Global J. of Engng. Educ., Vol.4, No.1
Printed in Australia

Effective Integration of Multimedia Courseware in Engineering Education at Ryerson Polytechnic University*

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As our world moves into the new millennium, new pedagogy, that of active teaching and learning, is emerging. In this paper, the power of integrating the new media technologies into the education process is demonstrated. Specifically, the use of web-enhanced courses in classical control theory and the hybrid application of Web and CD-ROM in spacecraft systems design are described and illustrated. Evidence shows that the students are better motivated and their achievement is superior to that previously obtained when more traditional methods of instruction were used for the same course content. Assessment of student work supports findings reported in other, similar programs, which show lower failure rates and the grade distribution curve shifted towards the high end of the grade spectrum. In the Ryerson experience these results were achieved both when the learnware was integrated into the more traditional lecture-laboratory setting, as well as when the multimedia modules were used in a distributed learning environment involving students studying simultaneously at several universities.

INTRODUCTION

This paper presents illustrative examples showing that hyperlinked text, simulations, animations, videos, images and sound can facilitate better visualisation and comprehension of theory. Websites created to disseminate lecture material, assignments and updates, enable students to access information asynchronously (at their own time and pace) outside the lecture room and laboratory. Moreover, students have access to course material created by experts from across several universities. The results confirm that educators can create courses in a multi-author, collaborative climate, involving the creative delivery of education in a multi-institutional setting. Teamwork and ffective communication are emphasised, mirroring demands of real world corporate and professional environments.

* An expanded version of a keynote address presented at the *2nd UICEE Annual Conference on Engineering Education*, where it was awarded the UICEE platinum award (second grade), by popular vote of Conference participants, for the most significant contribution to the field of engineering education

MULTIMEDIA AND WEB-ENHANCED COURSES IN ELECTRICAL ENGINEERING AT RYERSON

Background

Compared to the previous year, three more courses in the undergraduate program in Electrical and Computer Engineering are now taught using multimedia-based classroom instruction, supported by on-line material that is available through password-protected websites to students registered in the courses [1]. The courses are:

- ELE532: Signals and Systems
- ELE639: Control
- ELE749: State Space Control
- ELE829: System Modelling and Identification

ELE532 is a fundamental course that provides the basic instruction in the mathematical tools required for process control and communications courses. In this course students model and analyse both discrete-time and continuous-time signals and systems, exploring topics such as convolution, Fourier, Laplace and Z-transforms, sampling, and frequency response. Concepts learned in the lectures are reinforced via weekly problem assignments, solved using MATLAB[1] software. ELE639[2] is an introductory course in classical control theory, offering comprehensive treatment of the system transfer function models, stability and root locus analysis, PID controller tuning and frequency response compensation techniques. The lab component uses positioning servos implementing precision DC geared motors with an optical encoder and a DSP board. Students use MATLAB Control System Toolbox and SIMULINK[3] simulation software to complete their assignments, including a realistic modelling, controls design and trajectory planning for an x-y cutting tool. ELE749 is a follow-up course in state space control, with elements of optimal control. SIMULINK simulations allow an introduction of fairly complex and realistic design problems. Real-time control helicopter simulator[4], implementing LQR design, is also used in this course. ELE829 is an advanced course in system identification, with a heavy reliance on MATLAB System Identification Toolbox software. In all these courses the emphasis is on practical aspects of control. Real-time experiments and realistic, nonlinear computer simulations are an integral part of the courses in and outside of the classroom [2].

An intensive two-day course in PID Control for industry, offered through Ryerson's Corporate Training Division of Continuing Education, is another example of effective utilisation of new technologies in the classroom [3]. The course focuses on practical aspects of industrial process control. Lectures are delivered using technology-enabled instruction and cover process modelling and dynamics, basics of system performance specifications and PID control. Hands-on sessions involve application of the discussed concepts in real systems (geared servo, flexible joint or a self-erecting inverted pendulum, shown in Figure 1), including data collection, modelling, effects of nonlinearities, and PID controller tuning. The controller is first tested through simulation, then implemented using WinCon[5], a software package that runs SIMULINK diagrams in real time under Windows. WinCon links the diagrams to the C code automatically generated by the Real-Time Workshop[6]. Physical hardware is thus controlled in real time through a familiar SIMULINK interface without a need to write a single line of code.

