I. INTRODUCTION

Good morning. It's fairly standard procedure these days to begin any discussion on productivity in the U.S. with a lengthy recitation on the terrible dilemmas we face in that regard. But if the severity of the problems seems overwhelming, there may be some comfort in the problems others face.

(watermelon patch story)

Time doesn't permit me this morning to survey the whole "productivity patch." And certainly it's clear enough that the shortage of trained engineers and qualified engineering educators is a root problem with regard to this country's productivity and its international competitiveness. So what I will do is discuss the productivity of the process by which society obtains good engineers...and by that I mean the total knowledge transfer process involved in pre-college, college, and continuing engineering education.
II. PROBLEMS

Let me begin by identifying the major problems we must solve if we are to improve this process.

First, constricted budgets not only won't support the necessary number of qualified teachers, they must also bear the burden of a greatly increased need for research. Because of taxpayer revolts and a general shortfall in budget expectations in many other sectors of our economy -- not to mention inflation -- there isn't much hope for substantially increasing university budgets.

Second, is the need for a larger number of engineering students. Japan, with half the U.S. population, is graduating twice as many engineers as we do. 65% of the students in Japan choose scientific and engineering fields. In the U.S. that number is 30%.

Third, is the matter of people already at work. This problem has three distinct aspects: remedial training to correct past shortcomings; the increasing rate at which technical subject matter becomes obsolete means most graduate engineers must be essentially retrained every five years; and thirdly there are those who are older and/or must be employed during their educational process.
Fourth and finally is the problem of inadequate laboratory facilities. This is more than a simple budget problem. The rapid change in technology -- specifically in electronics -- obsoletes laboratory facilities at an ever-increasing rate.

There is no need for me to elaborate on these problems themselves. They are well known to all of us. Rather I will address my remarks to some solutions. As with any productivity problem solutions involve utilizing available technology and finding the financial and human resources to apply that technology.

III. AVAILABLE TECHNOLOGY

Let me discuss first the technology available to help us improve the teaching process. Personalized student instruction is generally accepted as superior to the lecture system as a learning methodology. But this simply has not been practical because of the time required on the part of the teacher. An engineering professor -- a friend of mine -- informed me that three times in one of his process control courses he undertook
to teach the class on an individualized rather than the normal lecture basis. A statistical survey on the results showed clearly that:

1) the students preferred this method;
2) they were more highly motivated;
3) they covered more material and learned considerably more;
4) the exceptional students reached desired peaks;
5) and there was no question that the poorer students attained minimum requirements.

So what was the problem? Time. It was more than a matter of just having individual sessions with each student. The process was further complicated by the spread of student accomplishments after the course was well underway -- some students were near the end of the course while others were near the start. As a result, he could not handle a class greater than ten students.

With the use of a fully developed CAI system, however, most of these problems are eliminated. The computer does testing, the tutorial work, and even record keeping. This permits the instructor to spend his time in consultation with the students and updating the courseware.
I should also distinguish between the general use of computers at the university to solve problems associated with various courses and a comprehensive CAI system which has all the features needed for university-level instruction -- namely: multi-media, stored information, transmission of information, true interactivity which permits a complete interface with the students, tutorials, assignments, record keeping, etc.

But computer-based learning technology offers even more than that. The way we learn best varies considerably from person to person. In a recent interview, Peter Drucker, in relating both his own learning experiences and his approach to teaching others, remarked: "There is no one right way to learn; learning is individual. When I consult, I always try to make people effective the way they are, not the way somebody else is. One of our basic problems in education is that we keep looking for the one right way that fits everybody."

We are at the point where a computer-based system can diagnose a student's knowledge and skill levels....can sense the method by which he or she learns best -- by analogy, for example, or by rote memory....can detect problems anywhere in the student's learning process....and then can deliver an individualized
course of instruction based on that information. What this amounts to is a sort of an educational equivalent of a medical prescription; understand the needs, diagnose the problems, provide a specific schedule of learning.

The whole learning process is further augmented by the ability to include real world problems in simulated form. In a recent address, Prof. Francis D. Fisher, Henry Luce Professor of Ethics and the Professions, Haverford College, described a program which is designed to teach gastrointestinal disease diagnosis. The following is his description.

