

## Industry's role in optics education

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### ABSTRACT

Industry has a vital and necessary role to play in the education of skilled optical scientists, engineers, and technicians. This role is not independent from that played by universities and other educational institutions; rather, it is one element of a continuous process, which is optimized when the interdependent roles that industry, academia, and government play are understood and coordinated in a strong partnership formed among the three groups. Examples from United Technologies are used to illustrate the contribution that corporations can make to the educational process.

### 1. INTRODUCTION

When this talk was first conceived, the title was "Industry's Stake in Optics Education", reflecting the view that what the industrial community needs is a dependable educational process from which to draw trained employees. This requirement, plus the fact that many companies have invested resources to promote such a process, means industry has a "stake" or a vested interest in optics education. With this viewpoint, industry must define its needs to academia so the universities, colleges, and technical schools can devise and deliver courses and programs to meet these needs. The concept might be as depicted in Fig. 1, where the universities accumulate knowledge, pass it to society and to students, who, educated and trained, join industrial organizations to apply this knowledge to produce products. Upon closer examination, however, it is evident that industry has a vital and necessary role in the education of optical scientists, engineers, and technicians. Those in industry are more than observers, promoters, and users of optics education; they are -- or need to be -- an integral part of the definition and delivery of optics education and training. In addition, government has an important role to play in supplementing and enhancing the overall process.

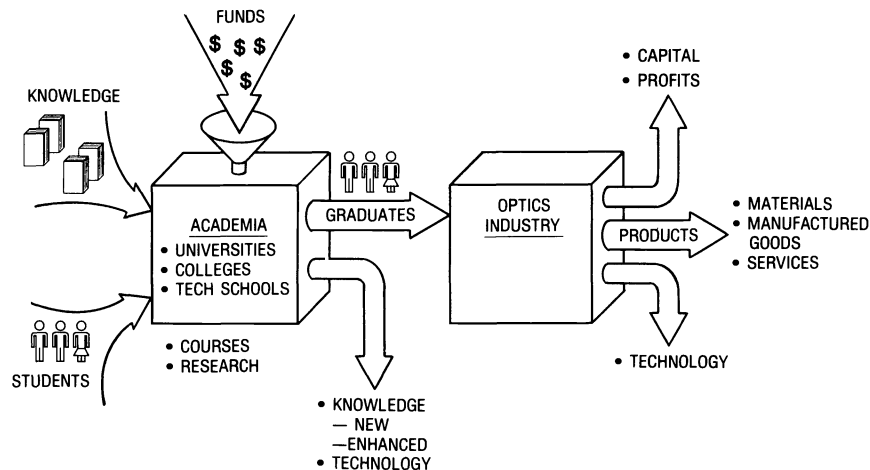


Figure 1. Schematic of the superficial relationship between Academia and Industry in which each group operates independently of the other with Academia supplying educated graduates to Industry.

## 2. THE PARTNERSHIP OF INDUSTRY AND ACADEMIA

The field of optics today has several characteristics that affect the educational process. First, it is a multidisciplinary field that draws heavily on physics, electronics, mechanics, and materials. Success in optics comes most readily to those who can integrate these technologies. Second, it is a rapidly changing field, driven by advances in lasers, materials, and electronics technologies, and by new applications in communication, data processing, and space systems. The rapidity of change causes rapid obsolescence of technology and of much of the specific, detailed knowledge gained during the formal educational process. Third, the costs of education and research have risen dramatically, while many of the traditional funding sources have stayed constant or shrunk. This has caused the universities to increasingly look beyond government and private sources to their customers -- industry -- for funding.

The result of these pressures is a requirement for increased communication and interaction between Academia and Industry. Robert Courant, in the preface to his well-known mathematical physics text, spoke to the benefits of "...reuniting divergent trends by clarifying the common features and interconnections of many distinct and diverse scientific facts. Only thus can the student attain some mastery of the material and the basis be prepared for further organic development of research."<sup>1</sup> Although Courant was specifically addressing the need to unite physics and mathematical methods, his comments apply directly to the need to unite Industry and Academia in the educational process to enhance its relevance and effectiveness.