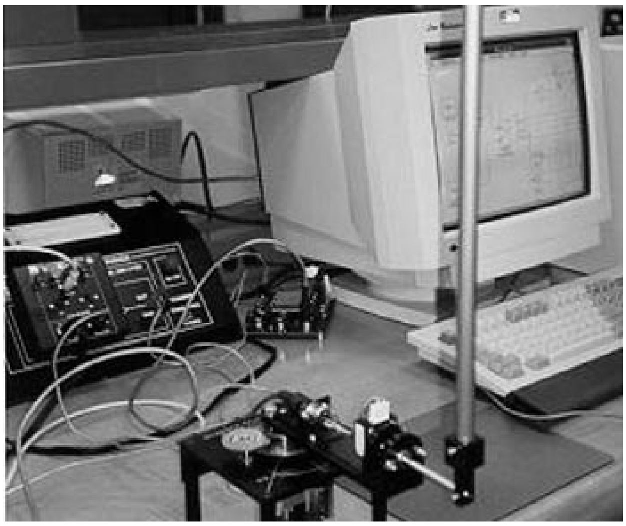

Figure 1: Inverted pendulum experiment.

Incorporating multimedia components in control instruction

We find that it is much easier to communicate theoretical concepts to students when one is not limited to classic teaching methods. Furthermore, teaching the design aspects of control inherently requires an iterative process, which can be greatly enhanced by introducing multimedia tools to illustrate the results. Hyperlinked textual information is combined with simulations and multimedia components, including video clips, animated gifs, Java and JavaScript applets and screen captures, which readily provide a visualisation of the theory and illustrate real-life implementations.

Introductory lectures in ELE639 are a good example of the effective use of multimedia. In the absence of any frame of reference and yet-to-be-defined *jargon*, pictures and video clips embedded in the HTML lecture are used to provide examples and a visual, intuitive understanding of what is process control. Using multimedia rather than a *real-life* demonstration has the advantage of being portable, faster, and allows showcasing of a variety of processes. QuickTime movies of an inverted pendulum, a flexible joint and two different servo systems were specifically created for use in the courses. Differences between effective and poor control and concepts of stability and instability are readily demonstrated. Later in the course, stability is related to locations of

[1] MATLAB is a registered trademark of MathWorks, Inc, *http://www.mathworks.com* (1998).

[2] General information on the course and a demo module are available at: *http://www.ryerson.ca/~ele639* (1998).

[3] SIMULINK is a registered trademark of MathWorks, Inc, *http://www.mathworks.com* (1998).

[4] 3D Helicopter simulator was developed by Quanser Consulting, Inc *http://www.quanser.com* (1998).

[5] WinCon is a registered trademark of Quanser Consulting, Inc.

[6] Real-Time Workshop is a registered trademark of MathWorks, Inc.

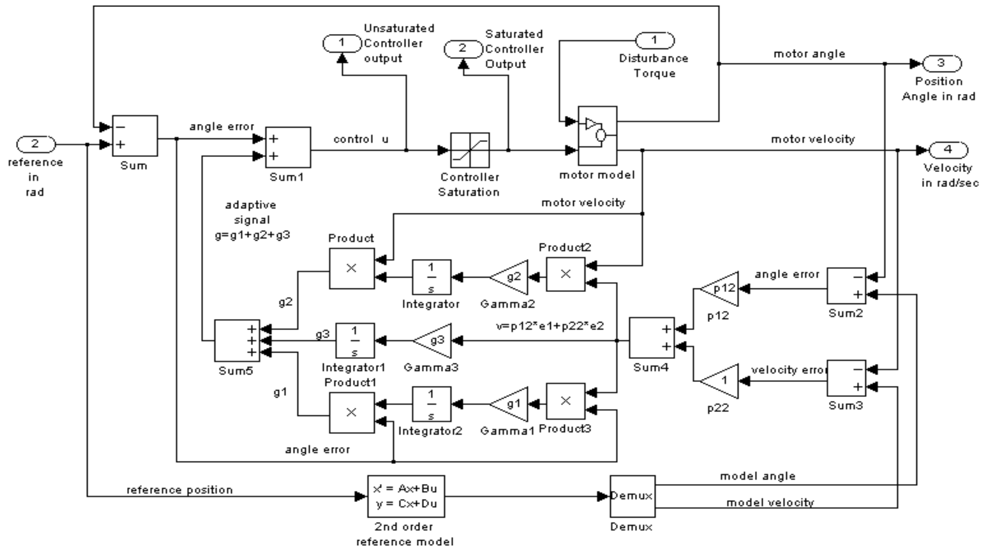

Figure 3: Example of a SIMULINK adaptive controller simulation.

the system poles through the use of an interactive Java applet, shown in Figure 2.

Another topic that is effectively enhanced by multimedia use is that of pole/zero locations and their subsequent effect on system behaviour. Using a classic approach one faces the tedious task of sketching diagrams or, at best, showing static overheads of the system response, typically to a step input, for various pole locations. Contrast this with the much more illustrative means provided by Java applets, which allow one to move the singularities around in the complex plane and immediately see the results on system time or frequency responses. Java applets used in our courses are in public domain and readily accessible on the WWW. Links to their locations are provided from the course websites. They can be accessed on-line during lectures in electronic rooms equipped with an Internet connection. Cached, the applets can also be used off-line in a classroom without the Internet connection.