"The scene opens (on videodisc) with the patient being wheeled into the hospital room....he describes the dizziness he experienced and other symptoms. Stop. The computer takes over, asking you, the 'student' doctor, what is wrong with the patient? What additional information do you want? What tests would you like performed? The computer prints out a menu of a wide variety of tests. You select some and the test results are displayed. Do you want to ask the patient some questions? You can select those also -- and get answers. If a picture of the patient is necessary, as in answer to the question, 'Show me where it hurts,' the laser picks up a TV segment showing the patient pointing to the appropriate spot. There is also a segment showing views through a sigmoidoscope, if you ask for
it. And you can stop the picture at any time for closer examination, or get 'instant replay.' You can also obtain expert opinion on certain matters.

When you make your ultimate diagnosis, the computer criticizes it, aware of the context of knowledge you had about the patient at each point you made a preliminary diagnosis or decided what question to ask. 'Yes,' the computer tells you, 'it was an ulcer, just as you guessed after the first test, but at that time it was a poor guess,' the computer points out, 'for there were strong counter-indications that were not explained away until later.' With a series of such cases, it is going to be possible to give a physician ten years of gastrointestinal experience in a few dozen hourly sessions."

Similarly real-world design problems can be fashioned for mechanical and electrical engineers; process design problems including flow sheet simulators can be presented to the chemical engineer and so forth.

There is much more that could be said on the matter of available technology, but perhaps this quick overview has at least provided some perspective on the truly exciting possibilities open to us. The price that must be paid is capital investment plus the cost of developing the courseware.
IV.  COOPERATION

As I mentioned at the outset there is no need to sit around and hope for budgetary magic that will somehow solve these expenditure problems. It won't happen. But through cooperation we can make better use of existing resources.

At Control Data we have engaged in extensive cooperative efforts -- spanning nearly 20 years -- to develop a computer-based learning system. It is called PLATO and uses not only computers but also virtually all other media, including video and audio tapes and discs, slides, and digital inputs and outputs. PLATO is nearly limitless in its versatility and its delivery of more accessible, less costly and uniformly high quality education and training. Virtually any activity can be simulated on PLATO. Because its features facilitate rapid, personalized learning, PLATO relates to a student's needs in a way not possible with books alone or in a classroom. It diagnoses student needs; teaches, drills, tests and grades in an individualized, self-paced, easy-to-use manner; and when the student reacts, PLATO responds immediately. There is a continuous interaction -- a give and take -- on a personal, one-to-one basis.
A computer-based personalized student instruction system such as PLATO offers many options, but a very important one for our topic today is the ability to deliver the first two years of an engineering curriculum with a minimum amount of faculty involvement. In this way, it can help alleviate the immediate crisis of a shortfall in faculty members and the inability to pay competitive salaries. Freeing those faculty members currently assigned to teaching basic courses makes them available for teaching advanced classes and individual student counseling and coaching. Moreover the money saved can be used to increase salaries to more competitive levels.

The systematic application of computer-based learning technology also does much to solve the other problems I mentioned at the outset: rapid obsolescence of subject matter, the need for remedial engineering education, and so on. But in the time I have left I want to concentrate on just two aspects of improving the productivity of engineering education: the need for a larger number of students and the need for cooperation to alleviate constricted budgets and inadequate facilities.
OUTREACH

First, let's take the need for more students. Even though there is a serious shortage in faculty to meet today's demand in terms of students, because of the ever-increasing need for new engineers, we actually need a vast expansion in the number of qualified students entering engineering schools. The situation presents a golden opportunity. Industry and universities working together can meet the need for more qualified students -- and at the same time meet another urgent need for more career opportunities for the disadvantaged. A number of activities have been mounted by engineering schools, foundations, corporations and community organizations in cooperative programs to expand enrollment of the disadvantaged, and to help them become good students. These efforts have been fruitful, but not on nearly a large enough scale; and most high schools in poverty stricken areas are not able to turn out graduates with adequate basic skills. What is required is a comprehensive national program to attract students of all types to select engineering as a career, to help assure that those who do so will be successful, and to improve the high schools, especially those in blighted areas.

