Apr 28th, 2:00 PM

# Paper Session I-D - A Plan for Small Physics Departments for the Twenty-First Century

J. D. Patterson
*Physics and Space Sciences Department, Florida Institute of Technology*

J. H. Blatt
*Physics and Space Sciences Department, Florida Institute of Technology*

M. B. Moldwin
*Physics and Space Sciences Department, Florida Institute of Technology*

T. D. Oswalt
*Physics and Space Sciences Department, Florida Institute of Technology*

M. A. Wood
*Physics and Space Sciences Department, Florida Institute of Technology*

# A Plan for Small Physics Departments for the Twenty First Century

J. D. Patterson, J. H. Blatt, M. B. Moldwin, T. D. Oswalt, H. K. Rassoul, and M. A. Wood
Physics and Space Sciences Department, Florida Institute of Technology
Melbourne, FL 32901-6988

## I. Introduction

The plan for our department is to build on the natural attributes available to us. Because of the location near Kennedy Space Center, our program attempts to capture the excitement of the space age. We offer degrees at all levels in both Physics and Space Science. Our Space Science students learn both science and technology, while our Physics classes often use space as a topic to motivate the physics. As we have built our department we have attempted to make a seamless fit between subfields, while emphasizing where possible natural connections to space science. We specialize in integrating interesting applications in the fields of condensed matter, optics, astronomy, astrophysics, space physics and plasmas, while using fundamental physics as the glue.

In this paper we make general recommendations for physics departments based on certain guidelines which we list and discuss. We believe, consistent with current trends, that physics departments will need to adapt or they will suffer. Our guidelines do not suggest a unique department, but we have found that pure pragmatism doesn't work either in planning for a future in which funding and student enrollments are increasingly hard to preserve. We think that many physics departments need to start from the beginning and rethink what they are doing. In particular we need to learn how to involve ourselves in current societal goals, such as the space program, without giving up the core of our science. In order to test if our ideas are tenable we use our department for a case study where we describe our successes and major problems. Finally, we emphasize the usefulness of space science as a unifying theme for a basic science department such as physics.

In section II we state our basic guidelines concerning what constitutes a good, viable department. These guidelines are collected from experience and are certainly not handed down from on high. But they do form the core of any plans that we believe will work in the future. Following the guidelines, we make a case study of our department in which we describe what is working and what is not. In section III we describe what we are teaching. Sections IV and V are devoted to research. Section IV describes some of our scientific research areas, and section V lists the nuts and bolts of our research such as funding, graduate study, equipment, and space. Section VI describes our successes and major problems, and our summary will end the article in section VII.

## II. Basic guidelines

We regard this list as the key to the paper. We have listed those guidelines that are either especially important for our department, or that are relatively unique.

1. Basic physics is central because in a certain sense, all scientific work is based on physics. Further, much of physics is expressed in the language of mathematics, and so good math-

ematical skills, involving abstract concepts, cannot be compromised.

2. Astronomy and space physics, which deal with the real world, are natural areas in which to broaden a physics department. They are based in fundamental physics, they address large problems, and are often accessible and interesting to students. Space physics, in particular, is an area of broad training, and we are advised that breadth is important for the future.[1,2] Also, it is well to remember that interweaving modern topics with fundamental physics not only enlivens a class, but may aid understanding of the basic principles.

3. Service courses are important and they produce revenue. In many cases the service courses justify the existence of the department to the university community.

4. Students are interested in applying physics—but they are often attracted to physics so they can apply it to the really deep problems—not necessarily where we think they should be trained so they can get jobs. This makes the areas of specialization that a department chooses a difficult task. Wolf[2] notes that many, but by no means all, physicists agree on the definitions that pure physics is "primarily directed to understanding fundamental laws of nature," while applied physics is "primarily directed to understanding phenomena of interest for practical application." We would put a limit on this definition of applied physics, by requiring (somewhat loosely) that it include only work in which the problem is approached "like a physicist." We believe strongly that physics students must be trained more broadly than they have in the past. The breadth of problems that our students will undertake must be enlarged if our field is to thrive.

