The End Of Physics ? (As We Know It)

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Other authors have discussed the impact of the end of the Cold War, with shrinking defense budgets, and the problems caused by attempts to cut the Federal budget deficit, on the level of funding for physics research and the problems new Ph.D.s in physics have in finding jobs in their field.[1,2] It is even possible to look at the longer term problem caused by past projections, which were unrealistic, for continued high growth of support for science in general.[3] Rather than look at the current problems as part of a temporary cycle of funding, there has likely been a fundamental change in some of the areas considered the frontier areas of physics, especially high energy particle physics.

Of the $171 billion spent on R&D in the U.S. in 1995, $29.6 billion was spent on basic research, with the Federal government supplying 58% of the funding for basic research.[4] With the pressure of reducing the budget deficit, this Federal funding has to be considered at risk and there will likely be a continuing shift to more applied research. Even the National Science Foundation allocates 10% of its proposed 1997 budget to research in engineering.[5] However, the linkages between physics and commercial and military applications has historically been the norm, rather than the exception.

As the information in Table 1 amply demonstrates, there has often been a fairly short span of years, at the most several decades, before fundamental physics research has led to applications of either commercial or military significance. In some cases, such as the development of electric motors and generators, the applications preceded the discovery of the fundamental processes, such as the discovery of the electron. Hence, those of us who teach electrical engineering and electrical engineering technology must deal with the fact that conventional current flow is opposite to the electron flow. Other examples are shown in Table 1.

The 1993 cancellation of the Superconducting Super Collider can be viewed as a major milestone in this shift of the support for major science projects, where incidentally about half of the physicists on the project had to take jobs outside their field.[6] This cancellation is less suprising if you consider that it has been 60 years since the invention of the cyclotron[7] and in that time no siginificant commerical or military application has been produced. The lack of any direct benefit from this project, or even any reasonable expectations of any direct benefit had an obvious affect on its cancellation. If you want better superconducting magnets, for example, then that is what you fund, not a multi-billion dollar project was such magnets as an indirect benefit.

For all of the reasons listed above, science in general, and physics specifically is likely to go through a period of “globalization” and “downsizing” comparable to the restructuring that has taken place in American business. The transition is likely to be messy.[8] The basic idea of this paper is to see if some of the approaches used by successful businesses might be applicable.

For example, in his book, Thriving On Chaos," Tom Peters concludes that excellence and dedication to quality alone are not enough and that the successful company of the future will have the following characteristics:[9]

- flatter (fewer layers of organizational structure)
- populated by more autonomous units (more local authority)
- oriented toward differentiation, niche markets
- quality conscious
- service conscious
- more responsive
- much faster innovation
- highly trained, flexible people as the principal means of adding value.

The idea of flatter organization with more autonomous units is key to the idea of faster innovation and is obviously at odds with the Byzantine structure and operations at most research universities and the similar structure in the government agencies that fund their research. Change in these areas is likely to be beyond the control of the individual researcher or even the physics department chair. However, change in this area is may come to both universities and government as they respond to financial pressures.

The idea of niche marketing may not seem as applicable to physics research, but at its most basic, niche marketing comes down to specialization. In business, it means the decision to focus on a particular segment of the business, rather than a broad approach. The decision is similar to the idea of retailing only clothes for young people rather than competing with Sears or Wal-Mart on a broader level. For a physics department this may mean a decision to emphasize, and excel at, a few area of physics, such as a particular sub-filed of condensed matter physics, rather than have groups in seven or eight major fields of physics research ranging from condensed matter, nuclear, to particle physics. A truly excellent center for particle physics is more likely to survive the future budget crunches than a mediocre department in a popular area, such as condensed matter physics. Another issue in product differentiation, relates to the calls for broadening the education of Ph.D. in physics.[10] The problem is that if you broaden the education too much, there will be little to differentiate a Ph.D. in physics from one in engineering, which raises the question of why have the physics graduate program in the first place.

It is in the area of customer service that the interaction with engineering becomes the most obvious. The engineering department at most universities is the largest customer for the physics department. At Penn State, for example, about half of the students in the freshman-sophomore physics courses are engineers. It will be very important for physics department and engineering departments to cooperate on the physics education for engineers. At Penn State, there is currently a joint task force looking at making major changes in the physics curriculum for engineering students. Physics departments which fail to realize their teaching/service mission will find the transitions of the next few decades even more difficult.

In the U.S. automobile industry, the failure to adapt to a new situation almost led to disaster and collapse in some cases.[11] In a similar fashion, the world of physics is changing and those physics department which move quickly to respond to this changing environment will be successful, and those that do not should not expect a Chrysler style bail-out to save them. The end of physics? Not really. But the end of physics as it has developed since the 1940s and during the Cold War? Very likely.

TABLE 1

TRANSITIONS FROM PHYSICS DISCOVERIES TO
COMMERCIAL/MILITARY APPLICATIONS

Steam Power		
	1769	The Steam Engine(Watt)[12]
	1824-1854	Early Thermodynamics(Carnot,Thomson,...)[13]
	1884	Steam Turbine(Parsons)[14]
Electric Power		
	1831	First Transformer(Faraday)[15]
	1860s	Early Motors/Generators(Wilde,Siemans,Wheatstone,...)[16]
	1879	Electric Light(Edison)[17]
	1897	Electron Discovered(Thomson)[18]
X-Rays		
	1895	X-Rays Discovered(Roentgen)[19]
	1896	Medical Use Of X-Rays[19]
Nuclear Power		
	1897	Radioactivity Discovered(Bequerel)[20]
	1898-1900	Radium Extracted(Curies)[21]
	1911	Nucleus Discovered(Rutherford)[22]
	1942	Controlled Chain Reaction(Fermi,...)[23]
	1945	Atomic Bomb[24]
	1956	First U.S. Commercial Nuclear Power Plant[25]
Radio		
	1870	Maxwell's Equations[26]
	1887	Hertz's Experiments[26]
	1895	Marconi's First Broadcast[27]
Electronics/Lasers		
	1897	Electron Discovered(Thomson)[18]
	1901-1936	Early Quantum Mechanics (Plank,Einstein,Bohr,Heisenber,Schroedinger,Dirac,...)[28]
	1906	Vacuum Triode(DeForest)[29]

1948	Transistor(Schockley,Bardeen,Brattain)[30]
1960	Laser(Maiman)[31]

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