The best way for me to explain what is needed is to use an example with which I am familiar. That's a program called
"Outreach" which is now operating in Minneapolis, St. Paul, and Toledo. It is a cooperative effort between industry (in this case Control Data), the University of Minnesota, and the local high schools.

The key elements of the program are:

1) First the program is certified by a unit of city or county government.

2) There is special attention given remediation through the use of computer-aided instruction; then there is an enriched curriculum including computer-based courses in mathematics, physics, and chemistry.

3) Career-related employment experiences begin in the 10th or 11th grade. This part-time in the school year and full-time in the summer.

4) Greatly expanded career counseling through the use of volunteer counselors and computer-based counseling techniques developed as a part of Control Data's job readiness programs.

5) After high school, vocational training or college is financed by a Control Data loan plus the income from the student's job.
As you can see, then, the cooperation of government, educational establishments, and industry is required to put together a meaningful program.

Another university-related program is the Microelectronic and Information Sciences Center at the University of Minnesota. The Center is an industry-university collaboration. The Center will not have to make a huge investment in laboratory and processing facilities, because it will have access to facilities in industry which represents an equivalent investment of more than $100 million. Thus, the Center will not have to dilute research dollars with the cost of facilities or salaries for operating personnel, who are in critically short supply. In fact, in the long run, because of the rapidly increasing complexity and cost of the facilities required for advancing the state-of-the-art in the field of microelectronics, costs will be beyond any single university and most companies.

"Cooperation" is the basic ingredient in all of the examples I have discussed. Cooperation, in fact, must be an integral part of the total solution to increasing the productivity of the engineering education process. There is just no other means by which adequate resources can be brought to bear on the problem.
At Control Data, we have not only been strongly advocating such broad-based cooperation — we have been practicing it with highly rewarding results.

As I mentioned earlier, PLATO itself resulted from a cooperative effort. This effort initially included the University of Illinois, the National Science Foundation, and Control Data. After approximately $22 million in government funding, feasibility had been verified. Since then, most of the funding has been provided by Control Data. The relationship with the University of Illinois has continued and is now one of 40 Control Data computer-based learning projects with universities.

One of the most comprehensive and important of these has the goal of a complete lower division engineering curriculum. Presently a consortium of seven universities including our hosts here at Texas A&M are working with Control Data to develop this curriculum. During the coming school year, PLATO courses will be available in basic physics, chemistry, computer literacy, computer programming, as well as remedial training courses. By 1984, 12 courses representing 39 semester credits will be available. Over time plans call for a lower division curriculum of 64 or more semester units. The development of such a comprehensive program simply would not be practical under current budget restrictions for any one organization operating independently.
V. CONCLUSION

Let me conclude by outlining some sorely needed action which you as individuals and this society as an organization could undertake.

First of all there is, as I have said, an urgent need for a comprehensive national program to increase the number and quality of high school students seeking an engineering education -- particularly among the disadvantaged. An effective community outreach program along the lines I described earlier must involve cooperation by a local college or university, local industry, and the local school system. But more than that each community requires a leader to make it all happen. Your challenge as individuals -- as people who by your very presence here today exhibit your interest in promoting engineering education -- is to provide that leadership. What ASEE can do as an organization is to be the catalyst -- to provide the framework and leadership for the nationwide program that is needed. That -- would be an agenda item of true significance for this organization.

The second challenge is to improve the productivity of engineering education itself. Our country has a desperate need for improved growth in productivity. What an ironic and tragic
thing it would be if that need went unfulfilled because the engineering profession did not apply advanced technology to its own educational process.

In that regard, I have described briefly the consortium which has been established to develop a computer-based Lower Division Engineering Curriculum. That is an excellent start -- but more, much more is needed. Other consortiums should be established to develop upper division courses in mechanical, chemical, electrical, civil, and aeronautical engineering. These consortiums could and should be established under the auspices of ASEE. No other single action by this organization would do more to improve the productivity of engineering education. The 1980's may not be recorded as the happiest decade in man's history, but I sincerely hope it will be recorded as the decade in which engineering education crossed the threshold into a new era of productivity. You here today are blessed with the opportunity to make that happen.

Thank you.