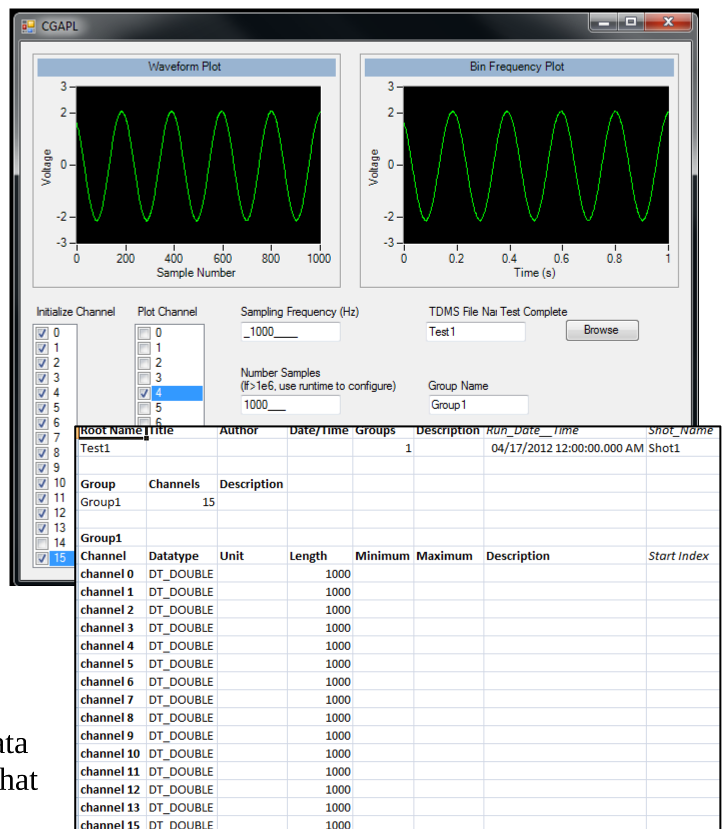
V. Conclusion

Student Project Results

Based on all considerations, mainly to allow students to complete their projects in time, it was decided to use .tdms file format for data storage in order to maximize the simplicity of the system while meeting the read-write capability requirements. In terms of software development, the NI Measurement Studio software package was used to integrate DAQ board and software through .net C# development environment.

We decided to remove the design and implementation of sensor signal conditioning and amplification from the original tasks. This decision was based on several factors. First and the most important factor was that our students were in either computer track or system track and as such, their knowledge in electronics was minimal. The second factor was the lack of sufficient time to characterize the sensors that were being developed at CGAPL in order to design the analog signal-conditioning and amplification device.

The final GUI interface provided some basic functionalities but it was not nearly as robust as the customer (CGAPL) wanted. Basically, the GUI interface provided two slots for plotting data from a single channel (instead of making that



Root Name	Title	Author	Date/Time	Groups	Description	Run_Date__Time	Shot_Name
Test1				1		04/17/2012 12:00:00.000 AM	Shot1
Group	Channels	Description					
Group1	15						
Group1							
Channel	Datatype	Unit	Length	Minimum	Maximum	Description	Start Index
channel 0	DT_DOUBLE		1000				
channel 1	DT_DOUBLE		1000				
channel 2	DT_DOUBLE		1000				
channel 3	DT_DOUBLE		1000				
channel 4	DT_DOUBLE		1000				
channel 5	DT_DOUBLE		1000				
channel 6	DT_DOUBLE		1000				
channel 7	DT_DOUBLE		1000				
channel 8	DT_DOUBLE		1000				
channel 9	DT_DOUBLE		1000				
channel 10	DT_DOUBLE		1000				
channel 11	DT_DOUBLE		1000				
channel 12	DT_DOUBLE		1000				
channel 13	DT_DOUBLE		1000				
channel 15	DT_DOUBLE		1000				

Figure 7- Sample Excel file

more flexible). The two plots are the same; one is in terms of samples and the other one in terms of actual time. A single setup in that program is shown in Figure 6.

The good news was that the program was able to store data received from selected sensors to an Excel file by porting TDMS files directly into an Excel document. This operation was needed to make the received data available for further analysis and processing by the user. A sample of such an Excel file is presented in Figure 7.