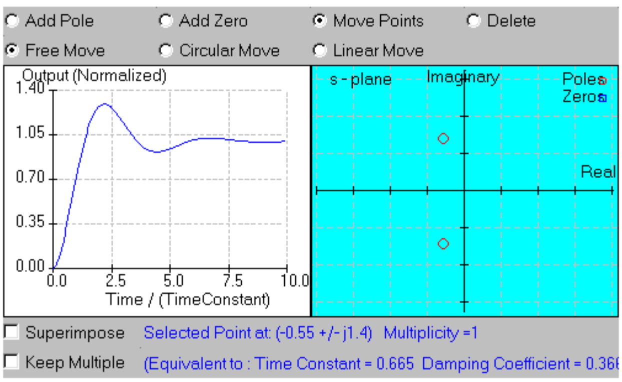

Figure 2: Java applet for pole-zero manipulations[7].

[7] WWW Java Applet by Dae Ryook Yang, *http://www.infosys.korea.ac.kr/Education/teleschool/lecture* (1998).

MATLAB and SIMULINK files are executed during lectures, providing simulation results as an instant illustration of topics discussed. This is especially helpful when discussing different aspects of control design. As an example, a SIMULINK model for an adaptive controller implementation is shown in Figure 3.

MATLAB *movies* were created to illustrate several topics requiring visualisation, such as relationships between system pole locations, its gain and phase margin, and its response, or Root Locus construction rules. QuickTime video clips and/or a VHS tape recording of the process behaviour under control are also used to reinforce the concepts. Examples of an effective use of animation and JavaScript include block diagram reductions, applications of the Mason's Gain formula and transfer function realisations of different canonical forms of state space models.

Outside of the classroom, implementing interactivity through the simulation software is more complicated since students must have access not only to tutorials through a browser, but also require the Student Editions of MATLAB and SIMULINK to be running simultaneously on their PC. Software files can be downloaded from a course website to be executed and modified as required.

Use of WebCT environment in course delivery

One aspect of incorporating digital technologies into teaching is to augment classroom presentations with communication tools, such as e-mail, bulletin board and chat groups, and to use the World Wide Web to provide lecture notes, assignments, scheduling information, on-line quizzes and surveys, student grading and tracking. Ryerson has adopted WebCT, a powerful and widely used software environment, to provide integrated support for on-line course development and management. Since January 1999, ELE639 website has been managed in the WebCT environment, with other courses to follow next semester. Currently[8], 57 students are registered in the course and accessing the password-protected website regularly. Ten weeks into the course the website has been accessed over 2400 times, with a number of individual student page-views ranging from a high of 689 to a low of 34 (with an average of 257). WebCT features most popular with the students are the bulletin board and on-line access to grades and course material.

Evaluation and outcomes

During the Winter '97 and '98 offerings of ELE639, the impact of Web-based material was most evident in the laboratory, resulting in a marked decrease of time required to complete projects. The average grade in the ELE639 course went from 67% in Winter 1996 to 81% in Winter '97 and 77% in Winter '98. The dropout rate was reduced to less than 2%. This trend continues in Winter '99. Interim results show an average mark in the course to be around 82%. The grade distribution in ELE639 (shown in Figure 4, normalised w.r.t. the number of students) shows a shift from a standard distribution curve towards higher marks in each of the three years.

Similar results are reported in the literature: final grades in an Electric Circuits sophomore course, ECE270, at the University of Illinois at Urbana Champaign were compared between student sections where classroom instruction was delivered in a traditional mode, and where it was augmented by the use of Asynchronous Learning Network (ALN) [4]. The ECE270 grades distribution is shown in Figure 5.

Faculty-Course Surveys (FCS) for ELE639 have shown that the students' perception of the difficulty and the amount of course material decreased, although there was no significant change in the course difficulty level or requirements. This seems to suggest that the new instruction technology contributed to course accessibility and thus affected perception of its difficulty level. The student overall evaluations of instruction as well as of the course increased slightly as well. This is consistent with the anecdotal evidence (informal discussions with students, and their unsolicited comments) suggesting that the retention and comprehension, as well as enthusiasm shown towards the course, increased.

We have also observed that the students, freed from time consuming note taking, participate more fully in classroom discussions. Most students expressed strong support for on-line, asynchronous communications and counselling, quoting hectic timetables and scheduling conflicts as a main reason for this preference over a personal contact with the course instructor. Since the introduction of WebCT in January 1999, there have been 221 bulletin board student postings as well as 312 individual queries through e-mail from the 57 students registered in ELE639.