5. Students need to find jobs. We must advise students responsibly about the opportunities which are available.

6. Computers are essential, but rational use is necessary. It is too easy to fall into the trap of letting the technology dictate activities. On the other hand, one should not overlook the obvious efficiences in office work, writing, data collection, and computation that computers allow. Space Science is a natural area to teach computer skills including simulation.

7. All plans should be flexible. A department should be able to respond to external events. For example, economics will probably force us to provide more remote site learning experiences than some of us might like. We all need to be flexible enough to respond appropriately to external changes.

**III. Teaching**

Having put forth our essential guidelines, we begin our case study by reviewing who we are and what we are doing. The physics program at the Florida Institute of Technology dates to the founding of Florida Tech as Brevard Engineering College. Founder and President Dr. Jerry Keuper was a physicist who intended for the new college to provide the continuing educational needs of the growing local population of Cape Canaveral engineers. The physics department merged with the space technology department in 1972 producing the physics and space sciences department. The space sciences programs at Florida Tech thus have their roots in the space technology master's program that was offered in the first year of the fledgling Brevard Engineering College. Space sciences as taught at Florida Tech today is roughly one third each of physics, astronomy and space physics. The space sciences have been very useful in attracting students. As in physics, space sciences offers bachelor's, master's, and doctoral degrees.

Our physics and space sciences department presently has a total of eleven full time faculty. Some of our major areas of teaching are below.

Undergraduate Physics, Service Component: The service component of physics is at the core of all the engineering and sciences programs. At the undergraduate level, between 9 and 13 semester hours of physics and physics labs are taken by all engineers (and all science majors). The service component is absolutely necessary, and the mission of the university could not be carried out successfully if the basic physics courses and labs were not offered. Primarily because of service courses, we teach a lot. In 1996 we taught a total of 3745 semester credit hours. This was comparable to what the other large physical science department that teaches service courses taught (chemistry at 3788).

Well over a million dollars in tuition per year is paid by the students for just these introductory courses. The importance of this figure is evident when it is compared to the overall yearly departmental budget which is about $600,000. We teach introductory physics in the traditional way, but we try to sprinkle in some “modern” topics whenever appropriate. We do not believe students should have to wait until modern physics courses before they encounter any

topics from 20th century physics. We also believe, of course, that students must master the fundamentals.

Undergraduate Physics Major: We offer a standard undergraduate physics major. Abraham et al. [3] has pointed out that Physics Department curricula are remarkably uniform—and we are not an exception. There has been a constant tension in our planning imposed by our desire to have our program be both complete and rigorous, as well as flexible. Flexibility allows students to include electives in fluid mechancs, continuum mechanics and other engineering subjects. Completeness would probably indicate more quantum mechanics and relativity.

Space Sciences: This curriculum is quite broad, and we believe it has a particularly important future. Space science students learn both science and technology. It is also interesting that developing countries have been attracted to space science programs, possibly using space as a theme to help teach science and mathematics, as well as developing a space program (which may or may not be needed).

Astronomy and Astrophysics: This space sciences option is more focused than the more general space sciences degree. One of the lessons we learned from introducing this curriculum was that to attract students we need to be able to excite them. To our surprise, more students enrolled in this option than we expected. We also feel that it is useful to have physicists as well as astronomers and space scientists engaged in this program.

Interdisciplinary Science: This is an *ad hoc* addition which allows great flexibility in pursuing a degree. It has been most popular with military science students who are interested in science, management tools, and perhaps business. It is not limited to students with physics or space science interests.

