Such a view of applied research is not necessarily accurate—even when it concerns problems outlined by Crewe.

The terms "applied' and "basic" appear to have become associated with "directed" and "undirected." The distinction lies in whether specific goals are to be attained within a definite time interval. In the extreme, directed research may have dictated in advance the tactical approach to a problem and the kind of results desired. Conversely, undirected research in the extreme may be totally devoid of long-range planning. Most research falls between these two extremes. This fact blunts the distinction between applied and basic research. The question, then, is how much applied research should be pursued. For example: Is applied research appropriate to either a master's thesis or a doctor's dissertation?

Applied research is not the easiest kind of research. Usually research must be completed within a specified time interval; consequently the plan of attack must be carefully considered. Applied problems involve usually more than one area and often more than one discipline. The results of such investigations and their significance must be communicated accurately and clearly to persons unknowledgeable in the scientific and technical aspects of the problem. To be adequate to these demands the researcher must have intuitive foresight, breadth of outlook and depth of understanding. These attributes are the basis on which the skill of precise thinking can be developed. They are the same attributes we hope to see in our graduate students. From these considerations, applied research may furnish appropriate problems for graduate research in, for example, physics—or any of the natural sciences.

R. Hobart Ellis Jr's editorial in the same issue suggested very realistic economic motives for pursuing applied research. There are equally realistic educative motives for the judicious acceptance of applied research as appropriate to graduate programs in the natural sciences.

SCHWAB S. MAJOR JR
University of Missouri at Kansas City

Cutting NBS budget

The cut, by Congress, of the budget of the National Bureau of Standards (PHYSICS TODAY, August, page 51) accentuates the peril that has threatened this valuable institution for quite some time. Whether the present stress on mission orientation is justified or not, it appears reckless to sacrifice to it a service of such importance to the scientific community for a gain of just $7.8 million (!).

Your story attributes this continuous misery to the lack of skill of NBS experts in expressing themselves to congressional committees. It appears to me that both Congress and the NBS dispose of plenty of witnesses, expert in science as well as communication, who could testify for the quality of men and topics sacrificed by this ruthless and petty decision.

NORBERT J. KREIDL
University of Missouri at Rolla

Baccalaureate Origins of PhD's in Physics

The "State and Society" section of the August PHYSICS TODAY published a report, "NAS Data Give Baccalaureate Origins of PhD's in Physics," stating that of all US students who earned PhD's in physics during 1958–66, 70% received their bachelor's degree from PhD-granting institutions, 19% from MS-granting institutions and 11% from four-year institutions. This report cites earlier data from M. Hugh Trytten, National Academy of Sciences, which indicate that in 1936–45 four-year colleges had been the origin of 35% of the 1160 physics PhD's. It continues with a discussion of "causes of decline," and concludes that four-year colleges now produce only about 11% of *future* physics doctorates.

Is there a decline in physics PhD's with baccalaureates from four-year or undergraduate colleges? Intelligent answers to questions related to the role and importance of various types of educational institutions require more than a superficial treatment. Analysis is not as simple as the PHYSICS TODAY report assumes. Several points should be considered: (1) It is not possible *in principle* to determine the present importance of various types of educational institutions, as baccalaureate