A formal study of student attitudes and outcomes in ELE639 is currently under way. Its aim is to analyse the impact of technology-enabled instruction on students' comprehension and to evaluate learning style preferences and attitudes toward asynchronous learning and on-line course management Assessment methodology and surveys were developed as part of a research project, which will continue over two more years to minimise variance and bias. Reports on formal assessments of the effectiveness of technology-enabled instruction in engineering education are rare [5]. It is hoped that this study will contribute to the subject. Early results seem to indicate a correlation between achievement and usage of on-line material. While 90% of the

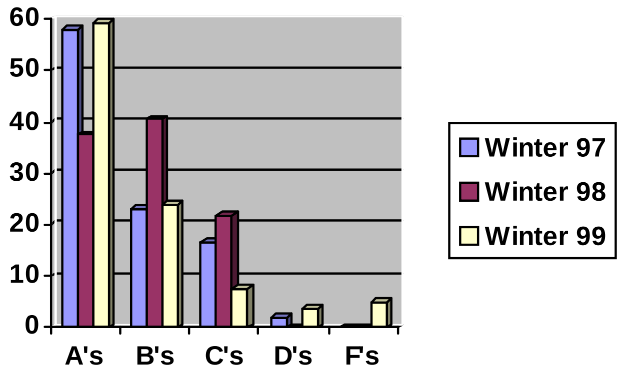

Figure 4: Grades distribution in ELE639 course at Ryerson (1997-99[9] data).

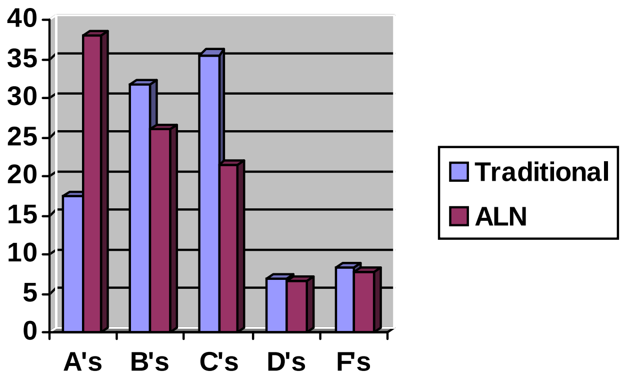

Figure 5: Grades distribution in ECE270 course at University of Illinois (1996 data).

[8] Winter 1999.

[9] Interim data for Winter 1999, as the course is still in progress at the time of writing.

students with above-median term grades had a higher than average number of web-site page-views, only 33% of the students with below-median term grades did.

Development work

By the end of the 1998/1999 school year, content creation and coding will be complete for all controls courses. Further refinements of multimedia components are expected to continue. A longitudinal study of student outcomes and attitudes will continue as well. Another project currently underway will allow students enrolled in control courses at Ryerson to access a real-life control setup remotely through the Internet. The process, shown in Figure 6, is a highly coupled, eighth order multiple input-multiple output, three degrees-of-freedom simulator of a helicopter, controlled in real-time by the SIMULINK/WinCon interface. Development work continues to have all experiments in the controls lab accessible over the Net, allowing the students to control them while off-campus and thus to have an option of completing their lab experiments in an asynchronous mode.

AN INTERNATIONAL INTERNET COURSE IN SPACECRAFT SYSTEMS DESIGN

The Interactive Learning Connection-University Space Network (ILC-USN) is a consortium of universities, industries, government and Ontario Centres of Excellence that has supported the development of an internet-based course in engineering systems design with spacecraft applications [1][6].

The ILC-USN Pilot Project was launched as proof of the concept that technology-assisted education would provide the following opportunities:

- Improved access for learners in terms of flexibility of time and location, ease of use, and the convenience of the technology employed.

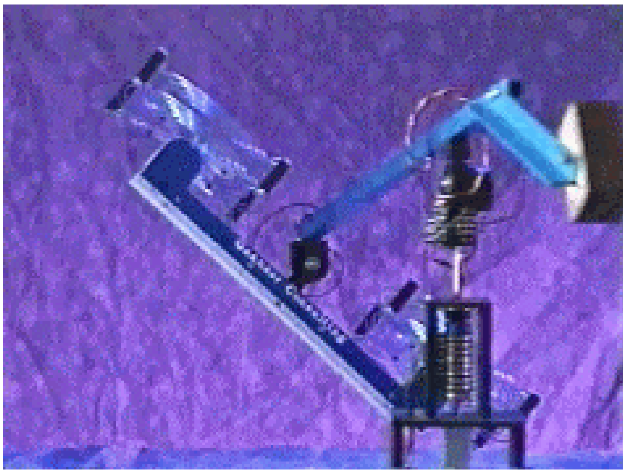

Figure 6: Quanser 3-D helicopter simulator.

- Improved quality of instruction, which results in better retention, higher skill and knowledge levels attained, and higher academic standards.
- Increased relevancy: better links to industry and societal needs.
- Improved efficiency through the reduction of duplication of courses, and the optimal use of resources.
- Stronger links between academic, industry and government sectors.
- Positioning for the future: restructuring the way in which knowledge, skills and attitudes are taught.