Table I shows the number of majors for the total department during the last six years. It is obvious that our numbers have decreased; however they are still relatively large. Langenburg[4] has stated that the typical physics department graduates about 10 students per year. If we include graduate students, and limit ourselves to physics, we average a little less than that; if we include space sciences, we average somewhat more than ten. Combining physics and space science (including astronomy) seems to work well for us, as it attracts a number of students interested in parts of the space program, and thus increases the number of our majors while broadening the kinds of courses we can offer. Largely due to the space sciences program, our enrollment tracks the success of NASA. Table I breaks down our student numbers into categories. The table makes it clear that, unfortunately, we are following recent national trends,[5] e. g. the number of our graduate students, as measured in the Fall of each year, is plunging. However, with space sciences, we are still a sizable department. Space sciences has declined a little, but it is still larger than physics (which has increased). Overall, we have some reason to hope that the numbers are starting to increase. Table II summarizes the bottom line, namely the number of graduates we have had in several categories. The numbers are not large, but they are healthy, especially considering that nationally, the number of physics bachelors hit a 30-year low in 1996. [5] In Table III, we document general areas where our graduates have gone. This chart is particulary useful when parents of potential students visit and ask whether there are jobs to be had if their children major in our department. The answer is yes, but careful planning is essential. Consistent with the national average, a little more than one-third of our graduating seniors go to graduate school (more in physics than space sciences).

## IV. Areas of Current Specialization

We are a private university located near the Kennedy Space Center, and so we have tried to weave a departmental tapestry involving space science in many different areas. Our work in astronomy and space science obviously connects with the space program. Even in solid state physics we have areas related to photovoltaics (which can be used to power intruments used in space) and ideas involved in characterization of crystals, particularly those grown in space. Although the precise areas in which we specialize are partly due to happenstance, we have tried to remain consistent in having basic physics as central, then broadening into several related areas of current interest, while maintaining a seamless fit across the department. This idea, together with developing areas natural for the region, should be transportable to any department. Even within the theme of space science however, there are many other ways to implement the basic plan. Our choice of niche area involves not only those that should be productive scientifically, but also those that should attract students. We have learned the hard way that the two are not always identical. We list below the areas in which we either do research or have special activities.

### Physics and Applied Physics

- Solid State Surface Physics—scanning probe microscopy.
- Solid State Nanophysics—electrochemical deposition of semiconducting thin films, including superlattices, for use in improved photovoltaic solar cells
- Theoretical Solid State—analyzing crystals grown in space—defect properties of narrow gap semiconductors as well as their characterization.
- Applied Optics and Machine Vision—applied to automated inspection, medical technology, space operations, and law enforcement.

### Astronomy and Astrophysics

- Observational Astronomy — photometry and spectroscopy of white dwarf and lower main sequence stars.
- Computational Astrophysics — white dwarf evolution and pulsation.
- SARA 0.9-m Observatory at Kitt Peak National Observatory.
- The SARA-REU Summer Intern Program is funded by the NSF Research Experiences for Undergraduates Site Program.

### Space Physics and Geophysics

- Development of magnetometer array from Florida to Canada—to study magnetic energy propagation through the earth's magnetosphere.
- Study of aurora from Greenland— utilizing upper atmospheric research facilities located in Greenland.
- Study of near earth space from satellites.
- Study of upward lightning from Kennedy Space Center—and a student project aboard the space shuttle in NASA's Get Away Special (GAS).

### Physics Education

- Virtual instrumentation

## V. Research, Graduate Studies, and Funding

There are at least two important aspects of the graduate program. One is academic. The other refers to research, i.e. what research areas are active, what financial support, laboratory, and equipment facilities are available. Offering as many programs as we do, it is a constant battle not to spread ourselves too thinly; for example, we have very little in the way of separate courses or seminars for Ph.D. students. One possibility is to move increasingly toward graduate study in only space sciences (or at least to have only one master's and one Ph. D. degree) and to hire faculty with at least bachelor's training in physics, but with a Ph. D. in astronomy, astrophysics, space physics, geophysics, or even electrical engineering (applied optics, or physical electronics). Such faculty, if carefully chosen, could teach much of the undergraduate physics curriculum while doing research in their own related areas.

Per year, per faculty member we average about $50K of externally funded research, and about 1 to 2 papers in major refereed journals. The distribution per faculty member is not uniform for either grant funds or publications, nor should it be, necessarily.

We have several laboratories where students may do thesis and dissertation work. These include (1) the applied optics laboratory, (2) the geospace physics laboratories, (3) the astronomical image processing laboratory, (4) the nanoscale materials fabrication and characterization laboratory, (5) the scanning probe microscopy laboratory, and (6) the SARA Observatory at Kitt Peak.

