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Chapter 1

What We Must Do Together to Increase Quality and Productivity[1]

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Convinced that future advancement in engineering education and research must come through international cooperation, we present the heuristic basis for a major increase of investments of resources – of time for personal involvement, and/or institutional resources as appropriate -- for international cooperation in engineering education and research. The current economic situation notwithstanding, a commitment to international cooperation must come from all stakeholders -- from students, faculty members, leaders of industry and academe, to funding organizations around the world. A judicious incorporation of an international focus in existing programs, especially by academic institutions working in consonance with the funding organizations, will help cultivate the

[1] Opinions expressed in this paper represent the personal views of the authors.

linkage of established, funded projects in different countries that complement each other. The ensuing leveraging can enhance productivity and quality of programs to an unprecedented scale. Increased investments by funding organizations will enable the initiation of new joint research and education projects, potentially unleashing new ideas and innovations that hitherto have remained untapped. Industry, in support of their increasingly globalized R&D efforts and workforce strategies, must increase its investment for international cooperation. We recommend several steps for the consideration of the international community.

INTRODUCTION

An expansion of current investments in engineering education and research into the international arena is justified by several considerations. These include the inherent beneficial enhancement of quality and productivity in education and research that inevitably accrues for collaborating nations when financial and human resources are mutually leveraged. Another consideration is the ongoing internationalization of industrial R&D that is driving the interest for international cooperation in research and education on the part of many leading educational institutions. A major expansion is also in line with the trend established in recent new program announcements by some of the government funding agencies.

Furthermore, there is little disagreement among educators worldwide, including faculty and administrators (presidents, chancellor, rectors) of academic institutions, that international cooperation in engineering research and education must be the cornerstone for the next major advancement in the profession.

Developments in engineering education around the world in recent years, in education pedagogy in general and web-based teaching and learning tools in particular, have led to increased parity in education development among nations, thereby enhancing the prospects and potential two-way benefits of joint activities.

Many nations have also increased their investments in engineering education the better to prepare graduates for the 21st century, with education objectives very similar to those in the U.S. In Europe, this is framed in part by the Bologna Declaration, a policy-level agreement signed by 29 European nations at the minister of education level in 1999 to, in effect, establish common education standards for European nations that are similar to those in the U.S. The expressed objectives of the Declaration are to enhance the mobility of graduates in employment. With a 10-year implementation time frame that is identical with that for the U.S. engineering coalitions program, and with more nations having signed on since 1999, the Bologna Declaration could be a major platform for educators worldwide to participate by sharing their experiences. European institutions can hasten their own progress through international collaboration.

Recent published results on multinational scientific collaboration speak positively as to its benefits as, for example, discussed in the February 16, 2001 issue of the journal Science and the December 14, 2000 issue of Nature. These journals reported major breakthroughs in the fields of plant and human genomics that came about because of joint research. Clearly, the fruits of such cooperation, sustained over time, can have remarkable payoffs.

These developments are creating heightened interest in international cooperation in engineering education and research. The needs for international cooperation also are growing more urgent. In the face of growing pressures on the national budgets of many nations, international cooperation will allow us to leverage each nation's funds while increasing productivity and quality.

THE CONTEXT FOR COOPERATION

Discussions held at recent international forums for engineering education and research show that educators around the world are increasingly convinced that international cooperation in engineering education can enhance its quality. They believe that engineering students, especially graduate students, are more likely to travel to other countries to receive an education than students are in any other academic discipline; hence engineering educators believe that an undergraduate curriculum in their home institutions that conforms to a certain international standard, and that incorporates an international perspective, will empower their students to achieve greater success in their postgraduate academic life.

More importantly, many educators hold the view that an education system that is informed by an international perspective also will prepare students better for a career in the world marketplace, and that international cooperation in engineering education can provide the cultural perspective that students need to become better engineers.

It is a truism, though not widely practiced for the lack of funding and networking opportunities, that cooperation also increases productivity, by expanding the scope of work and the number of personnel involved for each collaborating team, by adding a perspective from another culture, by sharing facilities and equipment and human capital, and by leveraging financial resources.

