Biomedical Engineering Design in the New Millennium

Paul H. King, PhD, PE
Vanderbilt University

Abstract:

The recent National Academy of Engineering/ National Research Council publication "Advanced Engineering Environments, Phase 2, Design in the New Millennium[1]" suggests that design efforts are evolving toward a comprehensive "Advanced Engineering Environment" rather than supporting individual or small group efforts as is most common now. A major result of the effort, and the most interesting, is a series of projections as to the status of various aspects of the design process as envisioned fifteen years from now. Briefly stated, design support applications are evolving toward environments that may or may not involve face-to-face interaction, such as Internet-related technologies and applications such as remote visualization. While the report was written primarily at the request of NASA and therefore has primary impact on NASA and Aerospace Industry planning efforts, the report (and interpretations of it) will have implications for Biomedical Engineering design efforts and plans. This paper will briefly review the National Academy Report, and then will consider current and related future design thrusts and applications in Biomedical Engineering.

1. Advanced Engineering Environments, Phase 2, Design in the New Millennium:

If you are involved in, or planning to be involved in design in the next few years this text is worthwhile reading. It can be purchased from the National Academy Press online or may be read for free by clicking on the link at: http://books.nap.edu/catalog/9876.html. The text presents a case for the development of "Advanced Engineering Environments", which are basically web-enhanced, highly interactive design environments in the not too distant future. Virtual reality akin to the Holodeck of Star Trek fame may well be in our near futures, and in fact is introduced as a projection in the prologue of this text.

The recurrent theme of this text is that Advanced Engineering Environments (AEEs) will necessarily be developed in the near future to enable the development of complex new systems, products, and missions, as well as to reduce current development times and costs. As this text was the result of sponsorship by NASA, the text is biased toward problems relating to Space Mission development and related software and hardware needs, as well as toward a request that the US Government do more to speed up development of the field.

The lessons learned in a section reviewing major developments by companies of AEEs will not be lost on the general reader. Boeing's use of CATIA in airplane design resulted in increased rates of production and lowered cost. Electric Boat's use of the software and development of modular design dramatically improved their production abilities, and lowered costs. Daimler-

Chrysler demonstrated similar gains. Computational fluid dynamics software proved to be a genuine cost-cutter for Concepts ETI.

A major portion of the text (Chapters 3 and 4) outlines the expected and needed developments in the current design process, and deals with the expected future of design at a 15-year in the future point. Chapter four emphasizes the changes that will need to be made to overcome various barriers to change that exist in our organizations and training processes. The final chapter concludes with a discussion of general approaches and roles of companies in the development of AEEs, the most major of which is that NSF and other governmental support needs to be strengthened and focused.

The message here is overwhelming. Use of the Internet and higher speed communications and computers will speed up development time, and will reduce costs. Teams will not need to be physically contiguous. Modular approaches will be used when appropriate; schemes will be developed to enable reuse of design approaches and the development of specialized modifications of devices to order. The use of mathematical modeling and simulation tools, in conjunction with developments in Virtual Reality will improve design and development cycles.

2. What does this hold for BME?

The future of design in BME will hold all of the above, and more. What follows will be a brief overview of this projection:

- Visualization: We have long used one or more medical images to assist in diagnosis and therapy planning; this has recently extended to image guided surgery. Virtual reality has been with this field for some time, these techniques will continue to improve to the point where a "flythrough" of a surgical site will be commonplace prior to surgery.
- Remote visualization and collaboration: This is the keynote of telemedicine; it is the current frontier involving the development of telesurgery.
- Design theory: As engineers dealing with a mixture of engineering and biological sciences, we are not likely to be bound by any traditions of our profession, we will borrow liberally from the most useful of techniques developed in other fields. These will include applications of structured design methods (Pahl[2]), axiomatic design methods (Suh[3]), guided design methods with historical information (Ideation-Triz[4]), etc.
- Modeling: Computational Fluid Dynamics programming efforts have recently been used to visualize fluid flows in the human, these will lead to improved valve designs. Modeling techniques have been used to "design" chemicals, vectors, and drugs, this work will only expand. Applications involving gene structure and function are nascent.
- Product development: From the development of perfectly fitting prosthetics to the development of specialized gene therapies, we will utilize or unique backgrounds.
- Design teaching: Without a long history of our own, we have a unique opportunity to develop new methods as well as unique case studies.
- Safety: The recent report, "To Err is Human[5]" will drive much of our design efforts as the need to reduce accidental death and injury in the practice of medicine will drive much of our educational and design efforts.
- Simulation: The need to ergonomically design our utensils and our environment will force us to use simulation packages such as the virtual human in the planned CATIA software packages.

- Information Management: The instruction of students in medical informatics and in process design will be included in most curricula, as this endeavor will be recognized as a legitimate design activity. Knowledge extraction techniques will also become a standard design case study.
- Collaboration: We are in a unique position. Everyone is or will be one of our customers, design programs that incorporate management, medical, entrepreneurship, and other engineering majors in their design projects will have a distinct advantage in providing educational benefits to their students. Design teams that involve students from freshman through graduate in real-life design teams (with industry) will have a distinct advantage.
- Prototyping and Manufacturing: Costs will decrease such that students will be able to create 3-D prototypes of designs using University-affordable hardware and software. Similarly, instruction in elementary manufacturing process will be within reach of most schools.
- Spin-offs: Medical technology has benefited from NASA technical developments, this exchange will become bi-directional in the near future.

3. Conclusion

Design in Biomedical Engineering promises to parallel, if not exceed, the technical advances discussed in the above Advanced Engineering Environments.

This work was supported in part by the Engineering Research Centers Program of the National Science Foundation under Award Number EEC-9876363

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PAUL H. KING
Paul H. King is an Associate Professor of Biomedical Engineering at Vanderbilt University. He holds similar titles in Mechanical Engineering and in Anesthesiology at Vanderbilt. He has taught Biomedical Engineering at Vanderbilt for the past 35 years, his current area of concentration is Senior Design in both his research and teaching roles.