SPACECRAFT SYSTEM DESIGN COURSES

The Spacecraft Systems Design Course is nominally one semester (13 weeks) in duration, with alternating weeks of study and assignments. This is an Internet-based course, and students located at several universities across North America study simultaneously each semester. Universities that have participated include:

- Royal Military College (RMC) of Canada
- Queens University
- Ryerson Polytechnic University
- University of Toronto
- York University
- University of Western Ontario
- University of Windsor
- University of Detroit Mercy

Students from Mexico have also taken the course.

A Systems Design Review (SDR) Final Report is the final deliverable, and the culmination of the Course is a presentation by the teams at a participant's location. One such presentation was at Spar Aerospace in January 1996. Other Final Report presentations were at:

- The ILC-USN Conference, May 1996;
- The Ryerson Rogers Communication Centre, on Internet websites, December 1996;
- A meeting of teams and staff at RMC, January 1997;
- MIT in May 1998, where teams presented their final project for the International X-Prize University Competition.

In January 1999 the students presented the results of the latest project, the design of an Asteroid Deflection Vehicle System (ADVS), once again at Ryerson. From these sessions a special request was made to present the students' work at the Ontario Science Centre (February 27, 1999) as part of the activities to launch Engineering Week in Ontario. This session was entitled *Collision Course- Asteroids, Engineers, and Hollywood*.

The course has been developed to achieve several objectives:

- To provide an understanding of the Systems Design Process and tools, including operations analysis.
- To develop the ability to integrate complex systems requiring interdisciplinary knowledge.
- To develop teamwork skills.
- To develop the ability to both participate in and lead teams.
- To develop the ability to apply design principles to real life problems.
- To acquire knowledge of key spacecraft systems, including;
    - Systems design;
    - Space operations;
    - Orbital mechanics, attitude control;
    - Propulsion systems;
    - Launch vehicles and environments;
    - Structural and thermal design/interfaces;
    - Electrical, computer and software design/ interfaces, communications;
    - Ground segments, operator interfaces;
    - Space manipulators;
    - Reliability and maintenance;
    - Other related state-of-the-art topics, such as manned spacecraft life support systems, and Extra-Vehicular Activity (EVA).

Multimedia learnware modules have been developed by professors from several universities, the modules being related to the systems design topics listed above. Not only do the students have access to the modules through the Internet or CD-ROM, but they have direct access, synchronously and/or asynchronously, to the subject matter experts who created the modules. The course has quickly moved onto the Internet with all modules now converted to HTML, password protected, and available through the ILC-USN website <http://www.ilc-usn.kcc.ca>.

Modules/Authors include:

- *Spacecraft systems*, W. Brimley, Ryerson
- *Orbital mechanics*, P. Somers, J. de Boer, R. Stockermans, S. Ranganathan, RMC
- *Satellites & probes*, P. Somers, T. Racey, RMC
- *Propulsion systems*, R. Sellens, P. Oosthuizen, J. Bryant, Queen's
- *Mechanical*, W. Brimley, Ryerson
- *Robotics*, R. Buchal, Western
- *Robotics assembly and maintenance*, L. Reeves, A. Hopkinson, RMC
- *Electrical*, W. Brimley, Ryerson
- *Space software*, L. Reeves, A. Hopkinson, RMC
- *Ground control*, J. Soltis, Windsor
- *Design of reliable systems*, H. Jack, ex Ryerson

One excellent example of the creative use of multimedia to illustrate basic concepts is the presentation of Kepler's Laws by Professor Phil Somers, formerly of the Royal Military College in Kingston, Canada. These laws describe planetary orbits, and Professor Somers uses text, voice-over, schematic planar drawings, as well as animated video to assist the students in understanding these important concepts. Kepler's first two laws are illustrated schematically in Figures 7 and 8, but it is the video that enhances the abilities of students to better-understand their use, especially as it relates to orbiting planets and spacecraft. The video was demonstrated during the oral presentation at the 2nd *UICEE Annual Conference on*

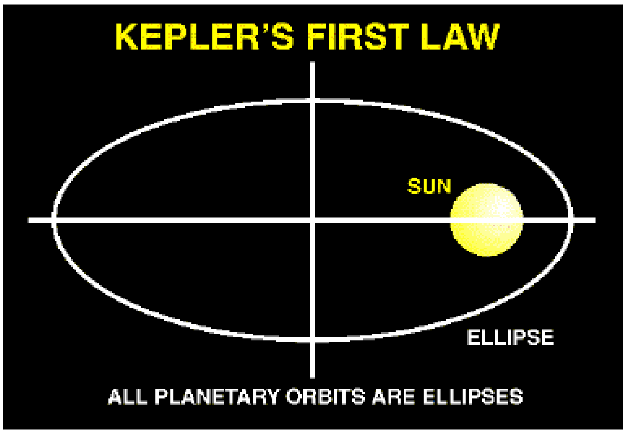

Figure 7: Schematic illustration of Kepler's First Law.