The dawning of the 21st century also led many universities to seek ways to broaden their engineering education systems. Universities are seeking to ensure that their graduates possess the new knowledge base that is the foundation of new technologies. Since the economies of nations are increasingly interconnected, these institutions are also seeking to ensure that their graduates possess the broad education needed to be successful engineers. Through international partnerships, these institutions seek to improve their own offerings, and gain recognition through international accreditation.

Furthermore, advances in information technology, in particular the onset of the Internet age, have made it easier for educators to communicate, and are stimulating the establishment of research and education partnerships.

Many multinational industrial companies also encourage international cooperation among academic institutions to aid the international R&D efforts of the companies, as well as to facilitate their global workforce strategies.

Convinced that their economies are increasingly dependent on technological innovations, many nations are increasing their investments in R&D. Examples include several Asian countries [1]. Countries such as South Korea and China have notably expanded their support for R&D (relative to GDP) and developments in science and technology. This is paving the way for returning international students. Armed with advanced degrees, R&D experience at Silicon Valley, and venture capital, international students have been returning to their own countries in increasing numbers. Out of 400,000 Chinese who have studied overseas during the past 20 years, about 140,000 have moved back to China.

This uptrend in R&D in what used to be known as emerging economies has come at a time when most if not all of the G-8 countries have invested at levels no higher than those at the beginning of the 1990's [1]. The implication of all of this is increased scientific and engineering capabilities in many developing nations, creating increased opportunities for mutually beneficial international cooperation.

The planned expansion of the European Union to include several countries from Eastern and Central Europe, along with China's economic reform now anchored by her entry into WTO, is having a palpable effect in stimulating the growth of international R&D, all in the last 1-2 years.

The emergence of new ideas is now no longer limited to a few elite nations. As evidence, witness the increasing number of companies in industrialized countries that have expanded marketing and R&D around the world, as summarized below.

RECENT GLOBAL DEVELOPMENT IN INDUSTRIAL R&D

While past corporate investments abroad were attracted by the lower costs in manufacturing, the new ventures were driven more by the quality technical workforce available at the new locations. Not surprisingly, this has led many companies to establish R&D centers in what have been called developing countries. For example, Proctor and Gamble tapped into the abundant brainpower available in several countries and, in 1998, had 22 significant laboratories located in 12 countries, with 40% of its researchers located outside of the U.S.

Investment in foreign R&D by U.S. companies has received attention only relatively recently, but published data [2] available for 1982-1998 show that the up-trend in foreign R&D dates from 1982, as shown in Figure 1.

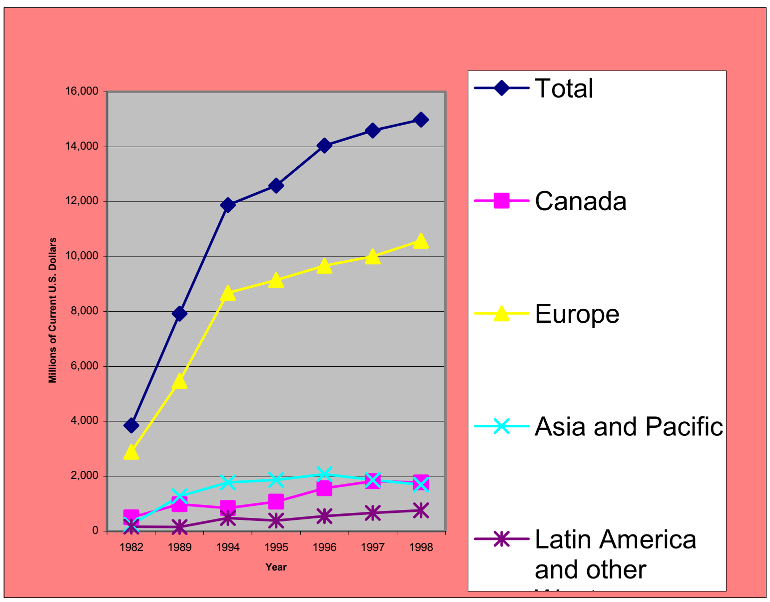

FIGURE 1

R&D PERFORMED ABROAD BY MAJORITY-OWNED FOREIGN AFFILATES OF U.S. PARENT COMPANIES (SOURCE: NATIONAL SCIENCE BOARD, NSF [2])

More recent reports indicate that the globalization of R&D has accelerated in the face of the current economic situation. An example is the General Electric Company, which has expanded its R&D efforts into Hungary. There, scientists are helping GE develop new technologies. The company has also established a new R&D center in Budapest dealing with new medical equipment like x-ray and MRIs. Also, in Budapest, Tata, the Indian software company, has hired dozens of local programmers for its new office. Nokia's R&D center now employs hundreds of engineers in Budapest working on software projects.

