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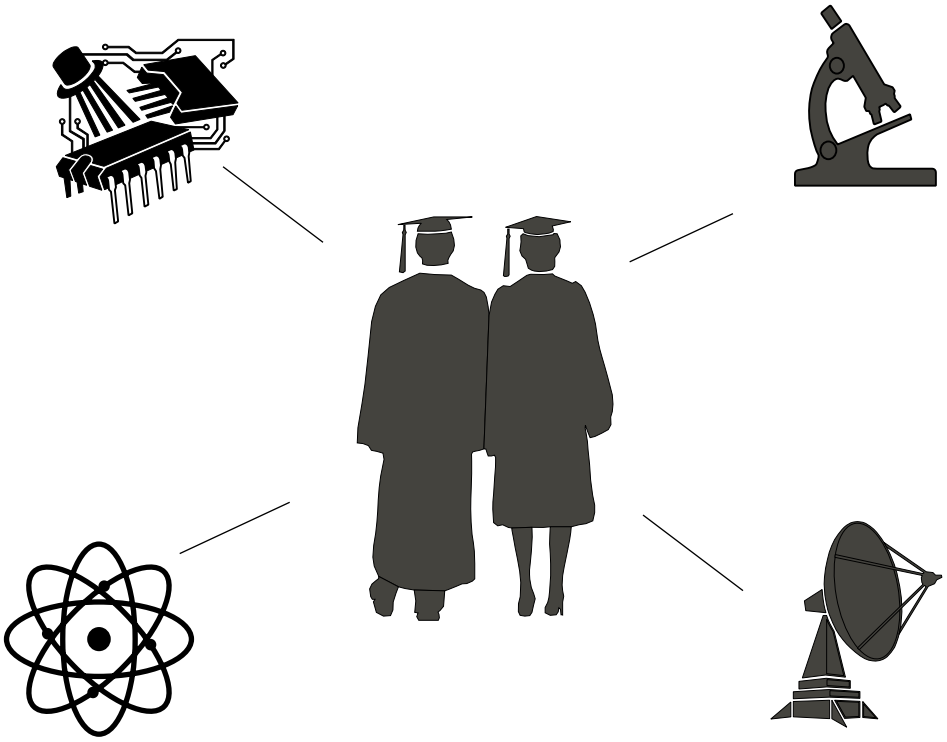

By Stephen D. Norton, Philip W. Hammer, and Roman Czujko

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Mastering Physics for Non-Academic Careers

An American Institute of Physics Report Commissioned by the Alfred P. Sloan Foundation on the Nature of Professional Physics Master's Programs in the United States of America

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Executive Summary

Over the last seven years, the US economy has been growing at an unprecedented rate. This growth is being driven, to a significant extent, by technological innovation with an especially strong demand for employees with scientific and technological skills.

The contributions to economic development by scientists and engineers with bachelors or Ph.D.s have been reasonably well documented. More recently, there has been increased discussion about whether master's degree programs prepare their graduates to play a unique role in the economy.

This study, which was supported by the Alfred P. Sloan Foundation, is one step toward increasing our understanding of master's programs. It involved a detailed analysis of all master's programs in physics departments in the US including both those offering a master's as their highest physics degree and those having a master's degree program running in parallel with a Ph.D. program.

Physics master's degree programs come in a variety of shapes and sizes. Most offer only a general academic curriculum. Many complement a general physics track with some form of specialization. Some programs maintain a narrow focus while others have multiple specializations.

The goals of this study were to:

1. Identify features distinguishing Professional (or employment-oriented) Master's Degree programs from traditional (or academic) master's degree programs.
2. Identify the strongest Professional Master's Degree programs.
3. Provide guidance to departments and to funding agencies.

The authors define a "Professional Master's Degree Program" as one that addresses the current needs of the economy as well as the needs of its students by providing both fundamental knowledge and specialized skills. Fundamental knowledge is the foundation on which students build throughout their working lives while specialized skills help advance their careers immediately by enabling them to smoothly transition into the work place upon graduation.

Professional Master's Degree programs have some combination of features falling into one of the following four general categories: bridge building, programmatic emphasis, research experiences, and non-technical aspects.

Bridge building between physics departments and the world outside of academe encompasses two essential goals: (i) developing formal mechanisms for identifying the needs and opportunities in the market place and (ii) providing feedback mechanisms to ensure adequate responses to the inevitable changes in demand over time. Relevant features include external advisory committees and networking with those in industry.

Programmatic emphasis is assessed in terms of exploitation of faculty specialties and the nature and extent of the cross-disciplinary coursework expected of students. Especially important are interdepartmental relationships combining the expertise of the physics department with those of other departments at the same institution.

Research experience is an important part of any professional physics master's program. Faculty collaborative ventures with corporations or government laboratories can provide potential opportunities for research assistantships. Hands-on research experience can also be inculcated through internships and/or specially designed lab courses.

Finally, non-technical aspects of the program are those that address the unique needs of potential students through evening classes, day classes or some combination of the two. They also include structured activities that provide students with expertise in non-technical areas that are essential to success in today's work place, notably communication skills in both oral and written form as well as interpersonal and team work skills.

Using these criteria, we have identified twenty-two (22) physics departments as the "Strongest Professional Master's Degree Programs;" seventeen (17) departments with "Strong Professional Master's Degree Programs," which, for a variety of reasons, fell short of our productivity threshold; and twenty-three (23) "New Professional Master's Degree Programs." These new programs all have desirable features but their success cannot be adequately evaluated due to their recent creation.

I. INTRODUCTION

Graduate education in the sciences has traditionally focused on preparing students in basic research with the goal that they would pursue scholarly careers in an academic setting. However, "traditional" careers are not the most common careers. Historically, most Ph.D.s in physics and related disciplines have worked outside of academe.

Contrary to popular belief, the number of academic jobs in physics has gradually increased over the last decade. However, there has been an increasing shift toward jobs in applied research and development so that academic jobs now represent a smaller proportion of available scientific positions. This is partly the result of the unprecedented growth of the US economy related to the explosion of internet technology. While most new graduates from science programs are absorbed into these non-academic positions, there are clear indications that finding employment today poses different challenges and requires different strategies.

In addressing this trend, the National Academy of Sciences report *Reshaping the Graduate Education of Scientists and Engineers* (Washington, DC: NAS, 1995) emphasized the need for developing educational strategies to complement existing graduate programs. A good deal of effort along these lines has been directed toward modifying existing doctoral programs so as to better prepare new Ph.D.s to work in non-academic jobs. A complementary approach, and one expressly advocated by Shelia Tobias in *Rethinking Science as a Career* (Tucson, AZ: Research Corporation, 1995), is the development of professional master's degrees as explicit graduate-level alternatives to existing Ph.D. programs.

While not disparaging the societal value of the traditional or modified Ph.D., the Alfred P. Sloan Foundation has instituted a program to spur the development of professional masters programs in the sciences. During 1997-1999, the Foundation provided support for the creation of new two-year professional master's degree programs at various Carnegie I Research Universities in a variety of disciplines – three of them in physics. However, to date, no comprehensive overview of the nature and success of physics master's programs has been produced. As Sloan moves into the next phase of their work – deciding whether to continue present funding or seed a new set of programs – such information could be quite valuable, particularly with respect to providing models and guidance to new and relatively new programs. AIP's Education Division, in cooperation with AIP's Statistical Research Center, partially addresses this deficiency in the current report by providing a systematic study of physics masters programs that currently exist in the United States.

II. OVERVIEW OF SURVEY RESULTS

The primary goal of our study was to determine which US physics departments have established professional or employment-oriented master's programs, gauge the success of such programs, and identify features conducive to success. Additionally, we have sought to develop useful

criteria by which to characterize programs to inform and advise on future funding efforts of the Sloan Foundation; provide guidance to new, under-performing, and/or future programs; and advance discussion and debate on further relevant educational reforms.

We conducted the study in six stages (see Appendices 4 & 5). In the first stage, we created a preliminary questionnaire and developed a list of all physics departments claiming to award master's degrees. To clearly delimit the scope of our investigation we eliminated from consideration separate interdisciplinary programs or hybrid-degrees not awarded by physics departments. Thus, for example, the University of North Carolina, Chapel Hill's interdisciplinary Applied and Materials Science program was not considered because it is a separate program. Neither did we include South Dakota State University's Master's in Engineering with physics emphasis since its College of Engineering awards this degree. Furthermore, health sciences, radiological sciences, and similar programs were only included if they were closely tied to a physics department.

