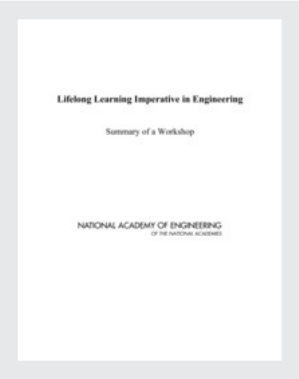


# Lifelong Learning Imperative in Engineering: Summary of a Workshop

**DETAILS**

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# Lifelong Learning Imperative in Engineering

## Summary of a Workshop

Debasish Dutta
Rapporteur and Program Chair

NATIONAL ACADEMY OF ENGINEERING
*OF THE NATIONAL ACADEMIES*

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This workshop summary has been reviewed in draft form by individuals chosen for their diverse perspectives and expertise, in accordance with procedures approved by the National Academy of Engineering (NAE). The purpose of this independent review is to provide candid and critical comments that will assist the author and the NAE in making the published report as sound as possible and to ensure that the workshop summary meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this workshop summary:

Nelson Baker, Georgia Institute of Technology
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John A. Casazza, American Society of Civil Engineers
Donald Keating, University of South Carolina
Sean Newell, Ford Learning and Development
Betty Shanahan, Society of Women Engineers

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the final draft of the report before its release. The review of this workshop summary was overseen by Alice Agogino, University of California, Berkeley. She was responsible for making sure that the independent examination of this workshop summary was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this workshop summary rests entirely with the author and the institution.

# Contents

# Lifelong Learning Imperative in Engineering Workshop

## National Academy of Engineering

**Debasish Dutta**
**Rapporteur & Program Chair**

**June 17-18, 2009**

**Hilton Arlington**
**950 North Stafford Street**
**Arlington, VA 22203**

# 1

# Background

The 21st century is witnessing a rapid increase in the pace of knowledge creation in the sciences and engineering. Competing in this global economy requires a science and engineering workforce that is consistently at the technological forefront. Dr. Charles Vest, President of the National Academy of Engineering, in a speech at the University of Michigan on October 15, 2007, put it simply: prospering in the knowledge age requires people with knowledge. The purpose of the Lifelong Learning Imperative Workshop was to consider learning opportunities for the engineering professional. The participants in the workshop addressed the necessity of lifelong learning, the history of continuing education[1], possible delivery systems, systems used by other professions, and the current state of learning when viewed in the light of the rapid rate of technological change.

Two decades ago, the U.S. National Research Council Panel on Continuing Education in its report, *Continuing Education of Engineers,* recommended a collaborative effort among industry, university, and government to "establish the spectrum of values and objectives of continuing education for individual engineers in industry, and academia and to describe how continuing education could or should operate in the engineering world of tomorrow." Since then many continuing education programs have been developed and are offered by professional societies and universities. However, due to the emergence of new and rapidly changing technologies a re-examination of the current framework for lifelong learning and its underlying assumptions is necessary.

More recently, the National Academy's report, *The Engineer of 2020,* reiterates the importance of lifelong learning for the engineering professional. It calls for engineers to expand their learning over a lifetime because their career trajectories will take on more directions, many new, due to the rapidly changing technologies. The broader implications of lifelong learning for national competitiveness were also considered in the 2006 Spellings Commission report on the future of higher education, which calls for the "development of a national framework for lifelong

[1] The terms "continuing education" and "lifelong learning" were used interchangeably at times during the workshop. In order to be consistent, after the Introduction where "continuing education" is used as a historic term, we will use "lifelong learning" throughout this report.

learning designed to keep our citizens and our nation at the forefront of the knowledge revolution."

The examination of lifelong learning has been initiated by the National Academy of Engineering in order to assess current practices in lifelong learning for engineering professionals, to re-examine the underlying assumptions, consider options, and outline strategies for the future. Some issues that need to be considered include; who decides what knowledge is needed, who provides the learning opportunities; in what format and where; who certifies it; who pays for it; what are the appropriate roles, respectively, for employers, professional societies, government, and academia; and should there be consideration for broadening one's field as well as for updating current practices. By bringing together stakeholders including policy makers, the LLI workshop has opened a national dialogue on lifelong learning for engineering professionals in the knowledge age. The workshop identified critical issues worthy of being pursued in depth.

# 2

# Content of the Workshop

The first evening of the workshop included dinner and a speaker who provided insights into lifelong learning in medicine and pointed to common ground in learning and applications shared by the medical and engineering professions. Charles Vest, who introduced the speaker, noted that it was indeed fortunate to have a speaker lead off the workshop by providing knowledge about what another profession does in regard to lifelong learning.

The speaker, Dr. Chris Cassel, President of the American Board of Internal Medicine, addressed the issue of what the medical profession has learned about lifelong learning, specifically some of the challenges and ingredients for success. It was noted that in the areas of technologies, systems, and processes, the medical profession owes a debt to engineering. There have been discoveries, applications, and advances in these areas that have been adapted to medical procedures. Medicine has many important commonalities with engineering, such as a rapid rate of technological advance, the need for to stay abreast of changing technologies, and the direct impact of the field on societal well-being. Dr. Cassel went on to talk about what the medical profession has learned about how to educate physicians and how to certify physicians. Medical professionals must deal with a complex adaptive system as new discoveries are made and as new techniques are proven and adopted. An important variable in the medical profession is the interaction between the provider and the delivery system. The physician's role is very complex because the physician, on the one hand, interacts with the entire delivery system; and, on the other, interacts as the provider of medical services. Dr. Cassel also addressed the certification of continuing education in the medical profession. An important issue is that board certification in the medical profession is a voluntary process. It is important for the "marketplace" (i.e., patients) to realize that maintenance of certification is a comprehensive assessment of up-to-date content knowledge, professionalism, and application of knowledge in practice, interpersonal skills, systems-based practice, and practice-based improvement. Dr. Cassel wrapped up her summary by pointing out that often conflicts of interest issues need to be addressed when considering who provides the continuing education. For example, accepting the offer of free education from a provider of a new piece of medical equipment is problematic.

In the question and answer session that followed, there was further discussion concerning possible conflicts of interest in medical research, education, and practice when manufacturers and suppliers become too involved. In addition, the connection between continuing education

and certification in the health profession was discussed at length. The question of the relationship between lifelong learning and certification was raised repeatedly in the presentations and discussions that took place during the workshop.

