Proceedings of the Third Annual International Symposium
National Council on Systems Engineering
Arlington, Virginia July 26-28, 1993

THE NEED FOR SYSTEMS ENGINEERING EDUCATION

Charles H. Samson, P.E.
Civil Engineering Department
Texas A&M University
College Station, TX 77843-3136

Lee L. Lowery, P.E.
Civil Engineering Department
Texas A&M University
College Station, TX 77843-3136

Abstract. As engineering specialization has increased, engineering education has also become more specialized in order to keep up with advances in technology. Likewise, engineering faculty have tended to become more specialized to keep pace with such advances, and to conduct research and publish at the leading edge of their fields. These circumstances have exacerbated the problems of melding specialized skills into a form for achieving the best designs of complex systems.

The writers believe that it is essential:

1. To require adequate preparation in systems engineering for every engineering graduate.
2. To provide opportunities for generalization in systems engineering for those who wish to become "general practitioners" capable of integrating the various specialized skills needed.

The writers suggest an approach to satisfying these needs that would complement rather than compete with existing engineering disciplines.

INTRODUCTION

During the last 250 years, engineering has continued to splinter into an increasing number of fields and specialties as technology has advanced. In engineering education, this trend has been accompanied by having to drop or severely compress traditional content in order to accommodate the infusion of new technical material into the "four-year" curriculum. To provide competent instruction in highly specialized areas, many engineering faculty have become severely focused in their interest and capabilities, sometimes losing sight of the need for engineering graduates to deal with real world problems associated with engineering systems.

It is obviously important that engineering graduates be given a foundation to practice in highly specialized areas. However, if the profession is to meet its obligations to society, two other needs must also be met:

1. Even though a graduate may choose a career in an engineering specialty, he or she must have an appreciation for and some understanding of the role that specialty plays in contributing to the broader arena of societal systems problems.
2. There is a serious need for engineering graduates who have an in-depth understanding of how to make the necessary compromises involved in multiple system objectives which will achieve the "best" overall system, and how to effectively merge the contributions of the engineering "specialists."

SYSTEMS ENGINEERING MODEL

Figure 1 illustrates the systems engineering process. It is adapted from A.D. Hall's "systems engineering morphological box" (Hall 1969). The model shows the phases (life cycle) of systems engineering. The logic axis indicates problem-solving steps that would likely be exercised many times in a given phase. The knowledge/skills axis indicates some of the many disciplines that are involved in various stages of the life cycle and that must cooperate closely if effective systems are to be achieved.

It may be observed from Figure 1 that in their practice, engineers may work in a very limited area of the model, or across a very wide region of activities. What, then, is required in the engineering curriculum to provide at least minimal preparation in the concepts, principles, and tools of systems engineering?