In stage two, we conducted phone interviews with department chairs or directors of graduate studies of each department on our target list. We then utilized this information in the next stage to identify "quality" professional masters programs and to develop a more refined questionnaire. We contacted these "quality" programs during the fourth stage, requesting more detailed information and reviewing each department's web site to evaluate how they portrayed their curricula and goals to potential students. In stage five, we canvassed alumni from these programs to get student perspectives. A final synthesis and assessment followed.

The result of our work is a comprehensive database of all master's programs in physics as of academic calendar year 1999-2000. Each department fell into one of four categories. The programs categorized as "Non-Professional or Nominally-Professional Master's Degree Programs," have either no employment oriented or applied training component or maintain only a token commitment to such training. Of the one hundred and eighty-six (186) physics departments contacted, we found just over half have no applied component at all. We also identified a number of programs that could only nominally be classified as providing an employment oriented curriculum.

We categorized a program as Nominally-Professional Master's if it exhibited at least two of the following criteria:

(i) an average of one of fewer graduates a year going into industry,
(ii) a heavy orientation toward preparing students for Ph.D. programs rather than immediate employment in industry,
(iii) no evidence of a systematic plan behind the implementation or development of a program, and/or
(iv) no formalization of the requirements for the applied degree.

One hundred and twenty-four (124) departments, or just over two-thirds of all physics master's programs, fell into either the Non-Professional or Nominally-Professional Master's Category. The remaining 62 programs each have made or are making substantial efforts to create viable professional physics master's options for their students.

III. FEATURES OF SUCCESSFUL PROFESSIONAL MASTER'S PROGRAMS

Our study has identified the existence of a number of different types of successful professional masters programs in physics, each with a different emphasis and strengths to exploit. In analyzing these programs, we abstracted a set of generic characteristics from which departments have drawn in crafting professional master's programs to meet the exigencies of their particular situation. No department implements all characteristics, but successful programs make optimal use of some subset appropriate to their situation. A brief overview of these features is in order before discussing the different types of programs and the relevance of these characteristics to their success.

In characterizing professional master's programs we used nine features that fall into four broad categories:

<u>Bridge Building</u>
1. External Advisory Committee
2. Networking and Promoting Interaction with Industry

<u>Programmatic Emphasis</u>
3. Exploitation of Faculty Specialization
4. Multidisciplinary Emphasis

<u>Research Experiences</u>
5. Research Ties with Industry (Non-Internship)
6. Negotiated Partnerships with Industry (Internships, Projects, etc.)
7. Hands-on Experience

<u>Non-Technical Aspects</u>
8. Class Schedule Flexibility (All night classes/All day classes/Mixed)
9. Structures for Improving Communication and Team Skills

A. ***Bridge Building***

Building bridges between physics departments and the world outside of academe encompasses two important goals for any successful professional physics master's program. First, developing formal mechanisms for identifying the needs and opportunities in the market place. Second, providing feedback mechanisms to ensure adequate responses to the inevitable changes in demand over time. These are best achieved through external advisory committees, and making connections and networking with those in industry.

1. *External Advisory Committee*

A pre-existing external advisory committee or interdepartmental university appointed advisory board does not constitute implementation of the first feature under "Bridge Building." Effective committees must be composed of members from local, regional, or national industry and research laboratories of relevance to the program and who might have a stake in the program's success. Appropriate committee members might be a company's president or chief scientist or engineer. Selected alumni with jobs in related fields are also desirable, as are academics from different institutions with similar programs. Committees must also be active in providing curricular and other advice so that programs remain in-tune with industry needs.

2. *Networking, Promoting Interaction with Industry (Colloquia, etc.)*

Networking is an essential component for the vitality of any program. Some programs are better than others at exploiting their research connections. For example, Case Western Reserve and the University of Rochester have instituted programs that formalize their connections in different ways. Case Western Reserve, which launched their Entrepreneurial Physics program in fall 2000, initiated a regular seminar series two years ago that recruits business people, physicists, and entrepreneurs to come to campus and meet with students to discuss career opportunities. The University of Rochester has established a unique Industrial Associates Program. Member companies pay a substantial fee each year for privileged access to students. Receptions are held twice a year. Members are provided with a book of student résumés and meet with them informally during lunches and dinners. The benefits of such an arrangement are clear and other programs would do well to follow Rochester's lead when possible.

B. ***Programmatic Emphasis***

Programmatic emphasis is assessed in terms of exploitation of faculty specialties and the nature and extent of the cross-disciplinary coursework expected of students. Especially important are interdepartmental relationships combining the expertise of the physics department with those of other departments at the same institution.

3. *Exploitation of Faculty Specialization*

Any department contemplating establishing a professional master degree program would be well served by playing to their faculty strengths. For example, a department with faculty specializing in optics could create a photonics program that requires their students to complete traditional optics courses. While such a program certainly exploits faculty specialties, it may not go far enough. The curriculum might be generic enough that almost any physics faculty member could teach the courses. However, if the courses were designed to exploit the special experiences and skills of those faculty actively doing research in optics then the program would be very specialized indeed. Medical physics degree programs provide another example. The curriculum for such programs is highly specialized and requires faculty with the appropriate background.

We would like to note that all of the professional physics programs we identified do exploit faculty specialties to some extent. However, some programs exploit specialties more than others do. Each approach has its advantages and drawbacks. A highly specialized curriculum can provide unique training opportunities that make students much more desirable to certain employers. A program with a more generic curriculum does not have this advantage; but it certainly will be more resilient to faculty changes.

4. *Multidisciplinary Emphasis*

Employers generally look for those with a broader range of technical experience and expertise than is generally provided by or can be provided by traditional physics master's degrees. We found that most of the strongest professional master's degree programs explicitly addressed this issue either with specially designed interdisciplinary courses or by requiring students to take relevant courses in other departments. Appalachian State University was a good example of the former approach. They offer few "standard" graduate-level physics courses. All their courses have been specifically designed with their instrumentation and applications focus in mind and have a strong interdisciplinary flavor. As one alumnus said, "The Electronics concentration provided me with a skill-set that to date has granted me the opportunities of working in the digital hardware and embedded software design arenas." Acquiring such a skill set would be just as difficult for traditional physics majors as it would be for both computer science majors, who would have trouble bridging the gap from software to design of digital hardware, and electrical engineers, who might struggle with writing the necessary code. Appalachian State provides its students with the skills necessary to be competent in both areas, thus making them immediately employable upon graduation.

C. ***Research Experiences***

Research experience is an important part of any professional physics master's program. Faculty collaborative ventures with corporations or government laboratories can provide potential opportunities for research assistantships. Hands-on research experience can also be inculcated through internships and/or specially designed lab courses.

5. *Research Ties with Industry (Non-Internship)*

The majority of successful professional programs have robust research relationships with relevant industries or laboratories. Such connections provide research opportunities, an insight into the current needs of the market place, and funds for graduate students and faculty. Research ties with industry also cultivate connections that might fruitfully be exploited for future employment purposes.

6. *Negotiated Partnerships with Industry (Internships, Projects, etc.)*

Negotiated partnerships with industry or government most often take the form of internships. Internships allow students to develop the applied and technical skills necessary to succeed in industry and can take the place of a master's thesis. An added benefit is that many students are hired after graduation by the companies with which they interned. Furthermore, an internship program, or other negotiated partnership, creates a direct human resource link between a department and industry that facilitates technology transfer. Both the department and employer benefit from the two-way information conduit made possible by such partnerships. Nevertheless, internships are not desirable for every department. For programs that largely attract students who are already employed, such as San Jose State University in Silicon Valley, internships simply do not make sense. Departments so situated find it more effective to allow individual projects that can be developed in conjunction with a student's employer. Other forms of partnership include degrees specifically tailored to an employer's needs. An excellent example of the latter is Virginia Tech's off-campus program that caters to the approximately 4000 employees at the Naval Surface Warfare Center at Dahlgren.

7. *Hands-on Experience*

Hands-on experience can be provided not only by internships but also projects and appropriately designed laboratory work. Such experience is one of the most important features of a successful professional master's program. This was emphasized repeatedly by alumni. For example, Appalachian State's instrumentation program lays heavy emphasis on developing skills portable to industrial settings. As one former student recounted, "App. State requires considerable lab time and the labs are not 'cook-book.' They require students to solve problems without step-by-step instructions. This is an essential skill in industry. The applied aspect of the program was a real confidence builder." This confidence derives from the ability of students to "immediately produce the goods" for an employer, making them much more marketable.