The goals of Academia, particularly engineering schools, and Industry<sup>2</sup>, particularly aerospace, are undeniably interrelated. Both are creators and users of knowledge and technology; both depend on the other for success; both are critical to the success of our society. Thus, for maximum effectiveness, Industry and Academia need to form a close partnership -- a team -- to meet the educational and training needs of both potential as well as current employees.

This concept, illustrated in Fig. 2, requires a continuous dialog and flow of information and people between the two groups of institutions. Each group needs to be aware of the needs and products of the other and how each contributes to effective operation of the interdependent "system" or process we call education. As resources become more scarce and competitive pressures increase, we must carefully define and coordinate the roles that Industry and Academia should play in the educational process. In this way, we will obtain maximum benefit from our financial and human resources, and maximize our competitive capabilities as companies, as industries, and as a nation.

Having stated the thesis -- that Industry needs to be actively involved with Academia in optics education -- the next step is to outline the individual role that each group plays. This definition will make apparent the interdependency of Industry and Academia in the educational process, and point out the important role of government in fostering this partnership. In conclusion, some thoughts are presented on how the vitality of the educational process can be increased by recognizing and promoting this interdependency -- by increasing the teamwork -- while still recognizing and enhancing the unique individual skills and roles of Industry and Academia.

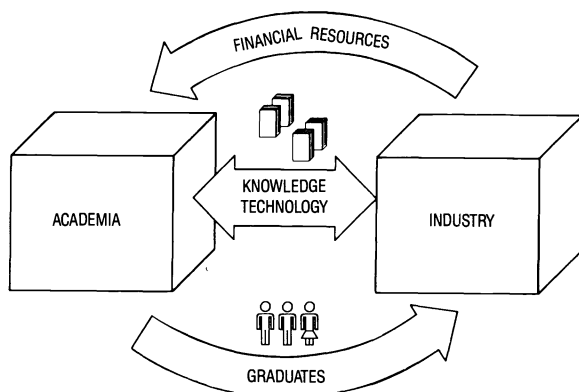


Figure 2. A close interaction - a partnership - between Academia and Industry is the optimum situation.

### 3. DEFINITION OF INDIVIDUAL ROLES

Education is a continuous process, whether for an individual or a society. To distinguish the roles played by Academia and Industry in optics education, consider the concept shown in Fig. 3. On one end of a continuum, a "spectrum", is "education" -- the imparting or receiving of knowledge, in part for its own sake, and in part because it is essential to achieving success in our increasingly complex society. We broadly educate people to enable them to grow and to deal with the widest possible range of future (and thus undefined) situations. This point was well-stated by Dr. Robert M. Hutchins, while he was President of the University of Chicago: "Education is not to reform students or amuse them or to make them expert technicians. It is to unsettle their minds, widen their horizons, inflame their intellects, teach them to think straight, if possible." The broader and deeper our knowledge, the more likely we can synthesize solutions to new problems, discover new knowledge, or create new inventions.

Proceeding to the right in Fig. 3(a), education blends into "training", or the development of specific skills, often in using tools we know are needed to solve known and recurring problems. Examples are mathematical analysis techniques, manufacturing techniques, and design skills such as drafting or use of computers.

On the far right of the educational continuum is "experience", the knowledge gained by applying the facts and techniques from education and the specific skills from training to solve a problem, to meet a requirement, or to produce a product. Experience often teaches us what doesn't work in a particular situation; we learn from experimenting and making mistakes. This is a vital and necessary step in the educational process that utilizes the previous steps, adds new knowledge and skills, and provides the feedback to the process so that the educational and training processes can adapt to the societal needs.

Both Academia and Industry contribute across this continuum, with Academia dominant in "education", Industry dominant in "application experience" and both providing "training," as illustrated in Fig. 3(b). It would be possible for the education provided by industry and academia to be highly independent. The process would then be serial in time, analogous to a pipeline, as illustrated previously in Fig. 1. A university (or other educational institution) accumulates knowledge and has students and funding as inputs to the process. Through coursework and research, graduates are hired by industry, which provides on-the-job experience. The result with time is experienced, trained engineers and scientists.