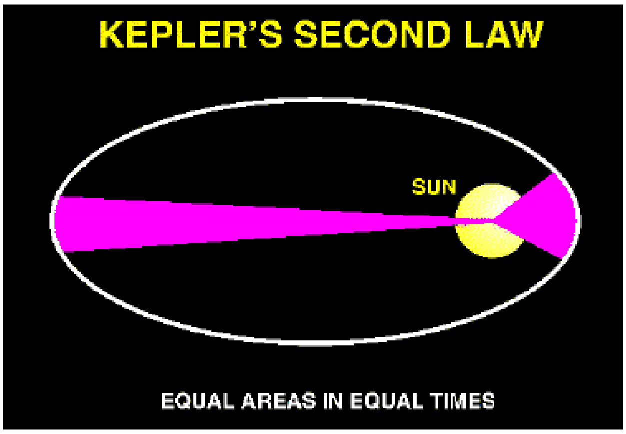

Figure 8: Schematic illustration of Kepler's Second Law.

Engineering Education, held in Auckland New Zealand, from 10-14 February 1999 [9].

Because of the power of the technology-enabled pedagogy, students can be challenged to meet very high expectations, and the students consistently rise to these challenges.

The course culminates with the students completing a major design project. The projects completed to date are:

- Design of a Small Orbital Servicing Vehicle (SOSV), Fall 1995;
- Design of a Mars Rover Sampler System (MRSS), Winter 1996;
- Design of a Lunar Transport Vehicle System (LTVS), Fall 1996 and Winter 1997;
- Design of an X-Prize Vehicle System (XVS), Fall 1997 and Winter 1998.

The project for 1998-99 is to design an Asteroid Deflection Vehicle System (ADVS). The challenge is to transport components for a manned space vehicle to the International Space Station, to assemble the spacecraft, execute a transfer orbit to the asteroid with the goal of deflecting or destroying it before it crashes into the earth, and then to return the vehicle to the space station. This project was based on the theme of the Hollywood movies, *Deep Impact* and *Armageddon*. The concept of the transfer orbit is illustrated in Figure 9.

The International Space Station would be in low earth orbit and part of the challenge was to design a space vehicle with the capacity and thrust required to change its velocity to move out of lower earth orbit to an orbit that would enable the spacecraft to intercept the asteroid at its farthest point from earth (Aphelion in Figure 9). The space vehicle designed by the Ryerson team is illustrated in Figure 10. It is noteworthy that the largest components of the space vehicle are the fuel tanks because the mass of the fuel required to achieve the changes in velocity necessary to execute the mission (to get from one orbit to the next) is more than ten times the mass of the habitat, control and storage modules.

The student teams have their vehicle design final reports mounted on the web. To access the design reports it is necessary to go to the student links at the ILC-USN website (www.ilc-usn.kcc.ca). Readers are encouraged to view these web-sites to examine, first hand, the quality and sophistication of the work of the students.

Another example of student work involving the design of the X-PRIZE Vehicle System (XVS) The XVS design concerned a vehicle that would be capable of carrying a pilot and two tourists into sub-orbit to view the earth from this vantage point and then return safely to earth. An additional requirement was that the vehicle design must allow for it to be serviced following a flight so that the next flight could occur within 14 days of the previous flight. Only 10% of the vehicle mass is expendable per flight. It is not possible within the limitations of this text to convey adequately the complexities involved in such an undertaking. For a full appreciation, the students' work is contained on the web-sites. However, an illustration of the vehicle designed by one of the Ryerson teams is given in Figure 11.

In addition to completing the design successfully, the students also created an animation of the simulated flight. The simulation was shown during the oral presentation of the paper at the Conference, which

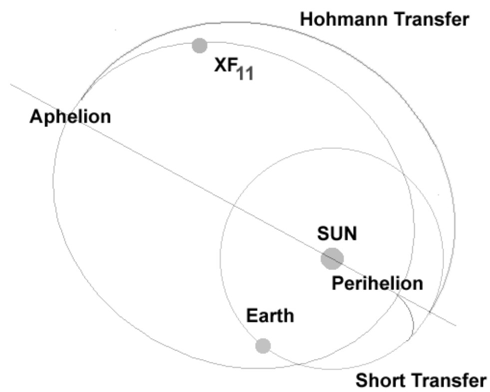

Figure 9: Schematic illustration of transfer orbits.