D. ***Non-Technical Aspects***

Finally, non-technical aspects of the program are those that address the unique needs of potential students through evening classes, day classes or some combination of the two. They also include structured activities that provide students with skills in non-technical areas that are essential to success in today's work place, notably communication skills in both oral and written form as well as interpersonal and team work skills.

8. *Flexibility of Class Schedule*

Though quite simple to implement in many cases, this component can contribute significantly to the success of a program. For example, San Jose State University offers a combination of day and evening classes which makes it possible for those working full-time to enroll in the program. In fact, seventy percent of their students fall into this category. Failing to provide a flexible schedule of classes limits the ability to attract such students. Flexible scheduling can be

beneficial, but it is not always called for. Some schools, such as Texas Tech. University in Lubbock, exist in areas with no significant constituency of full-time employees to take advantage of such a feature. Thus, it makes no sense for Texas Tech., or similarly situated schools, to offer night classes.

9. *Explicit Structures for Encouraging the Development of Communication and Team Skills*

Physicists working in the private sector are typically members of teams comprised of practitioners trained in a variety of different disciplines. In addition, people with physics master's degrees are often hired into supervisory positions. Thus, the need to interact with people having different technical expertise is ubiquitous in industry, and many alumni stressed the benefits of having had the opportunity to develop and polish their communication and team skills in the course of their graduate training.

The Radiological Sciences option at the University of Massachusetts, Lowell, strongly emphasizes the importance of encouraging teamwork and the ability to foster close working relationships. A number of their graduates echoed this, noting how important it is but how often it is overlooked in other programs. A number of other programs appear to inculcate these skills through informal interactions. While not disparaging such an approach, we based our assessment on formal structures within the program that foster the development of these valuable skills. We identified two programs that have effectively implemented this component.

Appalachian State University explicitly requires interactions between people with different technical backgrounds through various required projects. "This skill," one alumnus related "aids me every day as I associate with mechanical engineers, system-level engineers, and drafters in our design process." Similarly, Texas Tech. University emphasizes the development of team skills. This is done through specially designed laboratory courses in which the students are divided into teams with rotating leaders.

E. ***Note on Graduate Student Funding***

It was suggested to us that professional physics masters programs might operate on the model of other professional programs, such as law and medical schools, where students are expected to work part-time, live off savings, or acquire loans to support themselves. The underlying premise is that if students are willing to go into debt to earn a degree, then the degree must have value. In assessing our survey results, we find no strong correlation between funding, or lack thereof, and the nature and quality of a professional master's program. While it is true that many of these programs require internships, the primary emphasis of internships is to acquire hands-on experience and not to require students to support themselves. Of the sixty-two Professional

Master's Degree Programs we identified, only one (Columbia University's Medical Physics program) expressed a commitment to the pay-your-own-way model. Though many students in professional physics master's programs work full-time and thus do support themselves, there are many students in these programs who attend full-time and are supported by their departments with either teaching or research assistantships.

IV. PROFESSIONAL MASTER'S DEGREE PROGRAMS IN PHYSICS

The "Strongest Professional Master's Degree Programs" incorporate most of the features discussed in the preceding section, have an established track record, and award more than three applied degrees a year with most graduates finding employment in industry. We found twenty-two (22) programs that satisfied these criteria.

Strongest Professional Master's Degree Programs

Appalachian State University
Ball State University
California State University, Long Beach
Christopher Newport University
Columbia University
East Carolina University
Georgia Institute of Technology
Idaho State University
Illinois Institute of Technology
Northern Illinois University
Rose-Hulman Institute of Technology
San Jose State University
Texas Tech. University
University of Central Oklahoma
University of Massachusetts, Lowell
University of Oregon
University of Rochester
University of Texas, Austin
University of Utah
University of Vermont
University of Washington
Virginia Polytechnical Institute

"Strong Professional Master's Degree Programs" incorporate many of the essential features that we associate with professional or employment-oriented master's programs. However, for a variety of reasons they fell below our productivity threshold and awarded an average of three or fewer applied degrees a year. We identified seventeen (17) Strong Master's Degree Programs.

Strong Professional Master's Degree Programs

Alabama A&M University
Cleveland State University
Colorado School of Mines
George Mason University
Indiana University, Purdue
Montana State University
Northwestern University
Oklahoma State University
S.U.N.Y., Binghamton University
University of Maine
University of Maryland, Baltimore City
University of Massachusetts, Boston
University of New Orleans
University of North Carolina, Charlotte
University of Oklahoma
University of Southern Mississippi
Wright State University

"New Professional Master's Degree Programs" are those that have strong features and will either admit their first students soon or have been in existence for an insufficient length of time to assess their success. Our survey revealed twenty-three (23) such programs in the United States. These include the three physics master's programs that are presently funded by the Sloan Foundation.

New Professional Master's Degree Programs

Case Western Reserve University
De Paul University
George Washington University
Indiana University of Pennsylvania
John Carroll University
Louisiana State University, Baton Rouge
Louisiana Tech. University
Michigan State University (**Sloan**)
Northern Arizona University
South Dakota School of Mines & Tech.
Southern Illinois University, Edwardsville
Southwest Texas State University
S.U.N.Y. at Buffalo
University of Arizona (**Sloan**)
University of Arkansas, Fayetteville
University of Kansas
University of Massachusetts, Dartmouth
University of Memphis
University of Southern California (**Sloan**)
University of South Florida
University of Texas at Dallas
Utah State University
Washington State University

V. FACTORS RELEVANT TO SUCCESSFUL DESIGN

As noted, our survey revealed considerable differences among professional physics master's degrees. From our detailed analysis of the twenty-two (22) "Strongest" programs, various organizational, advisory, geographic, demographic, and economic parameters emerged which provide strong indicators of the type of professional master's program appropriate for a particular institution. The most important are displayed in the table in Appendix 1.

Taking these differences, both alone and in various combinations, one can produce many classification schema, *e.g.*, programs that emphasize hands-on training and development of interpersonal skills through specially designed laboratories or projects *versus* programs emphasizing the same through internships or practicums. While such schema may be useful for characterizing the fundamentally different types of programs, they fail to take into consideration the relevance of a department's internal and external circumstances in explaining programmatic differences. Rather than produce a strained typology of professional programs that has little efficacy in illuminating why some programs succeed and others fail, we chose to focus on those circumstances that dictate which subset of components 1-9 will be appropriate for a given department. We determined that the relevant factors fall into three broad areas: (a) faculty strengths, (b) institutional strengths and weakness, and (c) the nature of the local or regional industry.

A. **Faculty Strengths**

As already mentioned, programs will have a leg up on success if the physics department plays to its strengths. Faculty specialties are an important resource to exploit in this regard. For example, physics faculty members at Northern Illinois University are actively involved in acoustics research. They have successfully translated this expertise into a musical acoustics specialization within their applied program. Columbia and East Carolina University each had faculty specializing in medical physics, which made it possible for them to start these programs at their institutions.

B. **Institutional Strengths and Weakness**

Those considering cross-disciplinary programs would be well served by identifying relevant departments and assessing their strengths and weaknesses and to what extent the physics department is willing to collaborate with a department that might be perceived as a competitor. An engineering physics program, such as at Louisiana Tech. University, can be developed in collaboration with a strong engineering program, with program-specific courses being cross-taught and/or formal requirements in the other department. Far from perceiving this as competition, the college of engineering might view it as an opportunity to increase enrollment in its own courses. Another example is Case Western Reserve's Entrepreneurial Physics program which came on-line in fall 2000 and was developed in collaboration with its business school. Students in this program will be required to complete a core physics curriculum supplemented by various business courses and two newly designed physics/business courses titled "Modern Physics and Innovation."

Institutions with medical schools or strong pre-med programs are potential candidates for medical physics programs. For instance, the successes of the medical physics programs at Columbia and East Carolina University are partly due to close ties with their universities' medical schools. Institutional research centers or departmental laboratories can also play a key role in the success of a professional program. Idaho State University's Health Physics has integrated into its curriculum required work at one of its two departmental environmental laboratories while Oklahoma State University's physics department exploits its ties with the Center for Lasers and Photonics Research to provide opportunities for students in its Photonics program.