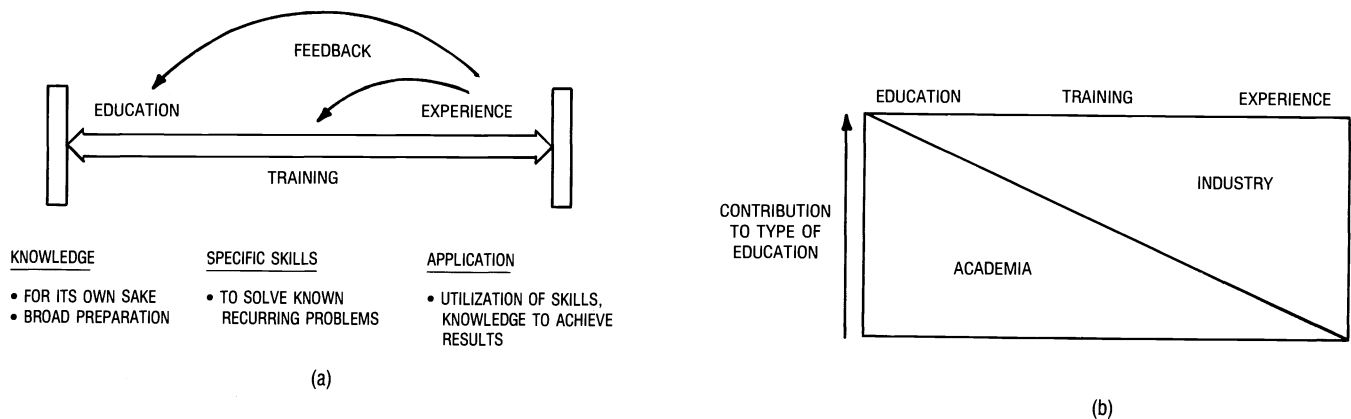


Figure 3. The educational process is a continuum. (a) "education" blends into "training" and then into "experience." Feedback from experience modifies the process. (b) Academia and Industry both contribute to all parts of the process, but concentrate in different areas.

This is a possible process, but not an optimum one. By connecting the inputs and outputs in Fig. 1, by forming a close interactive partnership or team, each organization stimulates and enhances the other, with resulting mutual benefit. Industry actually contributes more than experience to the educational process. It also provides funds, increases knowledge through research and development, develops technology, and even acts as an educator through in-house training programs. Industry can also be a source of students, often bringing funding to Academia for graduate degrees or continuing education, and can provide experienced professionals for faculty positions.

The result is a highly interactive system as illustrated in Figure 4. The system now has another product: educated, trained, and experienced scientists and engineers. Since the subject here is optics education, the point can be illustrated by analogy with two examples: coherence and optical resonators. When Industry and Academia cooperate beneficially, their coherent sum is greater than the sum of the individual parts:

$$|A + I| > |A| + |I| . \tag{1}$$

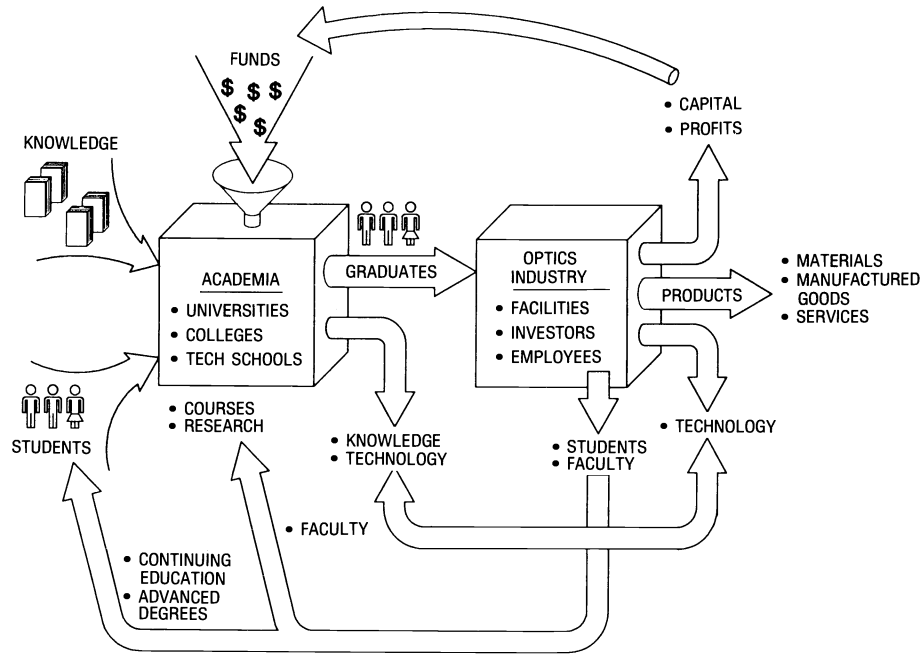


Figure 4. By connecting the inputs and outputs in Figure 1, the "pipeline" becomes a continuous system with feedback and enhanced total output.

When Industry and Academia cooperate and both contribute to the educational process, the system is like an optical resonator, as in Fig. 5. The "gain medium" is people, with Academia and Industry cooperating, but playing unique roles in producing educated, trained, and experienced engineers and scientists, while producing their unique products to society.

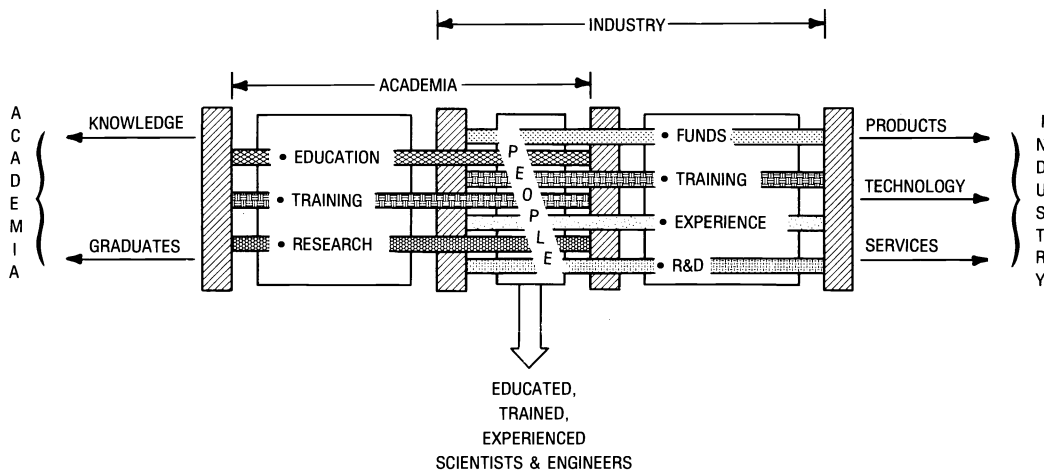


Figure 5. The educational process illustrated as a resonator, in which Industry and Academia work together on people (the "gain medium") to produce their individual outputs, plus the most valuable product: educated, trained, experienced optical scientists and engineers.

#### 4. ROLE OF GOVERNMENT

So far, the optics educational system has been defined as only Industry plus Academia. In reality, a third partner is present: Government. The role of Government at all levels -- federal, state, and local -- is to provide funding, to assure a sound educational system, and to promote the partnership of Academia and Industry so that the society as a whole benefits. Government thus becomes the "pump source" for both sides of the resonator, as illustrated in Fig. 6.