## VI. Successes and Major Problems

Over the past decade we have faced four major problems from which many others have flowed. These major problems are: (1) a reorientation of the direction of the University from that of a primarily teaching institution to that of a more balanced teaching and research institution, (2) a fairly large increase in tuition phased in over several years, (3) several years of ever tightening budgets, and (4) a declining number of potential students for science.

Our major successes have probably been in the area of good teaching. Good teaching on the upper division level is enhanced by small class size. We feel we have developed a solid comprehensive curriculum, and we are pleased with the electives that are available to our majors. For example, good astrophysics courses are available to physics majors, and we have been able, with some administrative difficulty, to develop interdisciplinary courses with the oceanography department as well as to offer some classes at Cape Canaveral Air Station and the Kennedy Space Center with engineering departments from the University of Central Florida. Also indicative of good teaching is the fact that we have a good record of placing our graduates, particularly at the bachelors level.

Another success we should mention is financial. Consider FY 97 as an example. Our total teaching credit revenue is approximately $1.918 million which is a healthy revenue to expense ratio (as measured by the budget) of over 3. Of these revenues, $1.644 million are due to physics and $0.274 million are due to the space sciences. Notice that although space sciences accounts for the majority of our majors (see Tables I and II), physics accounts for the majority of our teaching revenues (because of the service courses). Notice also that our revenues are considerably greater than our expenses, not even counting the approximately $500,000 in book value research. Even allowing for additional overhead expenses, we are clearly a “cash cow” for the university.

If we are constantly beset with problems, as all physics departments seem to be, we believe we are reasonably successful. We have built a department of which we are proud, and we have survived. We believe this is for two reasons, (1) we have used our smallness as an advantage by remaining collegial, (2) we have welcomed into our tent a fairly broad array of scientific interests.

**VII. Summary**

The only thing that can be predicted is that the future will bring change and that institutions who are prepared to manage change will fare better than those that are not. An important aspect of managing change is to have, more or less, universal standards and ideals towards which we steer our course. Perhaps our biggest success is in our undergraduate programs, although even here, attracting good students and maintaining standards is a constant challenge. In our graduate programs, we are probably stretching for too much and, as mentioned below, we may have to narrow and sharpen our focus to remain competitive. We suspect this problem will resonate with many departments.

We believe our quality is nearly optimized for the constraints under which we operate, thus we can only obtain better quality if some of the constraints are removed. In our case, an important constraint is the monetary support we receive from the school. For example, our graduate program is inadequately supported, suggesting the possibility of decreasing the number of graduate programs, so that they can be more focused in niches (perhaps in the space sciences) where we can compete more effectively. Unless the present situation changes it is likely that this is a direction we will need to take. If we do go this way, it is crucial that the resulting graduate programs both attract students and train them in areas where there are jobs.

**Acknowledgments**

Dr. Randy Alford, Associate Dean of the College of Science and Liberal Arts, has read this paper and offered advice as has Dr. Nabil Matar, of our Humanities Department. Dr. Wes Unruh, a former colleague with a variety of experience, and Dr. T. E. Bowman, Associate Vice President for Academic Affairs have been extremely helpful with suggestions. All members of the Department have helped in one way or another we would expecially like to thank Dr. Jay Burns.

**References**

1. Sol M. Gruner, James S. Langer, Phil Nelson, and Viola Vogel, “What future will we choose for physics?”, *Phys. Today* 48 (12), 25-30 (1995).
2. Werner P. Wolf, “Is Physics Education Adapting to a Changing World?” *Phys. Today* 47(10), 48-55 (1994).
3. Neil B. Abraham, James B. Gerhart, Russel K. Hobbie, Lillian C. McDermott, Robert H. Romer, and Bruce R. Thomas, “The undergraduate physics major,” *Am. J. Phys*. 59 (2), 106-11 (1991).
4. Donald N. Langenberg, “Physics: A Personal Perspective,” *Phys. Today* 47 (12), 42-46 (1994).
5. “ Graduate Enrollments in Physics and Astronomy Plunge,” *Phys. Today* 50 (6), 76(1997).