Other exciting possibilities may exist as a direct result of particular regional and institutional conditions. Alabama A&M and Appalachian State have each exploited the unique circumstances at their own institutions to implement successful programs. After realizing no schools in Alabama offered either optics or materials science, the physics department at Alabama A&M created its Optics & Lasers and Materials Science programs. In seeking to create a non-standard program, Appalachian State took advantage of the fact that their school has no electrical engineering department to craft an instrumentation concentration. Though more than an electrical engineering program, Appalachian State's instrumentation concentration covers ground traditionally under the purview of EE departments. Attempts to create a similar program at schools with EE departments might experience resistance.

C. **Nature of the Local, Regional, and National Economy**

Another important factor to consider in designing a professional physics master's program is the nature of the economy. The high demand for those trained in optics makes lasers and photonics an attractive option. Proximity to industries that have a high demand for technically trained workers or whose employees are potential students should also be considered carefully.

Some programs find themselves in close proximity to centers of industry and/or technologically oriented businesses. California State Long Beach, Christopher Newport University, and San Jose State are prime examples. These schools attract full-time employees from the surrounding industry by offering classes later in the day and at night. Research projects with a thesis will generally be required to complete a degree and many programs have the added attraction of allowing their working students to develop projects in collaboration with their employers. These, and similarly situated programs, will typically eschew formal internship programs.

Graduate students at schools not so favorably located are predominantly composed of those having little or no work experience. Programs in this position prepare students in different ways. Most departments simply rely on faculty grants and networking to secure research positions and summer jobs for their students. Others, such as Appalachian State, have relied on faculty-implemented, specially designed labs to impart the necessary skill. Texas Tech. exemplifies yet another approach. Because the school has few research connections in Lubbock and almost no local high-tech industry, it has opted for an internship program. Presently funded by the NSF, its program requires students to complete a seven-month internship away from the university. As one student said, "The internship was the best seven months of education I've ever had. It was the real life application of everything college gives you, from the freshman level communication and writing classes up to graduate level physics courses."

In selecting an appropriate type of applied or professional program to implement, physics departments should also carefully consider the types of employers that predominate within their region. Is the biotechnology or the semiconductor industry a major player in their area? Is there sufficient demand in local hospitals and government environmental programs to support another medical or health science program? Once potential consumers of the technical and work-force outputs of proposed programs are identified, further probing needs to be done to refine the direction and emphasis. For example, Christopher Newport University surveyed the companies in its area to determine what skills were in demand. They found there was a need for those with simulation and modeling skills, a knowledge of solid-state physics, and especially the ability to set-up and maintain digital instrumentation. Based on their findings, Christopher Newport University created a suite of options designed to meet these diverse opportunities.

VI. CONCLUSIONS

Our survey has revealed that the most successful professional master's programs implement, either by accident or design, subsets of characteristics 1-9 that exploit in important ways certain aspects of a department's circumstances. In section III, we laid bare the most important factors relevant to the selection of characteristic 1-9. Any proposals for a new professional master's degree should explicitly assess each of these factors in light of a department's particular circumstances so that an optimal subset can be implemented. We would like to suggest that a proposal which fails to do so requires further consideration and development before its viability can be adequately assessed.

Our findings also indicate that many existing professional programs would do well to reassess their methods in light of the three factors mentioned in section V. For example, some professional master's degree programs could immediately improve their situation by simply offering night classes. Another characteristic widely overlooked is the existence of an active external advisory board. The curriculum advice that such a body provides can, if implemented, make a department more attractive to potential students as well as help to produce graduates with more marketable skills. An external advisory board can also help to improve a department's networking capabilities which are so vitally important for establishing internship programs and helping graduates find employment.

Finally, we found regions of the country, such as New England and New Jersey, where high tech. companies and industrial research are concentrated but where few professional physics master's programs exist. The demand in these areas for those highly trained in technical work is real and represents an important area of potential growth for applied physics programs.

Appendix 1: Features of Strongest Professional Master's Programs

	Bridge Building		Programmatic Emphasis		Research Experiences			Non-Technical Aspects	
	1 External Advisory Committee **X** Have **O** Informal	**2 Networking** **X** Pro Active **O** Do not actively pursue	**3 Exploitation of Faculty Specialties** **X** Strong	**4 Multi-Disciplinary Emphasis** **X** Formal **O** Informal	**5 Research Ties with Industry** **X** Strong **O** Partial	**6 Negotiated Partnership (Internship)** **X** Required **O** Encourage	**7 Hands-on-Experience (Non Intern)** **X** Thru Reqs **O** Incidental	**8 Class Scheduling** **X** All Night **O** Mixed	**9 Interpersonal and Team Skills** **X** Explicit Structures
App. State		O	X	X	O		X		X
Ball State	X	O	X		X	O			
Cal St. Long B.	X	O						O	
Chris Newport	X	O	X	X	X		X	X	
Columbia		X	X	X	X	X	X	O	
E. Carolina	X		X	X	O	X	X	O	
Georgia Tech.			X		X		X		
Idaho State	X	X	X	X			X	O	
Ill. Inst. Tech.	X		X	X			X	O	
N. Illinois		X	X	X	X			O	
Rose-Hulman	X	X			X		X	O	
San Jose State		O	X		X		O	O	
Texas Tech.	O	X		X	X	X	O		X
U. Cent Oklah.	O	O		X	X		O	X	
U. Mass Lowell	O	X	X	X	X	X	X	O	
U. Oregon		O		O		O	X	O	
U. Rochester		X	X	X	X	O	X		
U. TX Austin	X	X				X			
U. Utah				X				X	
U. Vermont				O	X				
U. Washington	X						X	X	
Virginia Tech.	X			X	O	X		O	

Appendix 2: Brief Program Descriptions

Strongest Professional Master's Degree Programs

These programs have made substantial efforts to create viable professional physics master's options for their students and, on average, grant more than three applied degrees a year with the majority of their graduates securing employment in industry, as opposed to continuing on to the Ph.D. Certain borderline programs have been included because they are particularly well-designed.

Appalachian State
Highest Degree Awarded: M.S.
Carnegie Classification: Master's I (1994)
Master's I (2000)
Options: (1) Applied Physics, (2) Instrumentation (Physics or Astronomical), and (3) Interfacing/Electronics
Comments: Offers a non-standard, multidisciplinary curriculum that is heavily oriented towards the acquisition of practical experience through extensive laboratory work where students are expected to interface with individuals from different backgrounds. The lack of relevant engineering disciplines on their campus originally made such a program viable.

Ball State
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University I (1994)
Doctoral/Research University - Intensive (2000)
Options: Applied [Not a Formally Distinct Track]
Comments: This program has grown out of faculty specialties in condensed matter, nanoscience, accelerator work, and astrophysics. Students are employed by various local and regional industries as well as national labs.

California State University, Long Beach
Highest Degree Awarded: M.S.
Carnegie Classification: Master's I (1994)
Master's I (2000)
Options: Applied Physics
Comments: This department has an undergraduate internship program; but since most of its graduate students are already employed, a master's program has not been implemented.

Christopher Newport University
Highest Degree Awarded: M.S.
Carnegie Classification: Baccalaureate College II (1994)
Baccalaureate College - Liberal Arts (2000)
Options: (1) Modeling & Simulation, (2) Solid State Systems, (3) Advanced Computer Systems & Instrumentation, (4) Computer Science
Comments: A particularly strong and flexible (as indicated by their four concentrations) department which caters to employees of the local industry by offering only night classes. The program was self-consciously crafted with employment and advancement in industry as the primary focus. A special feature of the coursework is its emphasis on applications, laboratory experience, and extensive use of computer software and hardware. All of the courses for the master's program make extensive use of computers or require significant laboratory experimentation.

Columbia
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: (1) Applied Physics (2) Medical Physics
Comments: Most of the students completing option 1 are actually Ph.D. candidates. Our ranking them with the Strongest Professional Master's Degree Programs is based on option 2, which this department considers a professional program. Option 2 students receive no financial support.

East Carolina
Highest Degree Awarded: Ph.D.
Carnegie Classification: Master's I (1994)
Doctoral/Research University- Intensive (2000)
Options: (1) Applied Physics (2) Medical Physics
Comments: Option 1 exploits faculty specialties, especially in lasers. However, option 2 is the stronger program and requires extensive clinical work. The department is also very small, thus students receive excellent one-on-one attention.