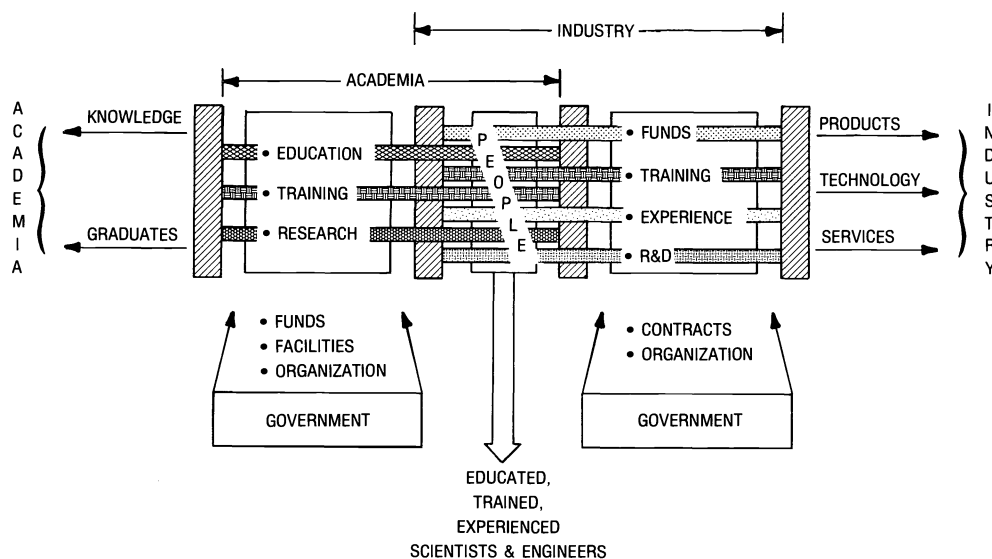


Figure 6. Government is the third necessary partner in a dynamic educational process, supplying funding and information on societal needs.

The role of Government is a vital one, but it should never become the dominant partner in the educational process. Government is the official, elected representative of the needs of society and the disburser of common funds to the educational process. In a free and democratic society, Government should influence, fund, and encourage the partnership between Industry and Academia, but not become the director of the process. If Government takes on too directive a role, or becomes too influential in the educational process, the independent aspects of the roles played by Industry and Academia will be reduced or lost, leading to a loss of creativity, and of the ability to rapidly respond to change.

#### 5. EXAMPLES OF INDUSTRY/ACADEMIA/GOVERNMENT PARTNERSHIP

There are many examples of how Industry, Academia, and Government have beneficially cooperated so that the separate as well as the common goals of each group are met. Within the optics industry, four examples come to mind:

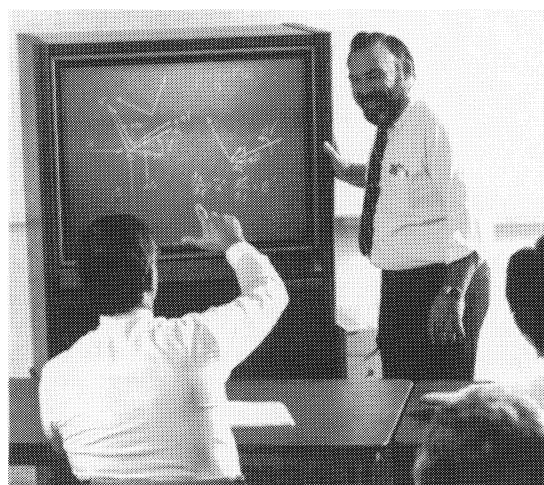
- 1) Corporate support, particularly from the Eastman Kodak Corporation and the Xerox Corporation, to the formation and operation of the University of Rochester's Institute of Optics and to the development of trade schools like Monroe Community College in Rochester.
- 2) Corporate and Government support to the development of the Optical Sciences Center at the University of Arizona. The Air Force Weapons Laboratory was one prominent player at the OSC, providing contract support to projects and promoting development in the mid-1970s of a special Masters program for its employees.
- 3) state Government support to the establishment of the Center for Applied Optics at the University of Alabama in Huntsville. The state's vision and commitment played a major role in the initiation of this rapidly developing center.
- 4) state, University, and Industry cooperation in fostering engineering education and optics development in Florida. Since the author is from Florida, and has participated in several of these cooperative efforts, two of the Florida activities will be used to illustrate what has been done.

The first example is the Florida Engineering and Education Delivery System (FEEDS). FEEDS is the successor to a program called "GENESYS", which began in the late 1960s to meet the needs of engineers in Florida industry. The program developed because Florida engineering universities (at the time the University of Florida in Gainesville and Florida State University in Tallahassee) were remote from where industry was establishing operations (mainly in the Cape Canaveral area). In the early 1980s, industrial high-tech companies such as Harris Corporation, Pratt and Whitney, Motorola, Martin Marietta, and Honeywell, joined with representatives of Eglin Air Force and the Florida legislature to expand GENESYS into what is now FEEDS.