News reports indicate that the Dutch multinational company Philips has invested $2.5 billion in China. The emphases are in knowledge-intensive fields such as product R&D and basic research. While in the past Philips viewed China as a place to sell products manufactured in Europe, and later as a place for manufacturing, now it treats China as the place to which to move processes for product development and technology innovations.

In 2002, Microsoft announced the investment of $400 million in India to be spread over three years, mostly for developing the .Net project. The company also will have a $100 million stake in a software development center in Hyderabad, viewed by many as India's cybercity. In announcing these investments during his recent visit to Bombay, India, Bill Gates of Microsoft emphasized the importance of collaborative work for future innovations in software engineering.

Since the beginning of 2001, the Hyderabad-Bangalore corridor in India is becoming a mecca for new R&D centers in information technology. More than 230 multinationals have established bases in Bangalore during the past 2 years. An additional US$1.5 billion are due to be invested in this area, while the 25,000 engineers that already work in R&D there will swell to 65,000 in three years.

Among the U.S. companies that have turned Bangalore into a strategic hub for R&D is Texas Instruments, which has harvested some 20 patents from its Bangalore operations. Oracle Corp. has 2,400 engineers working in R&D there. Intel completed a new $25 million R&D complex in Bangalore, and will increase its chip R&D staff from its current 950 to 3,000 by the year 2005. The company's three-year-old campus in Bangalore, the largest outside of Portland, Oregon, USA, has produced 62 patents for semiconductors.

In addition, Sun Microsystems has 400 engineers working on servers, and Cadence Systems, Alalog Devices, and Cisco Networks are rapidly expanding R&D in Bangalore.

Available data indicate that over in Brazil the trend in R&D efforts by U.S. companies, though comparatively small in absolute terms, has been also on the upswing. The data reported in [2] show that R&D performed by majority-owned Brazilian affiliates of U.S. parent companies grew from US$97 in 1982 to US$448 in 1998.

These are examples of a globalization of industrial R&D that recently is taking shape at an amazing speed. It represents a paradigm shift whose long-term impact is being viewed with trepidation by some nations and welcomed by others. One thing is certain: The globalization of industrial R&D is certain to have a profound impact on the internationalization of research and education at academic institutions around the world.

RECENT DEVELOPMENT AT NSF WITH INTERNATIONAL IMPLICATIONS

The need for international cooperation in engineering education and research is gaining recognition by funding agencies in several countries. Though just a beginning, some of these countries have taken steps to strengthen their support for international cooperation in engineering education and research. The U.S. National Science Foundation (NSF) is one such agency, as indicated below.

By supporting research and education programs, primarily at academic institutions, NSF is committed to advancing the frontiers of scientific and engineering research and education through the development of intellectual capitals, the integration of research and education, and the promotion of collaborative partnerships. In pursuit of its mission, NSF emphasizes the education and development of a culturally diverse workforce, and the support of women and underrepresented minorities.

Three years ago, the U.S. National Science Foundation celebrated its 50^{th} birthday. In its first 50 years, the agency was focused primarily on development of its domestic funding portfolio, in which it has had notable successes.

Recognizing the increasing importance of participation in international science and engineering cooperation and partnerships as a way of keeping abreast of important new insights and discoveries in science and engineering, in 1999 the National Science Board (NSB), which governs the NSF, formed a Task Force on International Issues in Science and Engineering. The Task Force issued its Interim Report in 2000.

The NSB report contains the recommendation that "NSF strengthen the coordination and management of U.S. international science and engineering research and education activities"; it also recommends that NSF "facilitate international collaboration in science and engineering research and education, particularly by younger scientists and engineers and with developing countries".