Georgia Institute of Technology
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University- Extensive (2000)
Options: Applied (with concentrations in optics & acoustics)
Comments: The applied degree is a one year program that was established over twenty years ago. Students are required to complete a practicum that culminates with a research report. The concentrations exploit faculty specialties. The program averages two to three graduates a year.

Idaho State University
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University I(1994)
Doctoral/Research Universe - Intensive(2000)
Options: Health Physics
Comments: Course work for this program is strongly multidisciplinary, and courses have been specifically designed for the program. While no internship experience is required, students acquire excellent hands-on training in the department's two environmental laboratories. The program has a strong placement record. Students generally take time off from their jobs to pursue the degree full-time.

Illinois Institute of Technology
Highest Degree Awarded: Ph.D.
Carnegie Classification: Doctoral University I (1994)
Doctoral/Research University - Intensive (2000)
Options: Health Physics
Comments: This is an interdisciplinary degree operational since 1997, granting the degree of MS in Health Physics. The program is geared towards working professionals in health and allied fields. Students are expected to complete a six-course health physics sequence as well as course requirements in environmental engineering, psychology, and technical writing. Course material is delivered *via* live classes, TV, and the internet. Classes are taught by full-time IIT faculty and adjunct staff who are working health physicists. Graduates generally continue working as health physicists in industry.

Northern Illinois University
Highest Degree Awarded: Ph.D.
Carnegie Classification: Doctoral University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Applied Physics
Comments: Special courses in material science and acousto-electronics were designed for this program which began during the 1970s. One of the specialties in the MS program is musical acoustics. A good number of students go on to work at Argonne and Fermi National Laboratories.

Rose-Hulman Institute of Technology
Highest Degree Awarded: M.S.
Carnegie Classification: Specialized - Engineering (1994)
Specialized - Engineering (2000)
Options: Applied Optics
Comments: Established in the mid-1980s this is a particularly innovative program that places a premium on laboratory training and has dynamic connections to industry. The program was designed to take advantage of the tremendous growth potential in the optics industry. The department is presently working towards establishing an internship program for its graduate students.

San Jose State
Highest Degree Awarded: M.S.
Carnegie Classification: Master's I (1994)
Master's I (2000)
Options: (1) Computational Physics
Comments: Located in Silicon Valley, about half the students are employed full-time and take classes at night. The department also offers a large number of laser/optics courses which students find attractive.

Texas Tech University
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University II (1994)
Doctoral/Research University - Extensive (2000)
Options: (1) Applied (2) Master's Degree in Science with Internship
Comments: Option 1 has been in existence for over thirty years while option 2 was started in 1996 with a grant from NSF. Those pursuing option 2 are supported for seven months of the year by an internship. The department provides extensive laboratory training in microelectronics and parametric testing. The laboratory courses are team oriented, with rotating team leaders and required team reports and oral presentations. Interdisciplinary courses are also offered and co-taught with the electrical engineering department.

University of Central Oklahoma
Highest Degree Awarded: M.S.
Carnegie Classification: Master's I (1994)
Master's I (2000)
Options: Industrial & Applied Physics (May change title to Engineering Physics)
Comments: Though the program is very flexible, the department encourages students to take six hours of management science to prepare them to work in industry. Over the last five years all of its students have been able to secure permanent positions which is in no small part due to its applied emphasis. All of the courses are offered at night.

University of Massachusetts, Lowell
Highest Degree Awarded:
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Extensive (2000)
Options: Radiological Sciences
Comments: This program very explicitly encourages cooperation and teamwork which fosters close working relationships among its students. The department has a distinctive multidisciplinary approach and a strong placement record. All courses are offered at night to accommodate and encourage older students already working to attend. The program is much more technically rigorous than other health physics master's programs. Students acquire experience through working at campus research centers as well as completing off-campus internships.

University of Oregon
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University II (1994)
Doctoral/Research University - Extensive (2000)
Options: (1) Applied Physics (2) Industrial Internship Program [Category III]
Comments: Option 1 was slated to begin in Spring 2000 while option 2 was established in 1997. Three terms of off campus internship experience are required for both programs. The express purpose of these degrees is to provide an alternative for those students seeking employment in industry or other professional careers for which more than a B.S. but not a Ph.D. is required.

University of Rochester
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: (1) Optics (2) One Year Co-Op Program
Comments: Large numbers of multidisciplinary optics courses are offered and the program has extremely strong ties with industry. All but one of the department's 16 full-time and 7 joint faculty are actively engaged in research. Its Industrial Associates Program provides unique networking possibilities. Member companies pay a substantial fee each year for privileged access to students. Receptions are held twice a year. Members are provided with a book of student résumés and meet with them informally during lunches and dinners. Though optics research and courses are found at other institutions, Rochester stands alone. Nowhere in the country can one receive as strong a background in theoretical and applied optics as at Rochester. Option 2 is under utilized with most students opting not to do internships.

University of Texas at Austin
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Professional Master's in Physics
Comments: This program was established in the mid-1990s and produces about four professional master's graduates a year and an additional eight graduates from their standard physics master's option. About half of its twelve yearly graduates find permanent employment in industry. The department has also established a master's program that is open only to the employees of Southwest Research Institute. This latter program can be completed remotely through taped lectures.

University of Utah
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: (1) Instrumentation (2) Computational Physics [Category III]
Comments: The department is primarily focused on the Ph.D. program. With that said, about five or six faculty are actively involved with the Instrumentation and Computational Physics options. The Instrumentation option has been in existence for about twenty years while the Computational Physics option was established around 1995. The Instrumentation option offers specially designed courses and produces seven to eight graduates a year. The Computational Physics degree is multidisciplinary and only produces one to two graduates a year. Nevertheless, there has a been a recent surge of interest in the Computational Physics program.

University of Vermont
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University II (1994)
Doctoral/Research University - Extensive (2000)
Options: Engineering Physics
Comments: This program was created during the 1970s and produces three to four graduates a year with most securing permanent jobs in industry.

University of Washington
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Applications of Physics
Comments: Created in 1976, this program has the objective of providing locally employed persons, with physics or engineering backgrounds, the opportunity to further their education in areas of applied physics. The curriculum consists of basic graduate-level courses that meet two nights per week. Courses are specially designed for returning students who are beginning graduate study after several (or many) years in the workplace, and who have an interest in applications of physics or related fields. Technical courses on aspects of physics instrumentation are an important part of the program, as are advanced specialized courses of particular interest to research scientists and engineers. This program produces between 8 and 10 graduates a year.

Virginia Polytechnical Institute.
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Applied & Industrial Physics
Comments: The industrial physics program is run from the main campus and requires an internship. The curriculum for the program is designed around standard physics courses with students strongly encouraged to take courses from other departments (not a feasible option for students at the satellite campuses). This programs was re-instituted about four years ago and produces about two graduates a year. Virginia also runs two programs for working students, one at the Naval Surface Warfare Center at Dahlgren and one at Falls Church. There are no faculty in residence at either the Falls Church or Dahlgren centers which is a big negative for the students. Courses are taught by Virginia Tech faculty when they can get to the satellite campuses. Otherwise adjunct faculty do the teaching or they teleconference classes. The program is run in cycles with students taking one course at a time.

Strong Professional Master's Degree Programs

These programs have made substantial efforts to create viable professional physics master's options for their students and produce an average of one to three graduates a year from their applied degree programs.

Alabama Agricultural and Mechanical University
Highest Degree Awarded: Ph.D.
Carnegie Classification: Master's I (1994)
Doctoral/Research University - Intensive (2000)
Options: (1) Materials Science (2) Optics/Lasers
Comments: This is an HBCU, Historically Black College or University. While some of its graduate students do internships, the department's formally negotiated relationships with industry are restricted to its undergraduate co-op program. There is also a consensus among alumni that more hands-on experience would be helpful. Both options were specifically designed to exploit faculty specialties and fill the needs of NASA, the US Army, and the industrial community. At the time of its creation, this program took advantage of the fact that no state schools in Alabama offered a Material Science or Optics degree. Eighty percent of its three to four yearly master's graduates matriculate in Ph.D. programs.