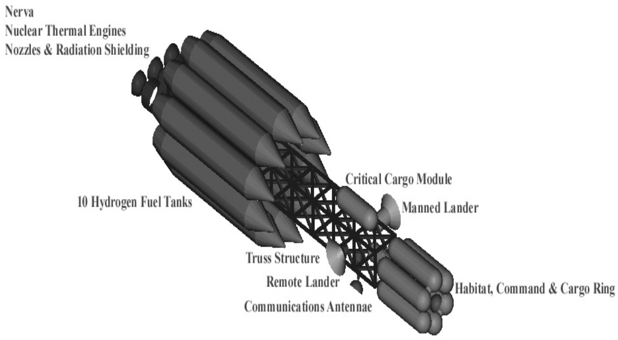

Figure 10: Asteroid Deflection Vehicle System (ADVS) Ryerson student team design (1999).

Figure 11: XVS concept, Ryerson team (1998).

unfortunately cannot be shown in this text. However, the flight profile is shown in Figure 12.

Student response and enthusiasm for the course and its projects has been excellent. More than two hundred students at seven different universities have participated since the first course offering in 1995. Students at each university form teams and collaborate in conceptualising and designing their own spacecraft which must meet the demanding functions specified at the beginning of each course. At each site there is a node co-ordinator who is often one of the professors who has authored or co-authored one or more modules. This provides student-professor interaction in real time. The students enjoy the team approach that fosters the development of personal interaction skills as well as providing opportunities to provide leadership. Final grades are based on marked assignments as well as written and oral presentations of the final design reports. The final grades distributions for the past three years, since the course was first introduced in 1995, are shown in Figure 13. These results are generally superior to results obtained by students taking similar courses using traditional pedagogy.

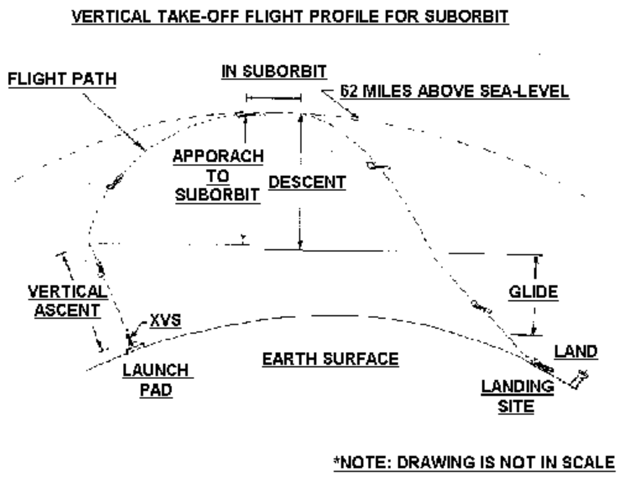

Figure 12: XVS flight profile.

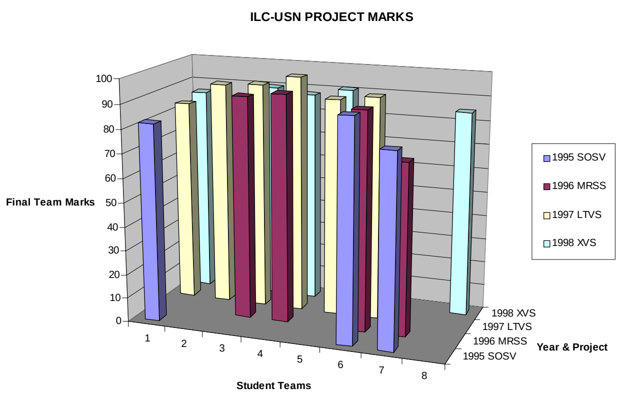

Figure 13: Final grades distribution, student design reports.

As noted earlier, at the completion of each semester, opportunities are provided for the teams at all participating universities to get together at one of the sites, to meet each other and to present their final reports to the other teams. These gatherings are usually exciting and worthwhile events for students and professors alike.

Student alumni of the ILC-USN have gone on to undertake graduate studies at many universities, including the International Space University's (ISU) Master of Space Science degree program, as well as being awarded scholarships to attend the ISU summer sessions [10].

CONCLUDING REMARKS

The projects described in this paper demonstrate the advantages of integrating the new media technologies into the education process to provide stimulating interactive learning environments for students and professors alike. In the controls courses, the software simulations of very practical systems are being used with great effectiveness in conjunction with classical teaching tools and mathematical details to illustrate control theory concepts. Realistic simulations, combined with practical experiments, impart a much better understanding between the ideal, theoretical systems and the practical, real life systems. The course web-sites, created to disseminate lecture material for all the courses described in this paper, the use of tutorial notes, the demands of weekly or bi-weekly assignments, frequent interactive feedback, Internet access to relevant supporting material, the availability of educational aides on CD-ROM, and-so-forth, enable students to work asynchronously, at their own time and pace, outside the lecture room and laboratory.