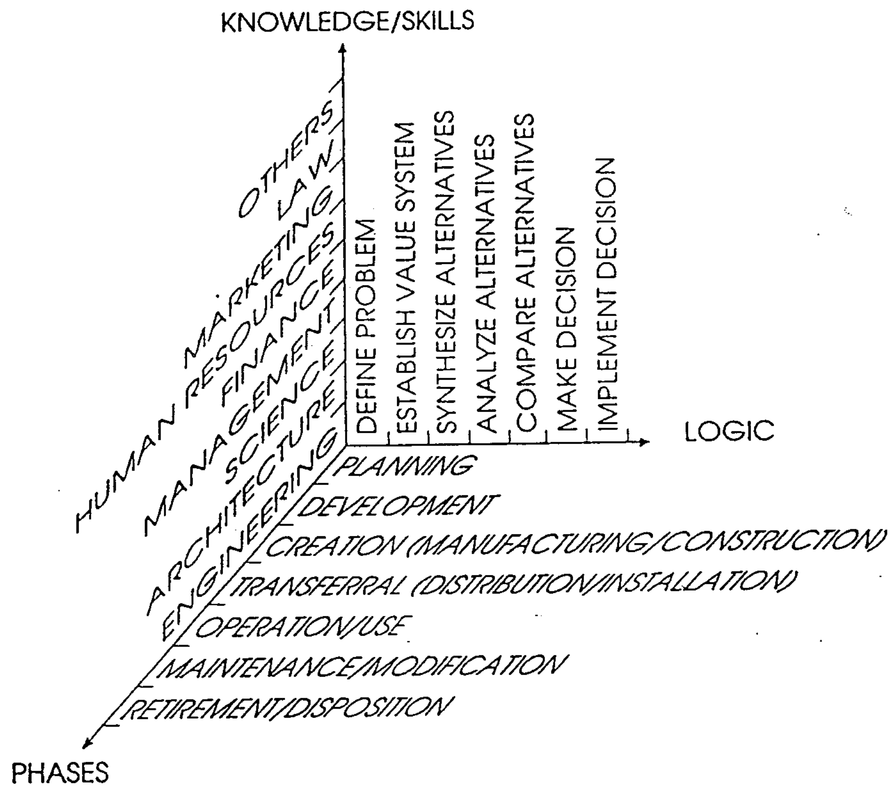

Figure 1. Systems Engineering Process

ENGINEERING EDUCATION

General Model. Figure 2 is a general model of an engineering curriculum (Samson 1990). It represents topical components (not necessarily courses) linked together as a curriculum "system." The model shows a freshman-level course that would provide the student with an appreciation of engineering as a profession, define a "system," give a picture of systems problems that are prevalent in the real world, how the curriculum is in itself a system of interrelated material aimed at providing the best possible preparation for engineering practice, and introduce the student to systems engineering concepts.

Content. The following content is suggested for freshman and senior level courses.

Introductory (Freshman) Course. Material should be provided at the freshman level that would include:

1. The Engineering Profession: Technical, Ethical, and Leadership Responsibilities.
2. Systems Engineering Concepts.
3. The Engineering Curriculum as a System.
4. The Management of Quality in an Engineering System.
5. The Importance of Communication in Systems.

This course would give the freshman not only a general concept of the systems nature of real-world problems faced by engineers, but also a picture of how fragmented coursework is linked as a "curriculum system." The material could be covered satisfactorily in one to two semester credit hours, and could be combined with other appropriate material needed at the freshman level (e.g., problem solving, engineering design and design graphics, and computer-aided design).

Systems Engineering (Senior) Course. A senior-level course should be provided as a prerequisite to the capstone design course now being included in most engineering curricula. It is envisioned that this course would require three semester credit hours and would include the following topics:

1. Review of the Systems Engineering Model.
2. Relationship of Previous Course work to Systems Engineering.
3. Systems Engineering as a Foundation for the