Cleveland State University
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Intensive(2000)
Options: Applied Optics
Comments: Established in the mid-1980s this program was closely allied with the University's Advanced Manufacturing Center and with NASA's Glenn Center which provided research opportunities for their students. The department awards an average of two degrees a year. Practically all their graduates hold industrial jobs. In the mid-1990, the scope of the program was broadened to include optical materials, environmental, and computational physics courses. As of 2000, the physics department began collaborating with the physics section in the Department of Radiation Oncology at The Cleveland Clinic. In Spring 2001, the department will offer an introductory course in medical physics. A new concentration in medical physics, which will incorporate several of the current optics courses, is also being planned

Colorado School of Mines
Highest Degree Awarded: Ph.D. (Applied)
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Intensive (2000)*
* As of summer 2000, Specialized Engineering Institution
Options: (1) Physics [with applied emphasis] (2) 5-year B.S. Engineering Physics M.S. (Engineering or Metallurgical and Materials Science Engineering)
Comments: Option 1 has a traditional physics core but there is heavy emphasis on preparing students to do applied research. All students are required to complete 12 research credits and write a thesis.

George Mason University
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Intensive (2000)
Options: Applied Physics
Comments: Established in the early 1980s, this is largely a coat-tail operation that exists because of the physics Ph.D. program and is run out of the Institution for Computational Sciences and Informatics (of which 60% of the physics faculty are members). The number of master's students is low and only about 40% end-up in industry.

Indiana University, Purdue
Highest Degree Awarded: Ph.D.
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Intensive (2000)
Options: (1) Bio-physics (2) Optical Physics (3) Materials Science
Comments: These programs were established in the mid-1980s. The department is now actively exploring the possibility for establishing co-op arrangements with local industry. However, the emphasis is on producing Ph.D.s. The department only awards an average of two master's degrees a year.

Montana State University
Highest Degree Awarded: Ph.D.
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Intensive (2000)
Options: Optics (Informal)
Comments: An optics option was created in 1990 to respond to the needs of the half dozen or so laser companies near the University. The program exploits faculty specialties and has informal multidisciplinary requirements. The department's optics emphasis also takes advantage of the Optical Technology Center and Spectrum Lab, both located on campus. While there are on average only about two graduates a year from the optics track, most graduates find immediate employment in industry after finishing the master's degree.

Northwestern University
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: (1) Instrumentation (2) Optics
Comments: Established in the late 1980s, these programs have stagnated. The optics option is multidisciplinary. The department's primary emphasis is on the Ph.D. program.

Oklahoma State University
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University II (1994)
Doctoral/Research University - Extensive (2000)
Options: (1) Professional Master's in Physics (2) Photonics
Comments: Option 1 was established in 1997 while 2 was started in 1995/6. The degree is closely tied to the university's Center for Lasers and Photonics Research. The department only awards a combined average of four master's degrees a year for options 1 and 2.

University of Maine
Highest Degree Awarded: Ph.D.
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Extensive (2000)
Options: Engineering Physics
Comments: The strongly interdisciplinary M.S. in Engineering Physics was established over twenty-years ago to build upon its existing undergraduate engineering physics program. The department awards only one or two degrees a year in this graduate program.

S.U.N.Y., Binghamton University
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Applied Physics (emphasis)
Comments: Created in 1975, the students are prepared for industry through individual design. The department appears to have a strong internship program with formal agreements with Lucent, Intel, and others. Though internships are not required, they are strongly encouraged. The program averages about five graduates a year with sixty percent of those going into industry. No external advisory panel exists, and classes are only offered during the day.

University of Maryland, Baltimore County
Highest Degree Awarded: Ph.D. (Applied)
Carnegie Classification: Doctoral University I (1994)
Doctoral/Research University - Intensive (2000)
Options: Applied Physics with concentrations in Optics, Condensed Matter, Atmospheric Physics, and Astrophysics
Comments: Both the master's degree and Ph.D. are applied. The master's degree was created in 1986 driven by the demands of local industry. The department produces an average of about two graduates a year with the majority immediately getting jobs in industry. The department has a flexible schedule of classes but no external advisory board.

University of Massachusetts, Boston
Highest Degree Awarded: M.S.
Carnegie Classification: Master's I (1994)
Doctoral/Research University - Intensive (2000)
Options: Applied Physics
Comments: This program was established over twenty years ago and has an industrial advisory panel. About a third of its four to five yearly graduates find employment in industry, another third going into secondary or community college education, and the last third going on to Ph.D. programs.

University of New Orleans
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Intensive (2000)
Options: Applied Science in Physics
Comments: Motivated by the demands of local industry and the lack of an engineering department at the time, this program was created in the early sixties. The department produces two graduates a year from its applied track and about five total. About sixty percent of its master's students secure jobs in industry. The department does not at present have an external advisory board, but it does have a flexible schedule of classes.

University of North Carolina, Charlotte
Highest Degree Awarded: M.S.
Carnegie Classification: Master's I (1994)
Master's I (2000)
Options: Applied Optics
Comments: An interdisciplinary program to be sure but with only about half of its three to four yearly graduates moving into industry.

University of Oklahoma
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University II (1994)
Doctoral/Research University - Extensive (2000)
Options: Engineering Physics
Comments: The undergraduate engineering physics program is the oldest in the country (est. 1920s). The master's program has tried to exploit the success of the B.S. degree but they only award two to three M.S. degrees a year.

University of Southern Mississippi
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University I (1994)
Doctoral/Research University - Intensive (2000)
Options: (1) Computational Physics (2) Polymer Physics
Comments: Option 1 was established in 1991 and requires course work in computer science and mathematics. Option 2 was started in the mid-1980s and requires course work in both engineering and chemistry. These options produce an average of three to five graduates a year with most finding permanent employment in industry.

Wright State University
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Intensive (2000)
Options: Medical Physics
Comments: This program was established in 1992/1993 and has connections with bio-engineering, physiology, and biology as well as with the University's medical school and area hospitals. The department awards an average of only two degrees in this area each year.

New Professional Master's Degree Programs

These programs have made or are making substantial efforts to create viable professional physics master's options for their students and will either admit their first students soon or have been in existence for an insufficient length of time to assess their success. These include the three presently funded Sloan physics master's programs.

Case Western Reserve University
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Entrepreneurial Physics
Comments: This program was started in Fall 2000 and supplements a core physics curriculum with courses from the Business school as well as two newly designed entrepreneurial physics courses.

De Paul University
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Intensive (2000)
Options: Applied
Comments: The Applied option was created in 1998 based on student interest and the demands of the regional industry. While an external advisory panel does not yet exist, members of industry were extensively consulted for curriculum advice. Traditionally, almost seventy percent of the master's graduates have gone on to Ph.D. programs.

George Washington University
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University II (1994)
Doctoral/Research University - Intensive (2000)
Options: Computational Physics
Comments: The option was implemented in Fall 1999. It has three new courses specifically designed for the program, and students are required to complete an internship.

Indiana University of Pennsylvania
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University I (1994)
Doctoral/Research University - Intensive (2000)
Options: Technology Management
Comments: This is a new program slated to begin by Fall 2001. The program is being designed in conjunction with the Business School and internships will be required of all students. The university is not sure which department will award the degree.

John Carroll University
Carnegie Classification: Master's I (1994)
Master's I (2000)
Options: (1) Applied (2) Interdisciplinary Medical Science [Neither Option has been formalized]
Comments: The department has a very strong applied slant overall and good placement in industry. The department is in the process of designing option 2 thus its ranking.

Louisiana State University, Baton Rouge
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University – Extensive (2000)
Options: (1) Medical Physics (2) Applied Physics
Comments: Both options listed are multidisciplinary. The medical physics option has specially designed courses and requires students to spend a year working at a cancer radiation treatment center. The material science option is scheduled to start in Fall 2002, though a dual degree program with computer science is already in place

Louisiana Tech. University
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University II (1994)
Doctoral/Research University - Intensive (2000)
Options: Engineering Physics
Comments: This option exists as a separate track within the master's program. It was implemented in 1998 and while internships are strongly encouraged they are not required.

Michigan State University ----Sloan Program----
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Professional
Comments: Funded by the Sloan Foundation, this program is due to come on-line in Fall 2000.

Northern Arizona University
Highest Degree Awarded: M.S.
Carnegie Classification: Doctoral University I (1994)
Doctoral/Research University - Intensive (2000)
Options: Applied Physics
Comments: Due to start in Fall 2001, this program encourages, but does not require, internships.