The important feature of FEEDS is the delivery of full engineering programs to the work location of the practicing engineer. The requirements for admission to FEEDS programs and courses are identical for the on-campus and off-campus student. The success of FEEDS requires a high degree of cooperation among faculty members and people in industry. The state financial support makes the system affordable. In this way, the on-site education arrangement provides quality graduate and continuing education for professional development. It is an interactive video system, usually using videocassette tapes of on-campus lectures, as illustrated in Fig. 7, with on-site company employees as tutors.



UNIVERSITY LECTURER



INDUSTRIAL TUTOR

Figure 7. Engineering education is delivered directly to company plant sites in Florida through the Florida Engineering Education Delivery Systems (FEEDS), an interactive video system. (a) Instructor at the University. (b) Company tutor at the plant site.

The program now includes six Florida universities and offers degrees in civil, computer, electrical, industrial, and mechanical engineering. Courses in other disciplines are offered to meet the needs of engineers -- such as optical and electro-optical engineers -- for professional development. To date, 65 degrees have been awarded statewide thru FEEDS. During the 1987-88 academic year, 2,600 students participated. The system provided graduate-level training in over 100 different subjects at 33 off-campus sites. The author's company, United Technologies Optical Systems, has provided courses in coherent optics, signal processing, control systems optical communications and dynamic behavior of structures. The company pays for full tuition costs, employee time at classes, and for the tutor's costs.

The second example in Florida is the state and Industry cooperation with the state University system and the Florida legislature in establishing the Center for Research on Electro-Optics and Lasers (CREOL) at the University of Central Florida in Orlando. In 1983, at the urging of industry, education, and state leaders, then-Governor Bob Graham established the Florida High Technology and Industry Council (FHTIC). The High-Tech Council (as it came to be known) was chartered to foster cooperation between Industry and Academia, with the specific goal of enhancing the growth of high-technology industry in Florida. The Council was given substantial state funds to allocate to the Universities in pursuit of these goals.

One of the first recommendations of the FHTIC to be adopted was the establishment of "Technology Focus Areas" and the creation of Research Centers for selected areas. Lightwave Technology is one of the focus areas, and CREOL was established as the corresponding research center (see Fig. 8). The state has acted wisely in CREOL's genesis by providing funding for faculty lines and capital acquisition, by motivating industry participation through research grants to CREOL on a matched-funds basis, and by requiring industry

participation in the oversight of the center. The detailed operation was left to the University of Central Florida, with guidance by an Executive Board of CREOL staff and industrial participants.

The result has been a real success story, in part because the State and Industry support facilitated the attraction of Dr. M. J. Soileau to the position of Director of CREOL. Under Dr. Soileau's leadership, after only two years CREOL now has 8 researchers, 18 joint faculty, and nearly \$6 million in funding for the coming year, of which \$2 million are state funds to provide an additional 4 support positions and 16 more faculty lines in optics and lasers.

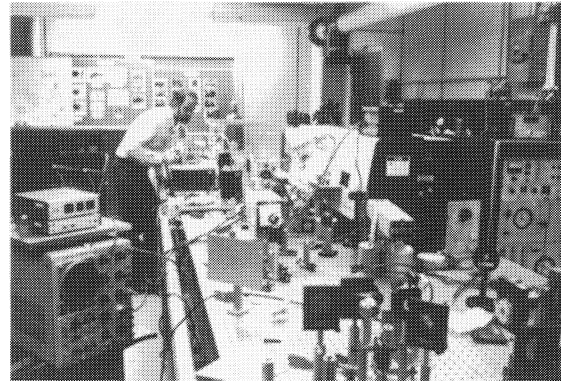


Figure 8. The Center for Research on Electro-Optics and Lasers at the University of Central Florida in Orlando was established and is continuing with the cooperative partnership of Industry, Academia and Government.

## 6. EDUCATION VS. OPTICS TRAINING

As attention is focused on making optics education more relevant and more available, a word of caution needs to be sounded. We must be very careful not to overemphasize optics training of students while they are at colleges and universities at the expense of education in its broader sense. The college experience is unique in providing the opportunity to learn other than specific job-directed skills. We must ensure that our curricula allow time for exposure to, if not in-depth study of the broad range of technical disciplines applicable to optics. This type of education is essential if we are to have the synthesizers, the inventors, and the systems engineers and integrators needed by an increasingly complex, and technically sophisticated field.