The full-day session of the workshop consisted of plenary sessions addressing the potential role of federal agencies in lifelong learning, examples of how the private sector approaches and uses lifelong learning, and the possible role of professional societies. The plenary sessions included individual presentations by notable experts in each area and two panels. Breakout sessions in the afternoon provided the opportunity for workshop participants to discuss the material presented in the plenary sessions. The workshop agenda can be found in Appendix B.

## 2.1 KEY ISSUES

The full-day session of the workshop began with welcoming remarks by Deba Dutta, Program Chair, and Linda Katehi, Organizing Committee Chair. Linda Katehi began with the statement that lifelong learning is part of an engineer's career—an observation that is understood by most, but seldom emphasized. She then introduced and thanked the Organizing Committee for this important workshop and the talented and powerful participants that were assembled there. Returning to the topic of lifelong learning as an integral part of an engineer's career, she further emphasized the economic necessity for lifelong learning and the need for engineers to have opportunities to learn throughout their careers. Engineers change careers many times during their professional life and due to economic factors and the introduction of new technologies and engineering methodologies. Methods and time needed to receive "instruction has also changed. What used to be called "long distance learning" (because the U.S. mails were used for correspondence courses) has now become "online learning" (because the individual can sit down at his or her computer). Learning opportunities via online learning are often close to being instantaneously available. However, neither long distance learning nor online learning includes the presence of an instructor or other classmates. Universities are important because they add the social element and the vitality of a live community. Universities have a responsibility to respond to the needs of the engineer with respect to lifelong learning.

Charles Vest, President of the National Academy of Engineering, began the plenary session by reiterating the importance of lifelong learning. He then outlined the history of continuing engineering education, provided observations concerning the current state of continuing engineering education, and formulated questions and ideas that might be discussed as the workshop progressed. Dr. Vest summed up the history and what has been the primary problem with lifelong engineering education with the observation that "faculty won't play and industry won't pay". In other words, academic faculty are concerned with teaching (that is, courses that provide credits for undergraduate or graduate degree programs), research, and tenure; and industry is worried that if they pay for engineers to advance their knowledge through lifelong learning, that knowledge might make them more likely to look for more lucrative employment elsewhere. This quandary led directly to the issue of who should be offering lifelong learning opportunities to the engineer. He gave examples of different scenarios of company and academic views as to how the question of continuing engineering education has been handled. One that was stunning was the example of the U.S. corporate view of lifelong learning for

engineers verses lifelong learning for management. Corporations are not predisposed to pay for engineers to participate in lifelong learning, but where a member of the management team is concerned, price is no object. After summarizing what has happened to the view of the need for lifelong learning for the engineer in the 1990s and the 2000s, he wrapped up his presentation with four reasons why lifelong learning for the engineer is very important:

1. There is reason to believe that our "free ride" on the backs of engineers from other countries is in jeopardy (there are increasingly equally good opportunities for these engineers elsewhere—other than the U.S.);
2. The impact of globalization (thus, the need to be current) on the American worker;
3. The evolving nature of national needs (again, the engineer must be current and retool, if necessary); and
4. The relentless pace of technological change (and again, the challenge of keeping current).

These can be summed up by noting, as Dr. Vest did, that this is an important workshop given the collective knowledge about lifelong learning represented by the participants. He urged that this historic opportunity not be lost. Lifelong learning for the 21st-century knowledge revolution must be realigned to better equip today's engineers to deal with present and future technological changes. The participants in the workshop constitute an excellent community to begin this process. Dr. Vest left the workshop participants with the following questions:

1. Is American industry serious about lifelong learning?
2. Who should and who will provide lifelong learning to the engineer?
3. How can this dialogue on lifelong learning be encouraged and advanced?
4. What is the role of government?
5. Is this the opening for a transformative opportunity for the United States in global competition?

Arden Bement, Director of the National Science Foundation, began by agreeing that the importance of lifelong learning for the engineer cannot be overemphasized. The traditional fields of engineering continue to evolve. New fields emerge, such as nano-technology, new and expanded variants of biotechnology, and informatics. There are also new demographics to take into account as the engineering profession progresses and adapts. There are over 1500 engineering programs in the U.S. It is important to remind ourselves that lifelong learning is not fixing something that is wrong, but it is enhancing and strengthening what is good in the profession. Lifelong learning spans 50 years of a career as opposed to 4, 6, or 8 years for a degree or advanced degree. But it does not even stop there—lifelong learning extends beyond a career to include mentoring of new engineers as they develop and progress. In today's world of rapid scientific and engineering advancement, the half-life of an engineer's technical knowledge is steadily reducing as the profession changes with time and new emerging fields. Lifelong learning can also help with job hunting (an important matter in this time of a slow economy), but the other side of the argument is that possible job hopping makes industry reluctant to pay. There are also financial factors when valuing investments in lifelong learning. Dr. Bement predicted that we will be looking for models of lifelong learning in other countries in the near future. The National Science Foundation can advance lifelong learning through the funding of new studies to better understand learning in the workplace; through funding of innovative

research; and through some programs that already exist. Times have changed—now we are concerned with "human capital" and a "knowledge infrastructure". Mobility of workers is not a good reason for industry not to make an investment in lifelong learning. However, Dr. Bement presented several points of concern regarding the concept of lifelong learning. Three that were most salient are that lifelong learning is focused on today's problems, not tomorrow's; the benefits of lifelong learning have not been quantified; and the paradox that when things are good, there is no time and when things are bad, there is no money. He summarized his presentation by noting that it is a good juncture at which to look ahead and to consider the ways that lifelong learning can make a difference in the lives of individual engineers, in the innovative and competitive capacity of our economy, and in the vitality and relevance of the engineering profession. Dr. Bement noted that the participants in this workshop are probably some of the most appropriate individuals to begin the process of redirecting lifelong learning to increase the capability of engineers in the 21st century knowledge age.

Dan Mote, President of the University of Maryland, began by reminding the workshop participants that lifelong learning brings engineers to the cutting edge of their fields. The rate of change in our culture regarding interaction with technology is accelerating and the half-life of knowledge that one graduates with is decreasing. He noted four examples: 1) one half of what is learned in the first year of study is outdated by the third year; 2) the top jobs in demand in 2010 did not exist in 2004; 3) the expected number of jobs a person will hold by age 40 is 5 to 6; and 4) engineers change jobs every 4 to 5 years. The role of universities to answer today's needs is to offer new degree programs specialized to meet goals, offer courses in complementary fields, provide opportunities beyond the curriculum, and provide lifelong learning opportunities. He noted that the cost of hiring and having an engineer become conversant with the job and the company (6-12 months) is $20,000 to $80,000. In comparison, the cost for lifelong learning for 100 hours is $5,000 to $10,000; and the lifelong learning required to stay current is 100-300 hours/year. Dr. Mote predicted that lifelong learning in the future will have more online courses and webinars; be more multidisciplinary; consist of more partnerships among universities, government, and industry; and have more international partners. He finished his presentation with a short story to make an employer think: A CEO had just given a long and enthusiastic presentation about the importance of lifelong learning to him and his company. A comment from the audience raised the question of the high cost to the CEO and his company if his employees left the company soon after their education at company expense. In response to that question, he agreed that this situation would be a loss to the company, but what worried him more was *not* educating his employees and having them stay with the company.