South Dakota School of Mines & Tech.
Highest Degree Awarded: Ph.D. (Materials Science & Engineering)
Carnegie Classification: Specialized - Engineering (1994)
Specialized - Engineering (2000)
Options: Materials Science & Engineering
Comments: While traditionally offered by engineering departments in other schools, the physics, chemistry, and metallurgy departments at this institution have combined their resources to offer this degree. The program was implemented two years ago and the college awards the degree, not the department.

Southern Illinois
Highest Degree Awarded: M.S.
Carnegie Classification: Master's I (1994)
Master's I (2000)
Options: Computational
Comments: No students have completed this track in their degree program. The department awards four to five M.S. degrees each year with about eighty percent of its students finding permanent employment in industry.

Southwest Texas State University
Highest Degree Awarded: M.S.
Carnegie Classification: Master's I (1994)
Master's I (2000)
Options: Materials Science
Comments: This program was started in 1993/4 and over 95% of its graduates find permanent employment in industry. The department is attempting to establish a formal internship program with local semiconductor companies.

S.U.N.Y. at Buffalo
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Intensive (2000)
Options: Medical Physics
Comments: This option was started in 1996 as a way to exploit the interest in radiology of two of the department's faculty members.

University of Arizona ----Sloan Program----
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Industrial Physics
Comments: This program is funded by the Sloan Foundation and began in Fall 2000. An internship or project is required. Formal relations with the biosciences and mathematics departments have been established. There is a common program coordinator for these efforts and common courses to be taken by all students but the degree is awarded by the different participating departments.

University of Arkansas, Fayetteville
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University II (1994)
Doctoral/Research University - Extensive (2000)
Options: (1) Applied (2) Photonics & Micro Electronics
Comments: Option 1 was established in 1998 while 2 was started the year before that. The Applied option has a multidisciplinary curriculum, requiring students to take business courses. Those taking option 2 have more formal advising than other students.

University of Kansas
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Computational Physics
Comments: Courses specifically designed for this degree and over 60% of their graduates find permanent employment in industry.

University of Massachusetts, Dartmouth
Highest Degree Awarded: Ph.D.
Carnegie Classification: Master's I (1994)
Master's I (2000)
Options: (1) Computer Science Physics (2) Engineering Physics
Comments: Each of these options was established approximately three years ago and internships are optional.

University of Memphis
Highest Degree Awarded: M.S.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Computational
Comments: This department is presently crafting a proposal for a computational physics option. The school's computer science, chemistry, and psychology departments as well as members of local industry have been consulted. An external advisory board and required summer internships are planned. The department averages two to three graduates a year.

University of Southern California ----Sloan Program----
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: Physics for Business Applications
Comments: Funded by the Sloan Foundation, this program started in 1999. Its newly developed physics courses emphasize modeling and applications technology. Students are required to complete an internship and take business courses in USC's school of business.

University of Southern Florida
Highest Degree Awarded: M.S.
Carnegie Classification: Research University II (1994)
Doctoral/Research University - Extensive (2000)
Options: Science and Applied Physics
Comments: Its applied option started in 1998. An external advisory panel exists for this option. Over the last five years around 75% of its students have found permanent jobs in industry, but the department has yet to graduate any students from the applied option.

University of Texas at Dallas
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Intensive (2000)
Options: Master of Science and Applied Physics (MSAP)
Comments: MSAP was established in 2000 to formalize service to the high tech industry in North Texas. The program has close ties with the Departments of Electrical Engineering, Computer Science, Biology, Chemistry, and the School of Management; and electives from these departments are part of the curriculum. Students are also strongly encouraged to complete an industrial internship. The program can be completed in two semesters by full-time students or, part-time, over five years by those currently employed.

Utah State University
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1994)
Doctoral/Research University - Extensive (2000)
Options: (1) Industrial Physics (2) Upper Atmosphere
Comments: Option 1 was projected to start in Fall 2000. A computational physics course and advanced laboratories have been specially designed for the program that requires at least one summer internship with a local company.

Washington State University ----NSF Program----
Highest Degree Awarded: Ph.D.
Carnegie Classification: Research University I (1996)
Doctoral/Research University - Extensive (2000)
Options: Optoelectronics
Comments: The Optoelectronics degree is awarded by either the department of physics, electrical engineering, or computer science depending on the home of the student. Funded by the NSF, this program admitted its first students in the spring of 2000.

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Appendix 4. How the study was conducted

The primary instruments of our investigation were detailed questionnaires completed by means of phone interviews with department chairs and/or appropriate departmental representatives. The first instrument consisted of 45 questions in five different categories (See Appendix 5).

The first group of questions consisted of general departmental information such as mailing address, URL, full-time faculty, highest degree awarded, etc. The second group dealt with details of the department's master's degree. An initial query as to the nature of the degree determined whether or not the interview continued. If we determined that a professional or employment oriented emphasis existed, no matter how slight, additional information was sought. This included the nature of the applied emphasis (e.g., optics, instrumentation, medical, etc.), when the program was established, whether or not internships or projects were required or even available, the flexibility of class scheduling, any formal requirements in other departments, special advising, and availability of funding.

The next group was a battery of questions dealing with the reasons for establishing the program. Reasons ranged from the formalization of options that had developed piecemeal over time and exploitation of faculty specialties, to meeting student and industry demand and increasing enrollments. All too often this information proved incomplete, largely anecdotal, and the quality was too uneven to be of use in assessing the quality or probable success of a program.

The fourth group of questions proved to be more revealing. These questions probed factors relevant to the design of a program and provided us with a fix on how serious a department was about their own efforts. For example, was the program designed according to some informal *ad hoc* procedure or was there a clear plan and objective in place? Were appropriate resources consulted, such as industry, similar programs, scientists working in relevant areas or other departments, and alumni? Two other concerns of paramount importance were whether or not an advisory panel was established to provide curriculum advice, either temporarily or as a permanent organ of the program, and the extent to which appropriate connections with industry and business were and are being cultivated.

The final group of questions concerned program outcomes. Two questions here were particularly important: (1) How many professional master's degrees are awarded each year by the department; and (2) What percentage of these graduates, over the last five years, had gone on to secure jobs in industry as opposed to academia or transferring into Ph.D. programs? Many departments that at first glance appeared to have strong professional master's programs failed to provide any evidence here of real commitment to the expressed goals of these options. For instance, we found physics departments that offered applied master's options and graduated a number of masters each year. However, on closer inspection, we discovered that 90% of these students went on to Ph.D. programs and only 10% secured permanent jobs in industry.

One hundred and eighty-five physics departments were probed with the first questionnaire. From this information we prepared a comprehensive database and developed criteria to assess program quality. Programs with no applied emphasis at all were immediately eliminated, as were newly

created programs and those just coming on-line. Various criteria combinations were proposed for assessing the remaining programs. Eight factors were finally selected:

(1) required internships/projects,
(2) flexible class schedule for working students,
(3) funding of students,
(4) consultation with appropriate sources in designing program,
(5) formation of an advisory panel,
(6) adequate industry connections,
(7) number of professional degrees awarded and percentage of graduates securing jobs in industry, and
(8) a serious commitment to their professional master's students as evidenced in departmental publications, *e.g.*, appropriately highlighting their program on the department's webpage.

Guided by these criteria, we chose 22 particularly active programs for further scrutiny.

The second questionnaire consisted of 12 questions that were to be answered in much greater detail. Program requirements were investigated. In particular, we wanted to know what had attracted students to these programs. Additional information was also requested on advisory committee composition, financial support, internships, industry connections, and student employment. At the end of this phase alumni were contacted for student perspectives on the value of their professional master's training.

Appendix 5: Survey Instruments

Stage I Questionnaire:

A. Department Information

1. Department Name: _____

2. Institution Name: _____

3. Address: _____

4. URL: _____ 5. Full-time Faculty: _____

6. Highest Degree You Award: _____

DEPARTMENT CHAIRPERSON

7. Name: _____ 8. Phone#: _____

9. Email: _____

B. Current or Projected M.S. Program Details

1. Is your master's degree primarily a terminal degree or is it designed to prepare students intending to pursue a Ph.D.?

2. Professional master's. program, i.e., oriented towards:
   Traditional Physics / Industry / Teaching / Individual Design Possible / Other

3. Is the program curriculum:

   Traditional Physics / Multidisciplinary (Formal) / Both / Ind. Design Possible

4a. Have physics courses been designed specifically with this program's emphasis in mind?