==================================================================

**Table I.** Physics, Space Sciences, Astronomy and Astrophysics, and Interdisciplinary Science Numbers.

| | B.S. | M.S. | Ph.D. | Total | Percentage |
|---|---|---|---|---|---|
| 1991 Physics | 15 | 4 | 3 | 22 | 20 |
| 1991 Sp. Scien. | 70 | 16 | 2 | 88 | 80 |
| | GRAND TOTAL | | | 110 | |
| 1992 Physics | 15 | 4 | 3 | 22 | 27 |
| 1992 Sp. Scien. | 46 | 11 | 3 | 60 | 73 |
| | GRAND TOTAL | | | 82 | |
| 1993 Physics | 20 | 4 | 4 | 28 | 38 |
| 1993 Sp. Scien. | 33 | 8 | 5 | 46 | 62 |
| | GRAND TOTAL | | | 74 | |
| 1994 Physics | 25 | 9 | 3 | 37 | 46 |
| 1994 Sp. Scien. | 34 | 8 | 2 | 44 | 54 |
| | GRAND TOTAL | | | 81 | |
| 1995 Physics | 17 | 5 | 0 | 22 | 29 |
| 1995 Sp Scien. | 39 | 8 | 1 | 48 | 65 |
| 1995 In. Scien. | 4 | | | 4 | 5 |
| | GRAND TOTAL | | | 74 | |
| 1996 Physics | 16 | 3 | 2 | 21 | 30 |
| 1996 Sp. Scien. | 28 | 5 | 2 | 35 | 51 |
| 1996 In. Scien. | 5 | | | 5 | 7 |
| 1996 Astro. | 8 | | | 8 | 12 |
| | GRAND TOTAL | | | 69 | |

==================================================================

**Table II**. Total Number of Departmental Graduates 1992-1996.

| | Undgr. | Graduate | Total | Percentage |
|---|---|---|---|---|
| Physics 1992 | 3 | 4 | 7 | 44 |
| Sp. Scien. 1992 | 7 | 2 | 9 | 56 |
| | | GRAND TOTAL | 16 | |
| Physics 1993 | 5 | 4 | 9 | 36 |
| Sp. Scien. 1993 | 10 | 6 | 16 | 64 |
| | | GRAND TOTAL | 25 | |
| Physics 1994 | 3 | 1 | 4 | 31 |
| Sp. Scien. 1994 | 6 | 3 | 9 | 69 |
| | | GRAND TOTAL | 13 | |
| Physics 1995 | 3 | 7 | 10 | 59 |
| Sp. Scien. 1995 | 6 | 1 | 7 | 41 |
| | | GRAND TOTAL | 17 | |
| Physics 1996 | 6 | 1 | 7 | 32 |
| Sp. Scien. 1996 | 9 | 3 | 12 | 55 |
| Astro. 1996 | 1 | | 1 | 4 |
| In. Scien. 1996 | 2 | | 2 | 9 |
| | | GRAND TOTAL | 22 | |

================================================================

**Table III**. Location of our Graduates for the year 1989-1996.

| | No. | Tot. Doc. | Grad. Sch. | Ind. | Gov. | Ed. | Other* |
|---|---|---|---|---|---|---|---|
| B.S. Physics | 27 | 19 | 14 | 1 | 3 | 0 | 1 |
| B.S. Sp. Sci. | 76 | 53 | 24 | 7 | 4 | 1 | 17 |
| B.S. Astro. | 1 | 0 | | | | | |
| B.S. Int. Sci. | 2 | 1 | | | 1 | | |
| M.S.-Ph.D. Phy. | 30 | 30 | 11 | 6 | 0 | 6 | 7 |
| M.S.-Ph.D. S.S. | 30 | 29 | 8 | 12 | 0 | 5 | 4 |
| TOTAL | 166 | 132 | 57 | 26 | 8 | 12 | 2 |

*Employed, but in a miscellany of occupations