The federal agency panel members consisted of Steve Koonin, Under Secretary, Department of Energy; Tom Kalil, Deputy Director (Policy), Office of Science & Technology Policy; and Tom Peterson, Assistant Director of Engineering, National Science Foundation. Each gave short presentations then discussion followed. Steve Koonin suggested possibilities for different types of lifelong learning experiences and funding opportunities that could be developed by federal agencies, such as lifelong learning for engineers with "real jobs", or a joint lifelong learning experience, where a mentor and student get away from the business world together for a learning experience. Tom Kalil noted that in the past lifelong learning has been somewhat focused on the disadvantaged. Perhaps a new possibility is to provide lifelong learning financial help through tax breaks such as Lifelong Learning Accounts (LiLA) or workers could set aside a pay increase

to engage in lifelong learning when there was a less busy time in the workload. He expressed the belief that it is important to teach skills that are transferable, and he noted further that if this community wants to engage the administration, then their articulation of the issues and progress will be better served if they are able to connect these issues with an administration initiative. Tom Peterson re-emphasized the necessity of lifelong learning and the need to prepare today to be ready to address "tomorrow's issues" when they arise. The example he gave was climate change. He also stated that lifelong learning is not a new issue. There needs to be more collaboration across agency boundaries, and he emphasized that the opportunity for doing something important in lifelong learning is now. The topics brought up for discussion by the workshop participants included:

a) What is the role of government in ensuring that federal employees have time and resources to pursue lifelong learning;
b) How do agencies and industries know what is available in the area of lifelong learning;
c) What money is available at the federal level;
d) Who are the stakeholders; and
e) Who is responsible in the government for lifelong learning.

While many of these questions resurfaced in the afternoon breakout sessions, the two key issues imbedded in these five questions above are: 1) what is the role of the federal government in assisting with the funding to establish a national framework and policy for lifelong learning; and 2) what are the lifelong learning opportunities for federal employees. This panel provided the workshop participants to gain perspectives on the first issue which is very important for a new approach to lifelong learning since the federal government is an important stakeholder. The second issue had been considered by earlier speakers but within the context of engineers in industry. The main difference is rooted in the volatility of the job market in the private sector.

The final presentation before lunch was by Nick Donofrio, IBM Fellow and Exec VP I&T Alumnus. He enlivened the workshop and gave the participants ideas to think about over lunch. He emphasized that an engineer needs to be learning, changing, advancing, and staying on the cutting edge throughout his career in order to be successful. Lifelong learning helps him to do that. He also noted that there are two areas in lifelong learning that are receiving increased attention now because of their importance to lifelong learning for the engineer. The faculty members who are providing lifelong learning for engineers are finding and supplying what industry needs; and employers are finding the value of replacing some work time with learning time has become increased with the rapid changes in technology. Among the stimulating concepts left for the workshop participants to ponder were ten emphases: 1) today there is a "technology immersion"—younger people accept technology as normal; 2) the world is getting progressively interconnected; 3) some things are learned by simply showing up; 4) regarding lifelong learning, it is important to listen to industry and understand its needs; 5) an engineer must be adaptable; 6) an engineer will perish if he can not change (advance); 7) engineering is a wealth generator; 8) the driving question of lifelong learning is "what is the value?"; 9) a service-based economy is a driver of change; and 10) in 2006, for the first time, there were more people in the service industry than in agriculture in the world.

After lunch, the professional society panel members, with Enrique Gomez from the Society for Hispanic Engineers, Gerry Galloway from the American Society of Civil Engineers, and Peter Finn from the Society of Women Engineers, each gave short presentations. Then discussion followed. Enrique Gomez noted why lifelong learning is important to his segment of the U.S. population. The Society of Hispanic Engineers has 10,500 members. However, while the Hispanic population in the U.S. is the fastest growing segment of the population, it is the least represented in STEM fields, has the fewest number of college degrees, and has the lowest median income. A solution lies in lifelong learning, which up to this point has not been an important part of the student's or professional's life. Gerry Galloway outlined the importance of lifelong learning to his members. In his view, it is essential that civil engineers continue professional development throughout their careers. In order to become and stay credentialed, they must attain the requisite body of knowledge; have experience; and continue their professional development throughout their careers. The American Society of Civil Engineers also supports specialty certification as an additional credential following licensure. The American Society of Civil Engineers serves as the interface between practitioners, educators, lifelong learning opportunities, and certification. Peter Finn noted that his members are self-directed learners. For the Society of Women Engineers, professional associations play a central role for professionals looking for lifelong learning opportunities. They use self-assessment activities to guide learning, and they blend individualized learning plans with mentoring and coaching. One of their main goals is filling the gaps in knowledge needed.

## 2.2 SPECIFIC OBSERVATIONS AND QUESTIONS RAISED

Breakout session were structured around specific questions related to the current framework for lifelong learning shown in Figure 1. The breakout sessions met for 1½ hours and then reported back to the workshop as a whole. The individual sessions, all moderated by members of the Organizing Committee, were LLI Models and Program Structure, with Jim Porter as Moderator; LLI Content and Certification, with Phil Woodrow as Moderator; Cyber-infrastructure support for the LLI, with Pat Natale as Moderator; and the Organizational Support for the LLI, with Betty Shanahan as Moderator. The general topic of the workshop was the pressing need (imperative) for lifelong learning and the present status of learning opportunities for engineers. Thus, the presentations during the plenary sessions set the context for the breakout sessions which provided an opportunity for discussion focused on more specific questions related to learning opportunities for engineers. Many ideas, observations, and questions surfaced during the breakout sessions. Each session was provided as an initial starting point with four general questions. Ideas, points for discussion, questions, and possible next steps were brought back to the gathered participants. The following are some that seemed to generate particular interest and discussion:

It is important to note that the four breakout groups were not Academy-appointed committees and that the summaries of each session reflects the views of the individuals who participated in the specific breakout session discussion at the workshop—not necessarily those of the institution or the workshop planning committee. The ideas and suggestions for next steps put forward should not be construed as consensus recommendations of the individual breakout groups, the workshop participants as a whole, or the National Academies.