4b. If yes, please describe.:

5. Does your program have any formal relation with other departments?

6. Is a thesis**: Required / Optional** ?

7. Is research experience: **Required / Optional** ?

8. What is the nature of this research?: **Experimental / Theoretical / Computational**

9. What form does this research take? **Directed Study / Internship / Other (specify)**

10. Are off-campus internships required or encouraged?: **Yes / No / Optional**

11. If so, where and for how long?

12. Is a flexible schedule of classes offered for those who work full or part-time?:
    i. **No**
    ii. **Yes-Regular Schedule with some Late Afternoon & Night Classes**
    iii. **All Night Classes**

C. Program History

1. Approximately when was/will this program (be) established?

2. What were the reason(s) for establishing this program?

3a. Was/Is your program (being) designed in consultation with individuals outside department?

3b. If yes, who?

4. Did/Will consultants provide curriculum advice?

5. Do/Will consultants exist as an external advisory panel?

6. Do any of the individuals you have consulted consider themselves potential consumers of the technical and work-force outputs of the program?

7. What other external ties exist between the program & industry?

8. How many master's degrees do you award each area per year (on average over the last five years)?

9. How many inquires do you get about your program each year?

10. How many applications do you receive for your master's program?

11. Are applications to & enrollment in program growing/shrinking/stable over the last five years?

12. What sort of explicit recruitment efforts have or will be pursued?

13. Which of your requirement efforts gets the largest response?

D. Student Demographics, Support, and Mentoring

1. How many students do you have in your department?

2. What percentage of your students are domestic?

3. Percentage of your students returning to school five or more years after having received their undergraduate degree?

4. How do students support themselves?

TAs / RAs / Tuition Waivers / Fellowships / Employer-Sponsored

5. What sort of career consulting/mentoring is available/required?

E. Outcomes

1. How many master's degrees have been awarded in each area?

2. What percentage of your master's students go into industry?

3. What percentage of your master's students go into teaching?

4. What percentage of your master's students go on to Ph.D. programs?

5. Are detailed records kept of alumni and are they available?

Stage II Questionnaire

A. Program Recruitment

1. Where do your master's students primarily come from?

2. How effective is your website in attracting students?

3. Have students mentioned what specifically attracted them to your program?

B. Program Specifics

1. What is the composition of your advisory committee? (Specific names, if not confidential, as well as their affiliation, *e.g.*, company, lab, university, etc.)

2. How do students support themselves?

3. If your students carry out internships, which companies have they interned with?

C. Departmental Research & Connections with Industry

1. What are the main areas of specialization of your faculty?

2. What industries are located near your university?

3. Can you give me the names of specific companies, labs, etc. that your department has connections with and the nature of those connections?

D. Student Outcomes

1. Are your students generally getting employed locally, regionally, or nationally?

2. What are the names of the companies where they're securing positions?

3. Can you provide us with the names of some recent graduates so that we might contact them regarding their impressions of the program and how well it has prepared them to work in their chosen field?

Stage III: Alumni Questionnaire

A. Job Search

1. What were your major sources of job opportunity information?

   a. Ads in professional journals.
   b. Word of mouth via major professors.
   c. Word of mouth via peers.
   d. Job fairs at professional meetings.
   e. Contact developed as part of graduate training.
   f. Other (specify):

2. How, if at all, was your department involved in your job search?

3. If you had or are still having difficulty finding a job, to what do you attribute your inability to secure a position?

   a. Job was designed specifically for a particular person.
   b. Job was not really in your area.
   c. The present state of the economy and market.
   d. Characteristic not related to your ability (e.g., gender, race, etc.)
   e. Insufficient experience.
   f. Don't know.
   g. Other (please specify):

4. If you were coming out of graduate school now, what would you have done differently in searching for a job?

B. Preparation for a Career in Science/Industry

1. What sorts of skills did you derive from your scientific training that have proven valuable in preparing you to work in industry?

2. Was the curriculum in your program overly specialized or did it prepare you to work in a number of areas?

3. Did your program adequately prepare you for the field you intended to enter? If you did not intend to enter the field you are now in, did your program adequately prepare you to work in this field?

C. Satisfaction

1. What aspects of your master's program training do you find to be the most satisfying with respect to your career goals and achievements?

2. Are there aspects of your master's training that you are particularly disappointed by, given your experiences in industry?

D. Opportunities, Barriers, and Obstacles

1. Were there programs in place in your department that brought you into contact with members of industry?

2. Was your department's job placement program effective in finding you a job?

E. Respondent's Prescriptions for Future Change

1. What, if any, changes to your graduate master's degree program would you recommend?

Appendix 6: Carnegie Classifications

*The information in this appendix was copied from the Carnegie Foundation website at: http://www.carnegiefoundation.org/Classification/index.htm
For the most part, we have only included those categories mentioned in Appendix 4 of this report.

1994 Carnegie Classification Scheme

The 1994 Carnegie Classification includes all colleges and universities in the United States that are degree-granting and accredited by an agency recognized by the US Secretary of Education.

Research Universities I: These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate, and give high priority to research. They award 50 or more doctoral degrees each year. In addition, they receive annually $40 million or more in federal support.

Research Universities II: These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate, and give high priority to research. They award 50 or more doctoral degrees each year. In addition, they receive annually between $15.5 million and $40 million in federal support.

Doctoral Universities I: These institutions offer a full range of baccalaureate programs and are committed to graduate education through the doctorate. They award at least 40 doctoral degrees annually in five or more disciplines.

Doctoral Universities II: These institutions offer a full range of baccalaureate programs and are committed to graduate education through the doctorate. They award annually at least ten doctoral degrees-in three or more disciplines-or 20 or more doctoral degrees in one or more disciplines.

Master's (Comprehensive) Universities and Colleges I: These institutions offer a full range of baccalaureate programs and are committed to graduate education through the master's degree. They award 40 or more master's degrees annually in three or more disciplines.

Master's (Comprehensive) Universities and Colleges II: These institutions offer a full range of baccalaureate programs and are committed to graduate education through the master's degree. They award 20 or more master's degrees annually in one or more disciplines.

Baccalaureate (Liberal Arts) Colleges I: These institutions are primarily undergraduate colleges with major emphasis on baccalaureate degree programs. They award 40 percent or

more of their baccalaureate degrees in liberal arts fields and are restrictive in admissions.

Baccalaureate Colleges II: These institutions are primarily undergraduate colleges with major emphasis on baccalaureate degree programs. They award less than 40 percent of their baccalaureate degrees in liberal arts fields or are less restrictive in admissions.

Specialized Institutions:
These institutions offer degrees ranging from the bachelor's to the doctorate. At least 50 percent of the degrees awarded by these institutions are in a single discipline. Specialized institutions include:

Medical schools and medical centers: These institutions award most of their professional degrees in medicine. In some instances, their programs include other health professional schools, such as dentistry, pharmacy, or nursing.

Schools of engineering and technology: The institutions in this category award at least a bachelor's degree in programs limited almost exclusively to technical fields of study.

2000 Carnegie Classifications

Doctorate-granting institutions

Doctoral/Research Universities—Extensive: These institutions typically offer a wide range of baccalaureate programs, and they are committed to graduate education through the doctorate. They award 50 or more doctoral degrees per year across at least 15 disciplines.

Doctoral/Research Universities—Intensive: These institutions typically offer a wide range of baccalaureate programs, and they are committed to graduate education through the doctorate. They award at least ten doctoral degrees per year across three or more disciplines, or at least 20 doctoral degrees per year overall.

Master’s (Comprehensive) Colleges and Universities

Master’s (Comprehensive) Colleges and Universities I: These institutions typically offer a wide range of baccalaureate programs, and they are committed to graduate education through the master’s degree. They award 40 or more master’s degrees per year across three or more disciplines.

Master's (Comprehensive) Colleges and Universities II: These institutions typically offer a wide range of baccalaureate programs, and they are committed to graduate education through the master's degree. They award 20 or more master's degrees per year.

Baccalaureate Colleges

Baccalaureate Colleges—Liberal Arts: These institutions are primarily undergraduate colleges with major emphasis on baccalaureate programs. They award at least half of their baccalaureate degrees in liberal arts fields.

Specialized Institutions

Schools of engineering and technology: These institutions award most of their bachelor's or graduate degrees in technical fields of study.