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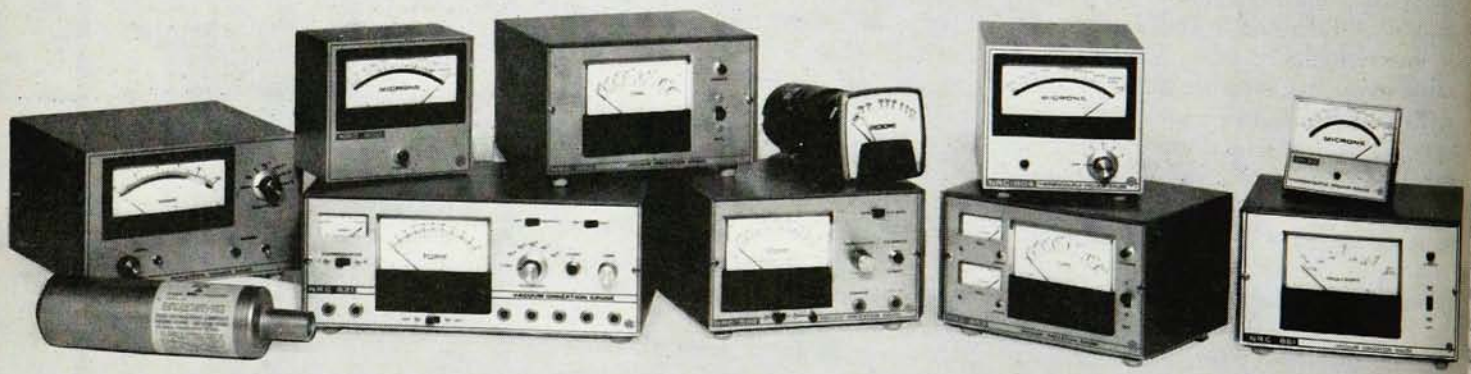

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sources of *future* PhD's in any field, from baccalaureate-source information on doctorates previously awarded; (2) baccalaureate-source data on doctorates awarded can reveal *only* what has happened at some time in the past and will always be at least as many years out of date as the time from baccalaureate to doctorate. Past trends could be projected into the future to estimate the percentage of physics doctorates n years from now who earned baccalaureates in various type of educational institutions in a current year. However even this approach would be quite speculative because of the almost violent state of flux of the higher educational system in the US in recent years (certainly including the 1958–66 period of the NAS study). Because of this dynamic educational situation, a classification of academic institutions in one year generally will not reflect the status of these same institutions several years later. Furthermore new educational institutions may be omitted entirely when using this method.

The PHYSICS TODAY report was based on characteristics current in 1960; that is, all institutions with one or more doctoral programs in *any field* are included as PhD-granting schools. Master's-granting schools include all those institutions, not in the PhD-granting group, with one or more master's programs in *any field*. All other baccalaureate-granting institutions, not included in either the PhD-granting or the MS-granting groups, were classified four-year colleges. This institutional classification scheme is extremely heterogeneous within each of the three groups. Both the PhD's and master's groups include institutions with generally little or no graduate work in science or more specifically, in physics. Therefore this type of classification may not be relevant for a study of baccalaureate sources of physics doctorates. Assuming an average of six years from baccalaureate to doctorate, doctorates awarded in 1958–66 would have received baccalaureates in 1952–60. Thus selection of 1960 as the base year for classification of *baccalaureate* institutions of the 1958–66 doctorates in physics is inappropriate. In fact, the baccalaureate institutions were changing so rapidly in 1952–60 that use of any one year for classification of academic institutions may seriously distort the analysis.

An alternative method providing a better insight into the problem is based on the following analysis of NAS data:

- Most physics PhD's have an undergraduate physics degree (according to the 1958–66 NAS statistics, three-fourths had earned bachelor's in physics). For studying undergraduate sources, classification of institutions could most reasonably be based on the type of physics program available at each institution.
- Because of the flux in academic institutions with time, any classification system should not be used more than one or two years.
- The base time actually selected for classification of institutions should reflect the characteristics of those institutions, as closely as possible, relevant to the study.

Using these principles I have examined the baccalaureate sources. Baccalaureate institutions were classified according to the type of physics program available. Doctorates awarded during 1965–66 (the most recent data available from NAS studies) were studied and baccalaureate institutions were characterized from the *Directory of Academic Physicists, 1959–1960*. This provides a base time approximating that when the baccalaureates were awarded (analysis was restricted to US citizens). The results in table 1 show that about one quarter

Table 1. Baccalaureate Origins of Physics PhD's, 1965–66

Origin, 1959–60	*Number of PhD's**	*Fraction (%)*
Doctoral physics institutions	1113	63.2
Master's physics institutions	190	10.8
Physics major program	402	22.9
All others	55	3.1

* 34 US citizens awarded PhD's where baccalaureate origins are unknown or are from defunct schools are omitted.