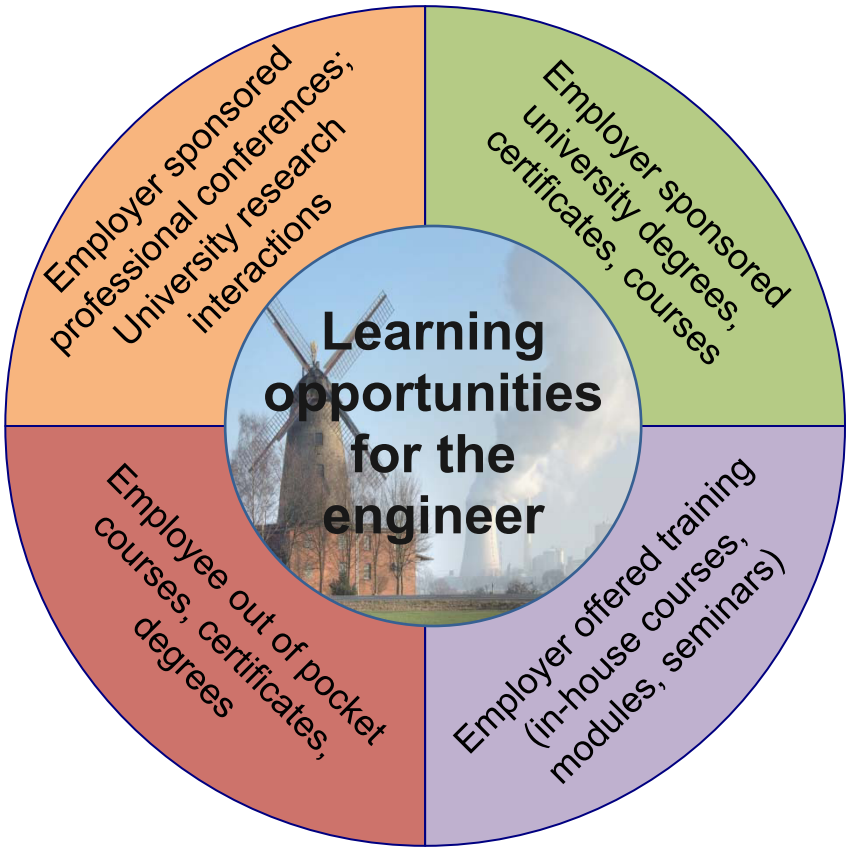


Figure 1. Current framework for lifelong learning

### 2.2.1 LLI Models and Program Structure

Participants in this breakout session addressed the issues of assumptions underlying current practices; learning needs of the engineer in the 21st century; unmet needs of the knowledge economy; relevant current practices; and a predictive model for fostering continuous improvement.[2] Some of the ideas of individual session participants brought back to the workshop plenary include the following:

- To gain the level of support needed to make LLI a sustainable model for engineers the benefits should be better quantified. This includes defining the value to all relevant stakeholders (employers, employees, and the economy).
- To have maximum positive impact any LLI components should be delivered on a (just in time) JIT basis.
- Learning needs will continue to evolve with the changing roles of engineers. Discipline specific technical fundamentals will remain necessary but not sufficient to allow the engineer in the 21st century to deliver and gain optimum value from their competencies and contributions. A functional understanding of and ability to apply leadership, team

[2] The breakout session was moderated by Jim Porter and included Bernard Amadei, Bill Badger, John Casazza, Enrique Gomez, Dominico Grasso, Nancy Martin, Kent Rochford, Debra Stewart , and Galip Ulsoy.

building, non-capital project and financial management and work process design skills will be imperative. In addition, an appreciation for cross competency fundamentals will be very helpful.

- Major drivers for lifelong learning are self-improvement and corporate need or opportunity. What is needed in addition are compelling core reasons, such as a culture that values lifelong learning.
- Some participants in this session questioned whether a common lifelong learning provider or coordinator would be helpful to make the issue of lifelong learning more compelling.
- Some major barriers to achieving sustainable systems for lifelong learning were identified, including deficiencies with regard to personal incentives, a convenient infrastructure, guidance for self-assessment, and assistance for what is viewed as an information disconnect between the CEO level and middle management regarding the value of lifelong learning.
- It is necessary to define the "big picture" (meaning a national framework) before defining a "sustainable model and structure" to achieve it.
- Key items missing in the current corporate environment are a well defined path for technical progression and a lack of value for a "learn, teach, learn" culture.
- Any sustainable model will need to be established as adaptable to evolving needs over time and be nationally leveraged. It will need to have a clearly apparent single point of contact developer and a formalized framework such as a competency/career aspiration matrix to guide the development and evolution. It will also need to include self assessments, common competency and performance standards, and a process to allow best practices and content to be rapidly shared.
- Some LLI core questions were noted as potentially valuable for future discussion:

  - Are there some existing continuing education programs that would be good reference models?
  - Should all engineers be licensed?
  - What would a LLI culture "look" like?
  - Who are the critical stakeholders related to LLI success: engineers; users; academia, professional organizations, society?

### 2.2.2 LLI Content & Certification

Participants in this breakout session addressed the issues of who determines, or what drives the content of lifelong learning for the engineer—who provides it, who measures effectiveness; i.e., certifies it; limitations in current practice in the workplace; elements from current practice that are worth preserving; and a predictive model for fostering continuous improvement.[3] Some of the ideas and questions brought back to the workshop plenary by individual breakout session members include the following:

[3] This breakout session was moderated by Phil Woodrow and included Rich Andrews, Susan Bailey, Henry Marcy, Roger McCarthy, Toni Marinilli, Kimberly Markiewicz, Frank Mayadas, Rick Miller, Steve Rottler, and Susan Zawislak.