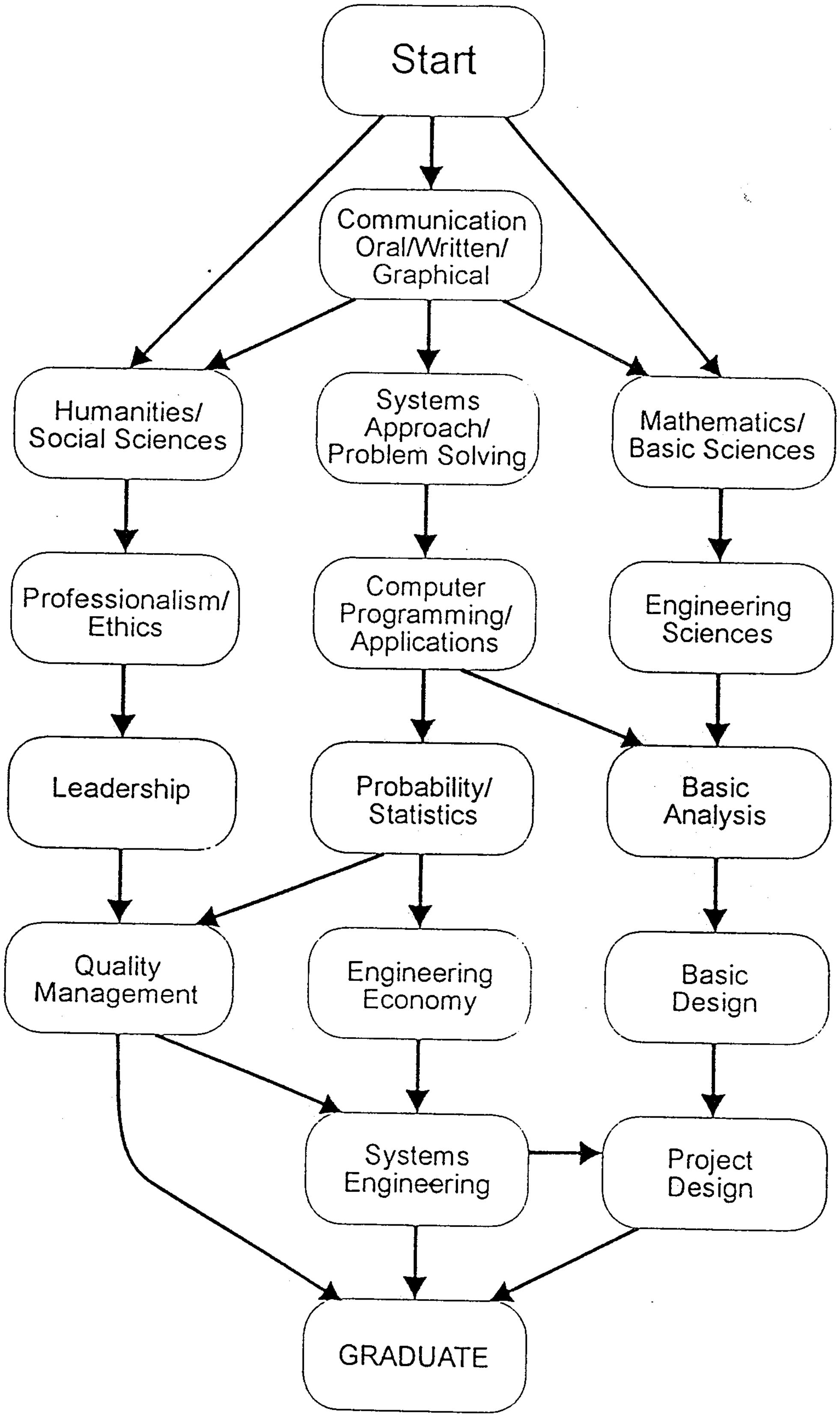

Figure 2. Element Linkages in Engineering Education

Capstone Design Course.

4. General Discussion of Decision-Making under Certainty, Under Uncertainty, and Under Risk, and With Single and Multiple Criteria.
5. Linear Programming.
6. CPM/PERT.
7. Decision-Making Under Uncertainty.
8. Decision-Making Under Risk.
9. Multi-Criterion Decision-Making.

Other Closely Related Coursework. While in a sense all the curriculum material suggested by Figure 2 is related to systems engineering, the subjects of engineering economy, statistics, and quality management have especially close ties and are regarded by the writers as essential to adequate coverage of systems engineering in the engineering curriculum.

CONCLUSION AND RECOMMENDATION

After a number of years in engineering education, the writers believe that the engineering graduate of the future must not only be technically literate but also have an appreciation for the critical role that systems play in the well-being of society, and an understanding of the systems engineering process and some of the basic quantitative tools useful in systems engineering decision making.

It is recommended that engineers involved in various systems engineering responsibilities become active in engineering educational activities such as the Accreditation Board for Engineering and Technology, engineering college activities, and engineering professional and technical societies to give voice to the requirement for adequate systems engineering education.

REFERENCES

Hall, A.D., "Three-Dimensional Morphology of Systems Engineering," *IEEE Transactions. Syt. Sci. Cybern.*, SSC-5, 1969, pp.155-160.

Samson, Charles H., 'Civil Engineering Education: Weak or Missing Links, *Proceedings, The National Forum on Education and Continuing Development for the Civil Engineer*, (Las Vegas, NV, April 17-20,1990).

BIOGRAPHIES

Charles H. Samson, P.E., is a professor of civil engineering at Texas A&M University, where he has served as acting president, vice president for planning, and head of the civil engineering department. He has taught various systems engineering courses at the senior and graduate levels. He is past president of NSPE, the National Institute for EngineeringManagement and Systems, and the Texas Society of Professional Engineers. He received the Engineering Honor Award from the University of Notre Dame and was named Distinguished Engineer by the Texas Engineering Foundation. He holds BSCE and MSCE degrees from Notre Dame and a Ph.D. in civil engineering from the University of Missouri-Columbia.

Lee L. Lowery, Jr., P.E., is a professor of civil engineering at Texas A&M University, and is a recipient of the Former Student's Texas A&M University Outstanding Teacher Award on the university and college level, the Zachry Award for excellence in Teaching in 1989 and 1991, and the Texas A&M University Gamma Sigma Delta Honor Society for Agriculture Award of Merit for Teaching. He has taught various systems engineering courses at the senior and graduate levels. He holds BSCE, MSCE, and Ph.D. degrees in civil engineering from Texas A&M University.