Engineering **DEFINITION & ENGINEERING AS A CAREER: from Bernard M. Gordon "What is an Engineer"**

I propose to define a *REAL (i.e., professional) ENGINEER* as "one who has attained and continuously enhances technical, communications, and human-relations *knowledge*', *skills,* and *attitudes,* and who contributes effectively to society by theorizing, conceiving, developing, and producing reliable structures and machines of practical and economic value."

"The greater the *breadth of knowledge,* the *more varied and accomplished the skills,* and the *more dedicated the attitude* of any *individual engineer,* the more significant will be the accomplishment, resulting in proper recognition as a role model, teacher, and leader."

Let us examine each of these three parameters of KNOWLEDGE, SKILL, and ATTITUDE, in turn, first with a brief overview and then with regard to some specific implications for the development of engineering education.

KNOWLEDGE

Knowledge, for a real engineer, is more than acquired data, and certainly much more than acquired engineering data. The *cognitive* process is different from the *acquisitive* process.

While today's computer and information technology may make any of the world's data *instantly* available, the real engineer has developed a relational *understanding* of the data and will have learned how to recall and correlatively process *relevant* data in order to synthesize *new information* to solve problems.

The areas of required knowledge are not limited to those of science or technology, as a consideration of the role of the engineer as a leader will reveal. An understanding of societal evolution through study of history, economics, sociology, psychology, literature, and arts will enhance the value of the engineering contribution. And, in the shrinking world that the new communications technology is producing, we should not forget the study of foreign languages; an item often ignored on the western side of the Atlantic.

SKILLS

A real engineer's skills are essentially scheduled problem-solving techniques of design in which the concentrated disciplines of science and technology are exercised with the personal creativity and judgment developed from training and experience. In addition, because engineering accomplishments are achieved in a group environment, the communication skills are critical to the roles as follower, and then, leader.

These skills can be acquired *only* by doing: the practice may be on simulated problems, or, as for the entry-level medical doctor, on real cases under expert supervision. However, no amount of "study" can replace the "practice" in learning how to "debug" a design, for example. The case study technique may be useful, but it is not sufficient to qualify the real engineer.

ATTITUDES

A real engineer's attitudes will directly affect the quality of his design solutions, whatever the problem. The real engineer is a *leader* of a *team* of resources: financial, personal, and material, at all levels of engineering activity.

Successful team leadership implies a degree of self criticism, where egotism and modesty have counterbalancing influences. It requires a spirit of curiosity and courage that leads to creativity and innovation. It is characterized by a forcefulness that gives orders, as well as receives orders, and accepts the challenges of competition in the market place with a perseverance to succeed. Leadership exhibits a loyalty downward as well as loyalty upward, and requires the earning of respect of project team members for personal competence, tolerance, and supervisory guidance.

ENGINEERING AS A CAREER… from Bernard M. Gordon "What is an Engineer"

Almost all definitions of engineering imply a *career* activity of acquiring new knowledge and insights, of sharpening old skills and acquiring new ones, and of maturing attitudes and personality. In effect, a person who pursues an engineering career is always practicing *to become an engineer*, and never really completes the required education, training, and experience. Along the route, however, we can identify milestones of achievement, and, although we may not reach the end of the road, we can certainly recognize progress along the route. Among my objectives for today is that of specifying some recognizable milestones along the route. Allow me to start by sharing with you my perceptions of what an engineer actually may be assigned to do during his career, without allocating any particular activity to any specific career position: entry-level, junior, senior, or higher levels of engineering. This brief and incomplete listing is oriented towards the task activities of a design-development engineer in almost any engineering discipline. No significance is implied by the order in which these activities are presented.