- The question of learned content and certification revolved around what is needed first. Learned content is needed to enter the workforce. Inherent in the learning needed to obtain an academic credential is the ability to learn how to learn. Lifelong learning is beyond learned content via academic venues. Lifelong learning is the opportunity to sustain and acquire further skills and to further increase the individual's capacity to contribute to both personal aspirations and to society. Certification is the assurance that the learning content has been realized according to expected levels of proficiency as measured by testing and, in some cases, experiential accomplishments.
- Certification is a term that will need better definition as it currently engenders a formal, recognized third party (state, professional society, etc.) administered process. Learning certified by these external bodies may need requirements for engineering professionals depending on their career paths, job requirements and to assure external credibility.
- There is a general need to demonstrate proficiency via effective application of learning. Some organizations deliver "training" for which the outcome is "learning" based on testing or other measures of proficiency (projects, etc.). Certification may be regarded as the highest level of learning assessment and can provide "common denominators" across the engineering profession and within specific engineering disciplines.
- Continuous improvement is an important aspect of lifelong learning. Behaviors that include self-assessment and willingness to change (advance), as well as a learning environment and an appropriate culture are key contributors to this continuous improvement mindset.
- When considering whether non-traditional learning processes; e.g., informal learning, can achieve credibility, the key is certification. Certification is necessary because degrees must be supplemented with post-academic environment learning and experience.
- Learning and proficiency (certification) are part of a learning culture based on principles of inclusion and diversity, collaboration, measurable outcomes; i.e., performance competency, and a life-cycle framework of renewal, adaptability, and professional growth.
- As organizations focus on continuously improving development of human assets, a disciplined and competencies-driven development of the knowledge, skills, and worker motivation is typical. This predictive model provides an on-going tactical and strategic assessment of competencies versus the capabilities of the workforce provides the driving force for defining learning needs. The resulting learning programs work to close the competencies and capabilities gap. In this model, is certification the only way to measure capabilities?
- As engineers work to innovate and serve the needs of society, how is society convinced that the engineer's training, learning, certification, and performance are credible? Similarly, how is this value-add demonstrated to all engaged stakeholders?

### 2.2.3 Cyber-infrastructure Support for LLI

Participants in this breakout session addressed the issues of modalities of delivery for lifelong learning; the space-time limiting factor in distributed workplace learning; new learning models enabled by cyber-infrastructure; whether a new workspace model is needed for the 21st century; social impacts of on-line versus face-to-face learning models; and a predictive model for

fostering continuous improvement.[4] Some of the ideas brought back to the workshop plenary by individual breakout session members include the following:

- Learning is fundamentally social. Peer-to-peer learning happens in study groups. Distributed and virtual study groups work well. Modalities of delivery could be tailored for focused discussion groups, study groups, personalized training, or an agent-based system. The opportunities are unlimited; however, it is not clear how some of these can be best accomplished online. Creativity and technology will drive this outcome.
- Regarding limiting factors, it was noted that there are still regions in the U.S. where access to the web is limited. Export control and questions regarding intellectual property must be carefully considered, and need to recognize that the virtual world is often very clumsy.
- Cyber-infrastructure has enabled learning on demand, and a new generation of highly visual simulation model for understanding complex systems. Larger simulations and models can be "constructed" because of the computational capacity that cyber-infrastructure enables. These simulations enable either individual or peer based tinkering—learning by experimenting and seeing the consequences. Hopefully such environments can also be augmented by intelligent agents that can coach and critique what the user is doing.
- The issue of accrediting content posted on a cyber-site was raised. This is an evolving issue in the web2.0 social media world that requires one to look at what information is now stable, what is not and the edit trajectories. The contested knowledge and analysis is a great learning experience.
- A big organizational challenge is how to restructure the workplace to become a learningscape since that might be the only way to keep up with the accelerating pace of change. Sending people back to colleges will create an alienated generation; hence perhaps we should focus more on intrinsic rewards that drive productive inquiry and peer based learning as part of one's natural ongoing work

### 2.2.4 Organizational Support for LLI

Participants in this breakout session addressed the issues of what current financial models exist; what human relations policies support lifelong learning for the engineer; what elements should be preserved; what organizational and personal culture supports lifelong learning in the 21st century; what management practices need to change to support lifelong learning in the workplace; and a predictive model for fostering continuous improvement.[5] Discussions included reports of what is already underway in large multi-national companies, and what else might be done to support and advance lifelong learning in these settings. There was agreement amongst participants and a common understanding of how essential this type of networking/exploration is to the organizations. Corporate leaders in this session engaged in serious discussion of whether a new organization needed to be created that would set standards for this new type of

[4] This breakout session was moderated by Pat Natale and included Nelson Baker, John Seely Brown, Gordon Day, Peter Finn, Gerry Galloway, Gaeta Isaura, Henn Rebane, Karie Willyerd, and Bill Wulf.
[5] This breakout session was moderated by Betty Shanahan and included Andy DiPaolo, Linda Katehi, Jud King, Terri Lomax, Nan Mattai, Sean Newell, Tom Paterson, Chris Riegel, and Karen Tancredi.

collaborative/cooperative learning and the parameters of what companies would provide and how employees might see their individual careers also benefitting.

Some of the ideas brought back to the workshop plenary by individual breakout session members include the following:

- Most outstanding was the strong agreement about the value of encouraging and supporting lifelong learning in the workplace on a formal and ad hoc basis, considered critical for nurturing the climate of innovation and creativity and permitting temporary networks to emerge, live, and terminate when their roles were over. The learning communities are a source for new thinking, new ideas, and possible breakthroughs on difficult scientific and engineering problems—central to the company's future success.
- There is a tension and possibly a disconnect between the lifelong learning objectives to ensure an individual engineer remains relevant through his/her career and the learning objectives an employer has for an engineer to be productive while he/she is an employee. This needs further study.
- If lifelong learning is a greater good, federal financial programs should encourage and facilitate it (such as flex benefits used for tuition).
- The drivers for organizational support and cooperation among stakeholders need to be better defined. Possibilities to justify lifelong learning include: (a) business cases for company CEOs that investing in lifelong learning for employees is a business investment that attracts and retains top employees; (b) business cases for policy makers that lifelong learning is a public good so that it is promoted and funded (c) the needs of individuals such as women returning to the workforce or retraining for engineers in diminishing technologies.
- Missing in the workshop discussion but necessary to consider: the implications of communities of interest in lifelong learning and also semi- and informal communities of practice; underemphasized university programs; and corporate universities structured around domains and competencies
- There was inadequate consideration of whether lifelong learning should be considered at a global, national, or state levels. Furthermore, insufficient attention was given to the role of international activities and to association such as the International Association of Continuing Education (IACEE) and the International Federation of engineering Education Societies (IFEES) which provide a forum for deeper engagement on continuing education.
- Perhaps a collaborative/cooperative organization to set standards is needed. Standards include competency models for minimum and expanded knowledge/skills in an area and transportable certification of knowledge/skills

## 2.3 NEXT STEPS

The workshop ended with a call for continued discussion and input. The workshop is documented at a website http://www.llproject.org/ which provides an overview of the motivation for the workshop, the workshop agenda including links to remarks delivered and presentation slides, a bibliography, as well as al listing of the organizing committee members and agenda of

the committee's meetings. The website includes a contact link so that visitors can providing further input.