In January 2002, NSF announced the establishment of the Office of International Science and Engineering. In June 2002 NSF issued a letter soliciting proposals from U.S. investigators in materials research who are interested in collaborating with their counterparts in European nations. Seventeen nations ranging from Austria to UK are involved, as is the European Science Foundation that is headquartered in France. The new funding opportunities will focus on extensive use of electronic communication, information exchanges, and databases to promote and facilitate research collaboration and educational activities at the international level.

In July 2002 NSF announced the continuation and expansion of the Integrative Graduate Education and Research Traineeship (IGERT) program that increases significantly the funding for international cooperation in response to the globalization of research and career opportunities. IGERT emphasizes providing students with an international perspective through internships and fieldwork.

Also in July 2002, NSF issued a letter soliciting proposals from U.S. investigators in materials research for collaboration with their counterparts in Argentina, Brazil, Canada, Chile, Colombia, and Mexico. Collaborating research funding agencies in these countries are CONICET (Argentina), CNPq (Brazil), NSERC (Canada), CONICYT (Chile), COLCIENCIAS (Columbia), and CONACYT (Mexico). Of interest are cooperative research projects that leverage the strengths of each country's scientific community, making extensive use of electronic communication, information exchanges, and databases to promote and facilitate research collaborations.

In August 2002, NSF announced the continuation of the Information Technology Research Program that also includes support for U.S. investigators who collaborate with international researchers.

POTENTIAL TOPICS FOR INTERNATIONAL COOPERATION IN EDUCATION

For many funding organizations, investing in education is increasingly important. Some of them hold the view that now is the time to significantly increase the role and visibility in funding international cooperation in the integration of research and education, with the focus on education, specifically engineering education.

More than in research, international cooperation in engineering education must involve communication and dialog; hence issues that must be addressed include problems posed by geographic separation, language, and cultural differences.

Recent dialogs in the international community have led to identification of several key topics in engineering education that are ripe for major breakthroughs through international collaborative efforts. These include the following:

a. Innovative approaches for distance learning and digital libraries.
b. Innovative approaches to address multilinguism.
c. Innovative approaches to address international assurance of quality and standards.
d. Establishing and implementating assessment and evaluation standards.
e. Integration of research and education in international partnerships.
f. Innovations in resolving intellectual property issues.
g. Innovations in institution-to-institution collaboration across international boundaries.
h. Approaches to international accreditation and standards.
i. Innovative approaches to international research-based student exchanges.
j. Development of joint degree programs.
k. University-industry cooperation in international cooperation.
l. Collaboration in senior design projects.
m. Establishment of international consortiums in research and education.
n. Innovative e-learning delivery methodologies including synchronous shared learning and asynchronous shared learning.
o. Joint development of e-learning courses and curriculum, and development of underlying technologies such as advancement in electronic information, multimedia technologies, and massive storage technologies.
p. Joint development of non-credit short courses at senior undergraduate and graduate level, and web-based course development.

CONNECTIVITY EVEN WITHOUT MAJOR NEW INVESTMENTS

Even without major new funding, international collaboration involving existing funded domestic programs in different countries that are in related subject areas would lead to increased productivity through leveraging, not to mention the potential for opening up new avenues for investigation. What is needed here is a relatively minor new investment in each case to effect connectivity.

SUMMARY AND RECOMMENDATIONS

We have outlined the heuristic justification for an increase of investments for international cooperation in engineering education and research by all stakeholders, based on the underlying belief that the next major advancement in engineering education and research will come through international cooperation. We believe that successful international cooperation requires commitments by academe, industry and government.

It is almost a cliché to say that we live in challenging time, but it is true that the world economy is not in good shape. Yet, we must move ahead and not wait for a better time to arrive. New generations of engineers will continue to be educated and they need to be educated better to help solve the complex problems we are facing. The current economic situation makes the job of the educator much harder, but that makes international cooperation more necessary, not less.

The commitment to move forward through international cooperation must come from everyone who is involved in engineering education, from students, faculty members, administrators, and especially leaders of industry and academe, to funding organizations around the world.