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of recent physics PhD's received undergraduate training at institutions that, at the time of the undergraduate work, *did not* have graduate physics programs. Also many master's programs are at institutions that are predominantly undergraduate. Accordingly, the statement, "based on NAS data, four-year colleges will provide only 11% of future physics PhD's," is highly speculative and will probably not be borne out by future events.

Undergraduate enrollments have increased at different rates in different types of institutions. Undergraduate enrollment increases should, therefore, be compared with science-doctorate contributions for various types of institutions. This has been done recently by Albert B. Stewart (physics department, Antioch College). The results are in table 2.

These statistics do not give a complete picture, and physics is not explicitly identified. However *all* undergraduate colleges have increased their number of science doctorates by a greater percentage than their enrollments have increased. In most cases the number has risen more in biological-science doctorates. In contrast, *leading* baccalaureate sources of doctorates have grown more rapidly in undergraduate enrollments than as baccalaureate sources of doctorates in science. Their contribution to physical-science doctorates in contrast with biological sciences has increased a good deal more. Technical institutions are more similar to undergraduate colleges, with much larger source increases than enrollment increases. Their contribution to physical-science doctorates has risen much more than that to biological sciences. These statistics certainly present a different and far more favorable picture of undergraduate institutions as doctorate sources than that indicated by the PHYSICS TODAY report.

ROBERT H. LINNELL
National Science Foundation

Table 2. Increases in Science-Doctorate Origins and Enrollments (%)

	*Increase as source of science PhD's**			
Type of institution	*Physical sciences*	*Biological sciences*	*All sciences*	*Undergraduate enrollment increase Fall 1951 to Fall 1958*
Great Lakes College Association[a]	+47	+46	+47	+22
Associated Colleges of the Midwest[b]	+81	+107	+88	+16
Central States College Association[c]	+22	+76	+56	+41
Three regional groups[d]	+64	+125	+82	+8
Leading private liberal arts colleges[e]	+59	+90	+68	+11
Leading sources of PhD's[f]	+40	+12	+30	+36
Leading technical institutions[g]	+98	+33	+93	+20

* Baccalaureate sources of PhD's awarded in 1950–59 as opposed to those awarded in 1961–65. The latter were multiplied by two and the percent increase then calculated.

[a] Albion, Antioch, Denison, DePauw, Earlham, Hope, Kalamazoo, Kenyon, Oberlin, Ohio-Wesleyan, Wabash, Wooster

[b] Beloit, Carleton, Coe, Cornell (Iowa), Grinnell, Knox, Lawrence, Monmouth, Ripon, Olaf

[c] Alma, Augustana, Carroll, Gustavus Adolphus, Illinois-Wesleyan, Luther, MacMurray, Manchester, Millikin, Mundelein, St. John's (Minn.), Simpson

[d] Amherst, Mount Holyoke, Smith, Bryn Mawr, Haverford, Swarthmore, Pomona, Occidental, Redlands, Whittier

[e] Oberlin, Dartmouth, Swarthmore, Amherst, Reed, Wooster, Vassar, Union, Wellesley, Mount Holyoke

[f] California-Berkeley, CCNY, Illinois, Chicago, Wisconsin, Harvard, Minnesota, Michigan, Columbia, Cornell

[g] MIT, Cal Tech, Carnegie, Rensselaer, Rice, Lehigh, IIT, Brooklyn Polytech, VPI, Case Inst.

A CORRECTION: PHYSICS TODAY stated my address incorrectly in September. Since June 1966 I have been an associate professor of astronomy at the University of Arizona, Tucson and in the Lunar and Planetary Laboratory.

ELIZABETH ROEMER