The system setup had shown that it is able to sample up to 32 channels with the maximum sampling rate of 1 MS/s. We also found that all unused channels should be grounded to prevent "cross talk." These are board specific issues and this particular NI board would perform optimally if 32 channels were used as 16 differential channels. For the CGAPL experiments, when they do not deal with short-lived plasmas, even 16 differential channels are more than enough for what they need in their experiments.

Capstone Contributions to EE Curriculum

The end result of the project will help Electrical Engineering to develop a system that will become a vital building block for its data acquisition needs for several data acquisition and digital signal processing experiments. Well-developed version of this system can also be utilized in EE labs for relatively cheap signal analyzer that is more versatile and flexible for educational purposes. There are also further opportunities for Physics and Electrical Engineering to develop systems to support Physics research and teaching, as well as develop experiments for Electrical Engineering labs in Signals and Systems, Controls and Digital Signal Processing

VI. Lessons Learned

We initiated the multi/single model with the expectation that having multi-disciplinary faculty advisors on a single project with a customer/mentor component would enrich the student capstone experience while providing a service to the Physics lab. From the faculty point of view, the opposite affects were realized. We did not observe any enhancement of the student experience with respect to the single/single model. In fact, there seemed to be a decrease in student results and effectiveness and the product did not meet the needs of the plasma lab.

There were several factors that may have caused this unfortunate result. One of our major challenges was to make sure that students are achieving the goals that were set for them in a timely fashion. In terms of students and definition of the project, everything was within our computer and system tracks. However, students had to coordinate properly with the adviser at CGAPL and EE in order to successfully complete their project. Unfortunately, this coordination was not executed satisfactorily from the EE and Physics faculty perspective. While this lack of satisfactory coordination did not cause a major set back in the project, but it resulted in a final product that still needed some improvement in the layout of the GUI interface.

The final GUI interface provided some basic functionalities but it was not nearly as robust as the customer (CGAPL) wanted. The plan was mainly based on students understanding of what CGAPL needed without double-checking with the adviser at CGAPL. While students were excused for their lack of proper cooperation with their advisers, but we as advisers came up with a better understanding of how to coordinate and plan such a project in the future.

This unique experience taught us several important lessons that we plan to use in future collaborative research efforts. These lessons are as follows:

1) The proposed project should be defined in coordination with all the involved advisers and should consider the number of students, the budget and other limiting factors that are particular to each involved discipline.

2) When dealing with undergraduate students on a very tight schedule, we have to make sure that advisers from all disciplines are always aware of the current status of the project and they stay on the same page and understanding.

3) While it would be beneficial to let students experience the process of procurement, especially in federal agencies, we must make all preparations so that students get what they need for their projects in a timely fashion.

4) There is a need of consistent and regular evaluation of students' progress in the course of the project so that they receive proper advising regarding project schedule and timing.

5) All preparations, expectations and outcomes for the project should properly communicated between advisers and students so that there will be no surprises at the end for any parties.

6) To avoid problems with conflicting schedules, students and their project advisors should have a common lab time. Multi/single projects could greatly benefit from students and advisors having a common lab time. For AY 2013-14, the Registrar has committed to scheduling Capstone students and advisors in common lab times.

7) Capstone documents should be available to students and advisors. Since there is no shared network drives accessible to both faculty and students, using a shared documents platform such a campus's learning management system, Google Docs or DropBox might be appropriate.

8) As a result of this collaboration, one major change was introduced to the Capstone courses to help advisors track progress. Advisors and students knew when major milestones were due, but students did not always understand the number or scope of the tasks required to meet those milestones. Weekly task sheets are now used to help everyone understand how the project is progressing. Each week, every student is given a number of tasks and associated deadlines. The tasks are graded using a 0-2 scale for performance and the completion date is logged. Following completion, each task receives a task score. The task score consists of the grade assigned by the technical advisor, de-weighted by an amount related to the lag between due date and completion date. Therefore, tasks completed late receive lower grades. Finally, each student is assigned an average task score for each week. The average task scores count for 15% of individual student grades.

An effort is currently underway to define a set of projects which would improve EE student returns on the multi/single capstone project model, while also continuing the collaboration with Physics labs on campus. This will have the double effect of providing a both an important graduation requirement for the students (the capstone project) while also exposing them to world-class fundamental physics research.

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