A relatively minor increase in support for international cooperation, especially by academic institutions themselves -- working in consonance with the funding organizations -- for their faculty and students, will enable the linkage of existing, funded projects[14] in different countries that complement each other. This can be accomplished, at the minimum, by a judicious incorporation of an international focus in existing programs, so that the need for a large infusion of funds is obviated. The ensuing leveraging effects can enhance productivity and quality of programs to an unprecedented level.

Increased investments by funding organizations will enable the initiation of new joint research and education projects, potentially unleashing new ideas and innovations in engineering education and research that hitherto have remained untapped.

Industry, in support of their increasingly globalized R&D efforts and workforce strategies, must increase its investment for international cooperation.

We recommend the following steps for the international community:

a. Adopt extensive use of electronic communication, information exchanges, and databases to promote and facilitate research collaboration and educational activities at the international level.
b. Leverage the work of organizations that promote networking and their websites as communication tools.
c. Promote international assessment and accreditation to develop sensible quality standards for engineering education around the world.
d. Increase visibility for international cooperation by incorporating international cooperation in research and education activities.
e. Increase publicity of available resources for international cooperation in education and research.
f. Encourage innovations among program managers to increase international cooperation in their funding portfolio.
g. To the extent possible, provide increased funding for international travel for professionals at the operating levels, which include faculty, students and program managers.

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[14] Here we refer to joint projects aimed at education and laboratory innovations. International exchanges and visits, per se, will take place based on project needs but are not the main purpose of the joint projects.

h. Create enabling mechanisms for faculty and students to meet their counterparts abroad. Opportunities must be created that focus on linkages generally as well as in specific regions. An increasing attention must be paid to developing countries. With relatively few exceptions, faculty members lack such opportunities and are looking for leadership.
i. U.S. companies should consider providing opportunities for students from the U.S. to gain international work experience by creating cooperative educational opportunities in their off-shore sites.
j. Continue development of international forums that provide opportunities for networking and partnership, such as the ICEE conference series. This series has as its central focus the promotion of international linkages. Conferences have been scheduled annually till 2006 and proposals for 2007 and beyond will begin this year. ICEE-2003 will be held in Valencia, Spain in July. Over 650 abstracts have been submitted from over 50 countries.
k. Develop and strengthen the regional conferences, such as the iNEER conference series. This iNEER conference series is being created to address the needs of local educators who cannot travel abroad to attend an ICEE conference, or who cannot wait until 2007 or later to have their own ICEE conference. It is also aimed at relieving the paper pressure for the ICEE conferences. Form an international committee to help development.
l. Be proactive in initiating workshops, retreats, and conferences that provide opportunities for developing new linkages and partnerships.
m. For universities and colleges in non-English speaking countries, invest in creating English translations of key sections of their websites.
n. Pool resources and invest in creating joint curriculums.
o. Invest in joint development of web-based learning programs for the international audience.
p. Form coordinating committee for international cooperation to develop an action plan for information sharing and networking among key stakeholders.

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Robert Altenkirch is President of New Jersey Institute of Technology, Newark, New Jersey, USA. Prior to that he was Vice President for Research at Mississippi State University (MSU), and served as Dean of College of Engineering and Architecture at Washington State University, and Dean of Engineering at MSU. A mechanical engineer, Altenkirch received the Ph.D. from Purdue, and has hundreds of publications and presentations to his credit.

Altenkirch is a fellow of ASME, a member of Phi Eta Sigma, Tau Beta Pi, Sigma Xi, ASEE and the iNEER Board.

Win Aung is member of the U.S. Senior Executive Service at the National Science Foundation. He was affiliated with Bell Laboratories in Whippany, NJ during 1969-1974. He received the first NSF Federal Engineer of the Year award (1985), and is a Fellow of American Society of Mechanical Engineers (ASME) and a member of its Council on Education. Author of over 120 technical papers, he also edited or co-edited 9 books. He received the ASME Classic Paper Award (1999) and the *Doctorem Honoris Causa* (honorary doctorate degree) from VSB – Technical University of Ostrava, Czech Republic (1999). He is the founder of the ICEE conference series, a co-founder of the International Network for Engineering Education and Research (iNEER), and is its Secretary-General. He has served as an adjunct or visiting professor at several universities. His field of research is in heat transfer.