In addition, we need to educate our undergraduates and graduates in the skills and operating philosophies needed in today's business world. Students need to understand economics and concepts of productivity and quality if they are going to successfully meet the challenges of international competition. We need to imbue in them the vital concept that "quality" is not "goodness", but quality is doing the right things and doing them right the first time. In short, quality is meeting all requirements of a customer.

We also need to educate students, and also engineers now in industry, on how to be effective communicators and leaders. Our optical scientists and engineers must be well schooled in writing and speaking skills so they can communicate effectively to their companies, employees, and customers. They need to be articulate spokesmen to our nation and to our government on the needs of the optics community and on solutions to broad societal issues.

Communication skills are just one of the requirements for effective leadership. A good leader also needs skills in motivation, in organization and management, and in creating a team environment wherein employees approach their job thinking, "This isn't just the company where I work, this is my company." Today's leaders in engineering must develop a sense of ownership for themselves and throughout his or her organization.

Our academic educational process must address these leadership skills in order to prepare graduates for the participative, highly competitive, team environment of today's industry. Academia needs to start this process and focus primarily on broad, basic education, particularly at the undergraduate level. Most specific, highly-directed training should be left to graduate school and to the application experiences provided by industry.

## 7. SUMMARY

Industry definitely has an important role, as well as a stake in optics education, and in assuring that it is timely, relevant, and affordable. The interdependency of Industry, Academia, and Government in the educational process is summarized in Table 1. Each group brings an important, independent element to the team, providing a necessary part of the educational process and contributing to each part of the process: creation, application, and transfer of knowledge. The numbers in the table represent the author's opinion of the relative contribution of each group to each of these three parts of the educational process. Academia makes the greatest contribution in the creation and transfer of basic knowledge, with industry leading in the application of knowledge. In return, each group receives benefit from the team, obtaining the resources and results required to meet its needs.

	INDUSTRY	ACADEMIA	GOVERNMENT
CREATION OF KNOWLEDGE; • RESEARCH • INVENTION	2	1	3
APPLICATION OF KNOWLEDGE • ENGINEERING • MANUFACTURING • MANAGEMENT • BUSINESS	1	3	2
TRANSFER OF KNOWLEDGE • TEACHING • EDUCATION • TRAINING	2	1	3

Table 1. The interdependency of Industry, Academia, and Government is demonstrated by each group contributing to each part of the educational process - creation, application, and transfer of knowledge. The numbers are the author's opinion of the relative contribution of each group.

Since the goals of Industry, Academia and Government are undeniably related, it is essential that a partnership be established and fostered among them. Each member of the team has a part to play in developing the partnership. It is also essential, however, that the independent, individual character of each group be maintained simultaneously with this partnership. In particular, it is important that Academia, particularly at the undergraduate level, concentrate on broad education that is so relevant to the multidisciplinary field of optics, and on the leadership and communication skills that are vital in today's competitive world. Increasing specialization on training should come in graduate school and through work experience in Industry. Government should focus on promoting the partnership and on providing enabling funding. In this way, long-term goals can be properly balanced with short-term needs so that the requirements of the optical engineering community are met, and so that the American society and economy remains healthy, versatile, adaptable, and competitive, with maximum freedom to pursue knowledge and compete in the world community.

## 8. ACKNOWLEDGMENTS

The comments and critique of Dr. Lucian Montagnino helped improve this paper. Dr. M. J. Soileau supplied the photographs and information on CREOL.

## 9. References

1. R. Courant and D. Hilbert, Methods of Mathematical Physics, Vol. I (Interscience, 1966).
2. Capitalized names are used to represent the broad range of businesses involved in optics and the variety of educational institutions providing optics training.
3. Robert M. Hutchins, quoted in Remarks of Famous People, J. M. Braude (Prentice-Hall, 1965).
4. W. C. Missimer, Florida Engineer, pg. 16, May, 1988.