## 2.4 SUMMARY

A repeated theme in the remarks of presenters is that in this age of rapid technological change and knowledge creation, an engineer must continue to learn throughout his or her career. Dr. Katehi observed that learning is a continual process throughout an engineer's career. Dr. Vest noted that engineers are often caught in a conflict between the goals of their employers and the goals of current continuing education providers. Dr. Bement suggested that new models for lifelong learning will emerge. And, Dr. Donofrio predicted that information technologies will play a prominent role in future lifelong learning. As recalled by Dr. Mote, there is significant employer interest and concern about the quality and currency of lifelong learning. Perhaps, a workplace appropriately structured and augmented by access to cyberinfrastructure can be a powerful way to achieve sustainable lifelong learning.

Some other observations made by presenters and participants included the belief that it is now clear that the engineering professional is no longer competing solely in a domestic market, but rather in a global economy. Career trajectories will take on many more directions. Further, lifelong learning should be provided through a collaborative effort among industry, academia, the government, and professional societies. It is not clear, however, where the leadership of this collaborative effort should be, nor was there agreement as to the relative responsibility of each of these entities. The responsibilities to be allocated include those for providing funding, accrediting educational materials, providing course delivery, and certifying learning by the engineer. In considering course delivery, several questions arise. For example: How important is the social aspect of lifelong learning? Where does the social aspect fit in the overall equation? Is online learning preferable because it is on-demand, or is it preferable simply because it may be less expensive to provide? How do questions of intellectual property factor in? The participants agreed that these important questions need to be explored further in a comprehensive study of lifelong learning.

Repeatedly mentioned, but with differing opinions about the direction, were the sometimes interconnected issues of lifelong learning and certification. Can education be separated from evaluation and still provide the credibility needed by the engineering professional? Is there an answer to the question of how to convince the general public that lifelong learning (or whatever it will be called so as to best capture the concept that was the focus of the workshop) is not fixing something that is wrong, but enhancing and strengthening what is good? When that issue is resolved, the question of demonstrating the added value of lifelong learning to stakeholders and the general public alike will be somewhat simplified.

Indeed, perhaps this revitalization of lifelong learning should have a fresh name to convey the ideas that the learning is social, situated, intended to deepen and broaden the engineer's knowledge and capabilities and is enhanced by the disposition of productive inquiry. Lifelong learning in the 21st century is dynamic and integrative in that it pulls together ideas from different disciplines and integrates those ideas with basic engineering training and knowledge. It

includes the agility and adaptability and an element of perpetual motion necessary to maintain a competitive edge. Lifelong learning is simply a necessary part of an engineer's career. Several of the plenary speakers expressed the belief that it is now time to redefine lifelong learning to strengthen and expand the role of the engineer in the interest of increasing our country's global competitiveness.

# APPENDIXES

# Appendix A

## Statement of Task

The Committee on Lifelong Learning Imperative, an ad hoc committee, will organize a public workshop in summer 2009 which will inform and lay the foundation for a future effort to synthesize, organize and disseminate information on lifelong learning for engineering professionals. The agenda for the workshop will be developed by the committee to highlight the key issues that undergird lifelong learning for engineers in the workplace. The workshop will help initiate a national discussion on lifelong learning in the 21st century knowledge economy by bringing together all stakeholders representatives from industry, professional societies academia and policy makers.

# Appendix B

## Workshop Agenda

June 17
6:30PM: WORKSHOP DINNER
*Life-long Learning in Medicine: What We Have Learned*
**Speaker: Dr Chris Cassel**, President, American Board of Internal Medicine

June 18
Lifelong Learning Imperative in the Knowledge Age: Needs, Challenges, and Opportunities

8:00AM: *The LLI Project Background & Workshop Objectives*
**Debasish Dutta**, Program Chair
**Linda Katehi**, Organizing Committee Chair

8:15AM: *Learning and the 21st Century Workforce*
**Charles M. Vest**, President, National Academy of Engineering

8:45AM: *Two Score and More: A Lifetime of Learning for Keeping Engineers at the Fore*
**Arden Bement**, Director, National Science Foundation

9:15AM: *Lifelong Learning and Universities: Options and Opportunities*
**Dan Mote**, President, University of Maryland

10:00AM: BREAK

10:10AM: *Federal agency panel*
**Steve Koonin**, Under Secretary, Department of Energy
**Tom Kalil**, Deputy Director (Policy), OSTP
**Tom Peterson**, Asst Director of Engineering, NSF

11:10AM: *Lifelong learning on a smarter planet*
**Nick Donofrio**, IBM Fellow and Exec VP I&T Alumnus

12:00PM: LUNCH

12:45PM: *Professional society panel*
**Enrique Gomez**, SHPE
**Jerry Galloway**, ASCE
**Peter Finn**, SWE

1:45PM: *Breakout sessions*

*LLI models and program structure*
**James Porter**, Moderator (Organizing committee)
**Myles Boylan**/NSF, Co-moderator (scribe)

*LLI content and certification*
**Philip Woodrow**, Moderator (Organizing committee)
**Anthony Walters**, Co-moderator (scribe)

*Cyberinfrastructure support for LLI*
**Patrick Natale**, Moderator (Organizing committee)
**Ping Ge**/NSF, Co-moderator (scribe)

*Organizational model for LLI*
**Elizabeth Shanahan**, Moderator (Organizing committee)
**Carol Stoel**/NSF, Co-moderator (scribe)

3:15PM: BREAK

3:30PM: *Report back session @ 15 min each*
**James Porter:** *LLI models and program structure*
**Philip Woodrow:** *LLI content and certification*
**Patrick Natale:** *Cyberinfrastructure support for LLI*
**Elizabeth Shanahan:** *Organizational model for LLI*

4:30PM: *Next steps & Adjourn*
**Debasish Dutta**, Program Chair
**Linda Katehi**, Organizing Committee Chair

Next steps in the Lifelong Imperative were left open pending the release of the summarization of the workshop. Everyone was encouraged to give the subject further consideration and they were invited to communicate any ideas to the program chair, Deba Dutta.

# Appendix C

## Workshop Participants

Bernard Amadei
Director, Mortenson Center in Engineering for Developing Communities
University of Colorado

Rich Andrews
Platform Curriculum Manager, Autodesk Learning

William (Bill) W. Badger
Professor, Del E. Webb School of Construction
Arizona State University

Susan R Bailey
Vice President, Global Network Operations Planning
AT&T Operations, Inc.