AN ENGINEER MAY BE ASSIGNED TO:

• STUDY the market potential for a proposed product.
• PREPARE specifications.
• MODEL solutions in terms of major functional blocks.
• ORGANIZE work efforts into manageable subdivisions.
•ANALYZE designs and test data.
• ESTABLISH performance error budgets for each major subdivision so as to meet design goals.
• ESTABLISH milestone schedules.
• ALLOCATE personnel and financial resources to engineering activities.
• MONITOR project results against established product performance, financial budgets, and time schedules.
• PERFORM detailed checking of designs or insure that all details have been verified.
• INSURE that produceability, maintainability, and reliability are *designed* into the product.
• TRAIN, EDUCATE, and SUPERVISE subordinates.
• SERVE as a project team member in an "apprentice" or "journeyman" role at the start of a career.
• DOCUMENT test procedures, test results.
• DESIGN and BUILD special-purpose test equipment.
• BUILD prototypes to validate production documentation.
• STUDY new technologies, new components, new instruments for applicability to product design.
• DEFEND design to reviewing superiors.
• SUPPORT marketing and sales activities with product presentations and literature.
• CONDUCT design reviews.
• CONDUCT training and indoctrination sessions for in-house and customer personnel.
• SUPPORT customer service with repairs, maintenance, and on-site assistance.
• PLAN production schedules.
• ANALYZE inventory requirements.
• HELP qualify vendors' and suppliers' products and services.
• RESPOND to the changing requirements on design imposed by various regulatory agencies, both governmental and trade.
• ASSIST corporate management in contract negotiations.
• INTERVIEW and EVALUATE prospective employees.
• PROTECT corporate investments by assisting in patent filings, design disclosure, and copyrights.
• SERVE on national and international committees.
• LECTURE on state-of-the-art technology.

Most who are part of the industrial engineering scene probably would agree to the inclusion of these functions in such a list of their engineers' duties. In all likelihood, a poll of engineering executives from diverse fields would add yet additional duties, functions, and task activities. Clearly, engineering is a *multi-faceted* activity. Specifying the requisite knowledge, skills, and attitudes that will prepare a neophyte for an engineering career is a complex task.

Most educational institutions (public or private, governmental or industrial) who profess to train engineers probably would claim that preparatory knowledge for the type of activities and skills represented in the previous listing are provided as part of the required curriculum or are available as electives. Or, they might, with some justification, claim that only "minor" modifications to the curriculum may be required, but that no radical changes are needed. And they would be right...If our concept of *real* engineering is limited to

carrying out assigned tasks.

In accordance with our definition, the REAL ENGINEER ***conceives and invents***. His outputs result in *products* that are innovative, inventive, and economically accessible. They are *useful* to society.

The REAL ENGINEER does not wait to be told to initiate the design of a new product. He (or she) imagines, conceives, proposes, propagandizes, pleads, and debates for a "cause", for "an impossible dream", ... and *succeeds*, in spite of the opposition of doubters and the discouragement of setbacks, in bringing order out of chaos, in producing something that is new, and, in the process, advancing the state of the art of engineering.

The REAL ENGINEER is willing to take a risk, a risk upon which his professional reputation will be at stake.

The definition of REAL ENGINEERING implies at least one other significant characteristic: that of multi-disciplinary project activity. Generally, a product is not brought to fruition solely by the talents of a single REAL ENGINEER, no matter how knowledgeable and skilled. The REAL ENGINEER calls on the specialized knowledge and skills of others as needed.

However, the REAL ENGINEER does not abdicate responsibility *for any phase of the project work,* no matter how minor or how foreign it may appear.

The REAL ENGINEER is intimately aware of every facet of design, development, test, and production, and he is capable of understanding and evaluating the minutest design detail that matters. He continuously evaluates and redirects the different efforts in the course of the project, planting new ideas and furthering inventions on the part of those who will contribute. Each capable talent is inspired and exhorted to perform beyond his (or her) recognizable limits. The REAL ENGINEER motivates each contributor to the project to *want to excel, to grow, and to take personal pride* in the project's successful completion.

In a word, the REAL ENGINEER is a *LEADER*.

When the education and training (both in academia and industry) add *LEADERSHIP* programs to the curriculum and to the work ethic, then we shall move closer to educating and training REAL ENGINEERS. We, of course, must recognize that not all ENGINEERS will become primary LEADERS. First of all, not everyone will have the necessary genes or will develop the necessary temperament. In fact, such an expectation may be counterproductive.

To paraphrase a popular American expression, "a team of all 'Chiefs and no Indians' is ineffective."