The implementation of web-enhanced courses has resulted in increased comprehension by students, has enabled them to grasp difficult concepts with greater ease, and has increased their success rates. Also, teaching faculty are used more effectively, providing more time to devote to other aspects of their professional activities, such as research. The new pedagogy encourages interdisciplinary interaction between students and faculty, not only within individual universities, but among institutions and industry. The sharing of strengths and resources has also effected cost savings. These conclusions have been confirmed by independent analyses, which have shown that, through the sharing of financial, capital, material, and intellectual resources, educational enterprises will not only be able to enhance the quality and richness of the learning experience for students, but also to accomplish educational and learning goals more efficiently and cost-effectively [4][5][7][8].

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BIOGRAPHIES

Malgorzata Zywno is a Professor in the Department of Electrical and Computer Engineering at Ryerson Polytechnic University. She studied at the Technical University of Lodz, Poland earning the Magister degree in Electrical Engineering. Subsequently she studied at the University of Toronto obtaining the MEng degree in Electrical Engineering, Controls Systems Group. She joined the Electrical Engineering Department at Ryerson in 1982, earning tenure and the rank of Professor in 1991. Professor Zywno's scholarly and research interests are in the areas of Control Theory, Advanced Control Systems, Network Analysis, System Models and Identification, and, more recently, in exploring the pedagogical applications of multimedia, information and communications technologies. She has extensive experience in developing multimedia and Internet-based courseware in Electrical and Controls Engineering. Professor Zywno is a member of the Institute of Electrical and Electronic Engineers (IEEE), and is a registered Professional Engineer in the province of Ontario, Canada. She has several publications in refereed journals and conference proceedings.

Professor Zywno has been actively involved with the Women in Engineering Committee at Ryerson, serving as Chair of the Committee for several years. She has also been a strong proponent and participant since 1991 in Discover Engineering, an annual summer camp for young secondary school girls to expose them to educational and career opportunities in Science and Engineering. She is the creator and web-master of the WIE website (http://www.ee.ryerson.ca/~womeng). Over the years, Professor Zywno has volunteered her services in a variety of capacities to the engineering profession, and to the Skills for Change Agency: New Pioneers Awards Selection Committee.

Dr Brimley is Project Manager, Distance Education Group in the Continuing Education Faculty, Ryerson Polytechnic University. He is also an Adjunct Professor, School of Aerospace Engineering, at Ryerson. He is a Professional Engineer, graduating with a PhD

in Mechanical Engineering from the University of Waterloo. He was a Canadian Astronaut Finalist candidate in 1983 and 1992, and has held numerous management and supervisory positions in the Canadian Nuclear and Aerospace industries. Dr Brimley has taught at several Colleges and Universities, including teaching positions at Sheridan and Seneca Colleges and Waterloo, Toronto, York and Ryerson Universities. He was previously responsible for co-ordinating the introduction of *New Media* and *technology enabled education* at Ryerson Polytechnic University, and management and development of the Digital Media Projects Office to provide support to faculty and staff in the introduction and use of multimedia and the Internet in their courses. He is presently responsible for providing the project management of all print, Internet and CD-ROM courses offered through the recently formed Distance Education Unit of Ryerson's Continuing Education Division. Also, he is operations manager of the Interactive Learning Connection-University Space Network (ILC-USN) *Spacecraft Systems Design* course, co-ordinating the participation of universities, and teaching (as adjunct professor in the School of Aerospace Engineering) at Ryerson.

Present pursuits are in the appropriate introduction of technology-enabled education at post-secondary levels, the use of multimedia in education, authoring multimedia CD-ROMs, web-authoring, 3-D modelling and animations. Certified in Interactive Multimedia Design and Production, and various multimedia and web-authoring software, Dr Brimley is President of Brimley Enterprises, developer, co-author and producer of aerospace CD-ROMs and web products. He is the author or co-author of numerous papers presented at conferences world-wide.

Dr White is currently a Professor in the Department of Mechanical Engineering at Ryerson Polytechnic University in Toronto, Canada. Formerly, he was Dean of the Faculty of Engineering and Applied Science at Ryerson. Dr White has more than thirty years experience as an educator, practising engineer, engineering consultant to industry, researcher, manager, and academic administrator. He has over sixty publications in refereed journals and conference proceedings, and has written more than 100 technical reports. He is a registered professional engineer and a member of several technical societies, including ASM-International, NACE-International, ASEE, ASME, CSME, among others. In 1995, Dr White was elected a Fellow of ASM-International. Dr White's professional expertise is in Materials and Corrosion Science and Engineering. More recently, he has been actively involved with the media in education group at Ryerson Polytechnic University and is an active proponent of Internet learnware designed to create stimulating interactive learning environments for students. Dr White is married and has two daughters. Outside his professional life, he is an active musician as part of the Oshawa Temple Band of the Salvation Army, and he participates fully in church affairs.