Nelson Baker
Vice Provost, Distance Learning and Professional Education
Georgia Institute of Technology

John Seely Brown
Co-Chairman
Deloitte Center for Edge Innovation

John Casazza
Managing Director, Continuing Education
American Society of Civil Engineers

Christine Cassel
President
American Board of Internal Medicine

Gordon Day
President
Institute of Electrical and Electronics Engineers

Andy DiPaolo
Senior Associate Dean, School of Engineering
Stanford University

Nick Donofrio
Executive Vice President, Innovation and Technology
IBM

Debasish (Deba) Dutta
Associate Provost and Dean, Graduate College
University of Illinois at Urbana-Champaign

Peter Finn
Director of Learning & Development
Society of Women Engineers

Isaura Gaeta
Manger of Technology Integration
INTEL Corp.

Gerry Galloway
Professor, Department of Civil and Environmental Engineering
University of Maryland

Enrique Gomez
Chief Executive Officer
Society of Hispanic Professional Engineers

Domenico Grasso
Dean, College & Professor of Engineering
University of Vermont

Thomas Kalil
Deputy Director
Office of Science and Technology Policy

Linda Katehi
Provost
University of Illinois

Jud King
Provost and Senior Vice President, Academic Affairs
University of California, Berkeley

Terri Lomax
Vice Chancellor for Research and Graduate Studies
North Carolina State University

Henry Marcy
Vice President, Corporate Innovation and Technology
Whirlpool Inc.

Anthony Marinilli
Raytheon

Kimberly Markiewicz
Manager, Employee Engagement, Diversity & Inclusion
DuPont

Nancy Martin
Manager, Technology Leadership Development
Global Research Center

Nan Mattai
Senior Vice President, Engineering and Technology
Rockwell Collins

Frank Mayadas
Program Director
Alfred P. Sloan Foundation

Roger McCarthy
Chairman
Exponent Inc.

Rick Miller
President
Franklin W. Olin College of Engineering

Dan Mote
President
University of Maryland, College Park

Patrick J. Natale
Executive Director
American Society of Civil Engineers

Sean Newell
Learning Manager, Engineering Core Competencies
Ford Motor Company

Thomas Peterson
Assistant Director, Engineering
National Science Foundation

Jim Porter
Global Vice President, Engineering and Safety, Health, and Environment
DuPont

Henn Rebane
Consulting Engineer

Chris Riegel
Manager, Process Improvement
Griffin Wheel Company

Kent Rochford
Acting Director
National Institute of Standards and Technology

Stephen Rottler
Vice President, Weapons Engineering and Product Realization
Sandia National Laboratories

Betty Shanahan
Executive Director and Chief Executive Officer
Society of Women Engineers

Debra W. Stewart
President
Council of Graduate Schools

Karen Tancredi
Manager, Environmental, Process Safety, and Fire Protection
Dupont

A. Galip Ulsoy
William Clay Ford Professor of Manufacturing
University of Michigan

Karie Willyerd
Vice President and Chief Learning Officer
Sun Microsystems Inc.

Philip Woodrow
Executive Director
Merck

Wm. A. Wulf
Professor, Computer Science
University of Virginia
President Emeritus, National Academy of Engineering

Susan Zawislak
Director, Corporate and Community Programs
Delaware Technical & Community College

# Appendix D

## Biographies of Organizing Committee Members and Rapporteur

**Linda P. B. Katehi (Chair)**
Linda Katehi is the Provost and Vice Chancellor for Academic Affairs at the University of Illinois at Urbana-Champaign and Professor of Electrical and Computer Engineering. Prior to joining the University of Illinois, she served as the John A. Edwardson Dean of Engineering and Professor of Electrical and Computer Engineering at Purdue University, West Lafayette, IN and the Associate Dean for Academic Affairs and Graduate Education in the College of Engineering and Professor of Electrical Engineering and Computer Science at the University of Michigan, Ann Arbor, MI.

Dr Katehi has pioneered the development of on-wafer integration techniques that led to low-cost, high-performance integrated circuits for radar, satellite, and wireless applications. She has supervised, mentored and graduated over 70 post doctoral fellows, PhD and MS students in Electrical and Computer Engineering 21 of whom are faculty members in research universities in the US and abroad. She has focused on expanding research opportunities for undergraduate students and improving the education and professional experience of graduate students, with emphasis on underrepresented groups.

Dr Katehi is a member of many national committees and boards including member of the National Academy of Engineering and fellow of the American Association for the Advancement of Science (AAAS). She has served as the chair of the NSF Advisory Committee to the Engineering Directorate, a member of the NRC Army Research Lab Advisory Committee, a member of the NSF Advisory Committee to CISE and a member of the Advisory Board of the Extraordinary Women Engineers Project. She is also a member of the NAE committee on the Assessing the Engineering Research Enterprise in the US.

**John Seely Brown**
John Seely Brown (JSB) is a visiting scholar at the University of Southern California and was the Chief Scientist of Xerox Corporation until April 2002. He previously served as the director of the Xerox Palo Alto Research Center (PARC) until June 2000—a position he held for twelve years. While head of PARC, Brown expanded the role of corporate research to include such topics as organizational learning, complex adaptive systems, micro electrical mechanical system (MEMS) and NANO technology.

JSB's personal research interests include digital culture and rich media, ubiquitous computing, web service architectures and organizational and individual learning. A major focus of his research over the years has been in human and community learning. Part scientist, part artist and part strategist, JSB's views are unique and distinguished by a broad view of the human contexts in which technologies operate and a healthy skepticism about whether or not change always represents genuine progress. He is the author of many influential publications on learning,

including "Learning in the Digital Age" (2002) and "The Social Life of Learning: How can Continuing Education be Reconfigured in the Future" (2002).

JSB is a Fellow of the American Association for Artificial Intelligence and a Trustee of Brown University, the MacArthur Foundation and In-Q-Tel. He also serves on numerous boards of directors and advisory boards. He received the 1998 Industrial Research Institute Medal for outstanding accomplishments in technological innovation.

**James J Duderstadt**
Dr. James J. Duderstadt is President Emeritus and University Professor of Science and Engineering at the University of Michigan, where he has also served as Dean of the College of Engineering, Provost and Vice President for Academic Affairs and President. He currently holds a university-wide faculty appointment as University Professor of Science and Engineering, directing the University's program in Science, Technology, and Public Policy, and chairing the Michigan Energy Research Council coordinating energy research on the campus.