Carlos Henrique de Brito Cruz was appointed as President of the State University at Campinas (Unicamp) in 2002. He graduated from the Instituto Tecnologico da Aeronautica in Electrical Engineering in 1978, and received the M.Sc. degree in Physics in 1980 and the D.Sc. in Physics in 1983, both from the Physics Institute "Gleb Wataghin" at Unicamp. He was a researcher (1986) at the Quantum Optics Laboratory at the University of Rome, a resident visitor at AT&T Bell Laboratories in Holmdel, NJ (1987) and at AT&T Bell Laboratories in Murray, NJ (1990). He has been Vice-President (1995-1999) of the Brazilian Physics Society, a member of the International Advisory Committee of the Optical Society of America (1991-1994), and Director of the Physics Institute (1991-1994, 1998-2002) and Dean of Research (1994-1998) at Unicamp. During 1996-2002, he served as President of the Foundation for the Support of Research in the State of Sao Paulo (FAPESP). His research areas are in ultrafast phenomena in condensed matter. Dr. Brito Cruz is a member of the Brazilian Academy of Sciences.

John Garside was appointed Principal and Vice Chancellor of UMIST in 2000. He was previously a Pro-Vice Chancellor with responsibility for academic planning and development. A chemical engineer, he holds a Chair in that subject and held posts at University College London and ICI, as well as sabbatical positions at Iowa State University and in Japan. His research specialization is in the broad field of crystallization, and is the author of over 150 research publications. He has been President of the Institution of Chemical Engineers and is the UK delegate on the Executive Board of the European Federation of Chemical Engineering.

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Justo Nieto received the Ph.D. from Polytechnic University of Catalonia. He was elected Head of the School of Industrial Engineering of Polytechnic University of Valencia (UPV) in 1979. In 1986, he was elected Rector, and holds that position today, following several re-elections. The founder and President of the Biomechanics Institute of UPV and a former President of the Iberian Society of Biomechanics, Nieto has published over 200 research articles in specialised scientific journals. The recipient of numerous awards, scholarships, cultural and scientific honours, he has been granted the degree of *Doctorem Honoris Causa* by 3 universities in Peru and one in Cuba.

Vaclav Roubicek stepped down as Rector of VSB – Technical University of Ostrava in 2003 and remains as Vice Rector for International Affairs. In 2002, he was elected to a Senate seat in the Czech Government. A specialist in mining and mineral resources research, he is the author of numerous papers and text books, and co-editor of the 2002 iNEER Special Volume: Engineering Education and Research – 2001: A Chronicle of Worldwide Innovations. A co-founder of iNEER and member of its Board since inception in 2000, he was General Chair of ICEE-1999.

Gary Thomas, Chancellor of the University of Missouri – Rolla, Missouri's technological university, was educated at the University of California at Berkeley where he received his Ph.D. in Electrical Engineering and Computer Science. Prior to assuming the position of chancellor, Thomas was Provost and Senior Vice President at New Jersey Institute of Technology. He is an editor and contributing author to the three-volume Handbook of Electrical Engineering and Computer Science published by McGraw Hill. He was a AAAS Congressional Fellow.

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Che-Ho Wei has been Chairman, National Science Council (NSC) since 2001. He was Vice President at National Chiao Tung University. He received the B.S. and M.S. degrees from National Chiao Tung University, and the Ph.D. from University of Washington, Seattle. Wei has received numerous awards, including the Distinguished Research Award in 1990 and 1996 from NSC, the IEEE Third Millennium Medal, the IEEE Circuits and Systems Society Golden Jubilee Medal, and the iNEER Achievement Award. He was co-chair of ICEE-2000 and chairman of the iNEER Board from 2001-2003.

Wojciech Zielinski became Rector of Silesian University of Technology (SUT) in 2002. Prior to that, he was Vice Rector for Education. He obtained both the M.S. and Ph.D. degrees at SUT. He was Head of the Institute of Organic Chemistry and Technology of SUT during 1991–1997. He is a member of the Scientific Council of the Institute of Organic Industry in Warsaw, the Council of International University in Zittau, Germany; Polish Committee of Standards, and Polish Academy of Sciences. His research interests concern synthesis of organic compounds. He received Achievement Awards from the Ministry of Education in 1976, 1978, 1984 and 1987.