Dr. Duderstadt currently serves on or chairs several major national study commissions in areas including federal science policy, higher education, information technology, and energy sciences, including NSF's Advisory Committee on Cyberinfrastructure, the National Commission on the Future of Higher Education, the AGB Task Force on the State of the University Presidency, the Intelligence Science Board, and the Executive Board of the AAAS.

**Patrick J Natale**
Patrick J. Natale has served as the Executive Director of the American Society of Civil Engineers (ASCE) since November 2002. ASCE is the oldest national professional engineering society. He provides executive leadership to a staff of more than 230 and an active volunteer workforce of over 7,500, facilitating ASCE's tradition of supplying high-quality and high-value products and services to its members and other customers worldwide. In May 2003, Natale became President of the American Society of Civil Engineers Foundation (ASCE Foundation). The ASCE Foundation owns and manages ASCE's World Headquarters building in Reston, Virginia and has a mission *to generate resources for the civil engineering profession.*

In January of 1999, Natale was appointed the Executive Director of the National Society of Professional Engineers (NSPE), a national organization of 60,000 members representing licensed engineers from all technical disciplines. Prior to joining NSPE, he held numerous top-level management positions with the Public Service Electric and Gas Company (PSE&G) of New Jersey.

Natale holds a B.S. in Civil Engineering from Newark College of Engineering, and an M.S. in Engineering Management from the New Jersey Institute of Technology. He has completed the Executive Management Program at Yale University, and is a licensed Professional Engineer in New Jersey. He is also a Certified Association Executive (CAE).

**James B Porter**
James B. Porter, Jr. has been chief engineer and vice president - Engineering and Operations for DuPont since July 1, 2006. He has served in a variety of field and business units at DuPont

including the vice chairman of the DuPont Corporate Operations Network. He has extensive knowledge about the chemical industry and the educational needs of its technical workforce.

Mr. Porter has served as chair for the Construction Industry Institute (CII) and Delaware's United Negro College Fund. He was the 2004 recipient of CII's Carroll H. Dunn Award of Excellence and in 2005 received the Engineering and Construction Contracting Association Achievement Award. He is a member of the Board of Directors for AIChE, FIATECH, the Mascaro Sustainability Initiative, and the Fieldbus Foundation and participates on various industry advisory boards including AIChE's Center for Chemical Process Safety and is a member of the University of Tennessee's College of Engineering Board of Advisors and the National Academy of Construction. He was the first recipient of FIATECH's "James B. Porter, Jr. Award for Technology Leadership." He is a member of the Board of Governors of the Argonne National Laboratory.

**Elizabeth Shanahan**
Betty Shanahan became the executive director and CEO for the Society of Women Engineers (SWE) in 2002. Prior to joining SWE, Betty spent 24 years in development, engineering management, and marketing for the electronics and software industries. Over her career has been responsible for products and technologies in document viewing and conversion, parallel processing, signal-processing, and computer-aided software engineering. Most recently she was the vice president of product management and marketing for the Software Components Division of Stellent, Inc.

Betty has earned a B.S. in electrical engineering from Michigan State University, a Master of Software Engineering from the Wang Institute of Graduate Studies, and an M.B.A. from the University of Chicago, Graduate School of Business.

Betty participates in several forums that advance diversity in the STEM pipeline and engineering profession, including the JETS Board of Directors, Clemson University College of Engineering and Science Advisory Board, the National Girls Collaborative Project Champions Board, and the Engineers Week Diversity Council. Betty is a fellow life member of SWE, a Certified Association Executive, and a member of the Institute of Electrical and Electronics Engineers, the Association for Computing Machinery, and the American Society of Association Executives.

**Philip T Woodrow**
Philip T. Woodrow works in the Merck Manufacturing Division of Merck & Co., Inc. as Executive Director, Strategy & Integration. His responsibilities include groups providing technical expertise in the materials science and engineering and applied statistics and data analysis areas. In addition, he is responsible for business process support to Merck's capital program, rotational entry point programs for new engineering and science talent and other entry level technical talent programs, processes and associated grants. Previous responsibilities included positions related to compliance initiatives and process development for new drug candidates.

Prior to joining Merck, Dr. Woodrow was Corporate Director, Process Technology for Rhone-Poulenc, Inc. Before this he worked at Union Carbide in several divisions and locations, his

final position was as Director of Research and Development for the Union Carbide Agricultural Products Co., Inc.

Dr. Woodrow received B. S., M. Eng., and D. Eng. degrees all in Chemical Engineering from Rensselaer Polytechnic Institute in 1971, 1972, and 1974 respectively. At Rensselaer, he is the chair of the ChE Industrial Advisory Council and a member of the Key Executives group. He is also a member of the ChE Dept Advisory Committee at the University of Texas at Austin. He is also a member of the Management Advisory Committee for the National Action Council for Minorities in Engineering (NACME).

**Wm. A Wulf**
Dr. Bill Wulf is currently University AT&T Professor at the University of Virginia. He is a member of the National Academy of Engineering, a Fellow of ACM a Fellow of IEEE and a member of the American Academy of Arts and Sciences. In 1997 he was elected President of the National Academy of Engineering and he held that position until 2006. He is the author or co-author of three books, two patents and over 100 papers on national science policy, computer architecture, security, and hardware-software codesign.

Dr Wulf has experience in academia, industry and federal government. He started his academic career at Carnegie Mellon University as Assistant Professor of Computer Science, becoming Associate Professor in 1973 and Professor in 1975. In 1981 he left Carnegie-Mellon and founded Tartan Laboratories and served as its Chairman and Chief Executive Officer until 1988. The next two years he was Assistant Director of the National Science Foundation. Dr Wulf has a keen interest in lifelong learning for S&E professionals and continues to write and speak on this topic.

**Debasish Dutta (Rapporteur and Program Chair)**
Debasish (Deba) Dutta is Associate Provost and Dean of the Graduate College at the University of Illinois at Urbana Champaign, and a Scholar-in-Residence at the National Academy of Engineering. During 2004-07 he served at the National Science Foundation as Acting Director of the Division of Graduate Education, IGERT Program Director and as Advisor in the Office of Assistant Director, Education and Human Resources. He chaired the Learning and Workforce Development sub-committee during the development of NSF's Cyberinfrastructure Strategy (Vision for 21st Century Discovery).

At Illinois, Dutta is Edward William and Jane Marr Gutgsell Professor of Mechanical Science and Engineering. Prior to this he was on the faculty of mechanical engineering at the University of Michigan, Ann Arbor. A Fellow of ASME, Deba Dutta has received several awards including the ASME Design Automation award and the NSF Director's Award for Collaborative Excellence. He is a member of AAAS, ASEE and SME.