COLLEGE and UNIVERSITY RESEARCH in PHYSICS

By John I. Mattill

THE IMPACT of the current national defense effort on scientific education has been the subject of wide concern in colleges and universities. An important part of this problem—and one which especially concerns physicists—is the colleges' growing participation in research.

A recent study of college and university research resources by the Engineering College Research Council gives ground for optimism: though some institutions may be overtaxed, all have resisted temptations to abdicate their basic educational purposes. Indeed, the present needs for research provide a remarkable opportunity to broaden college and university research experience and so to capitalize more fully on the many benefits it bestows.

Physicists are at the center of this problem, since they are responsible for more college defense research than scientists in any other field. Research in physics, not including electronics, accounts for nearly 20% of all government-sponsored research in the engineering and physical sciences in American colleges and universities, according to figures from the ECRC survey. Electronics, much of which represents the work of physics faculty members, accounts for another 10% of the total.

Three out of five physicists on college and university faculties now have some kind of research projects underway. These studies—and the graduate-level teaching and administration associated with them—take somewhat more than half the time of those faculty members involved. A full-time research staff of over 850 senior workers would be needed to equal the research effort this represents.

Yet there remains room for still more research without sacrificing teaching in many physics departments. Today, with an urgent need for all scientific and technical studies, the problem is to find and fill the holes in this national pattern of physics research activity.

The research potential study covered all physical and engineering sciences. Physics ranked second on the list, with more qualified faculty members and graduate students and with more research underway than in any other field except chemistry. In all, over 24,000 faculty members and an equal number of graduate students were reported. Physicists numbered 10% of the faculty and 14% of the graduate students.

The survey project was undertaken by the Engineering College Research Council, a unit of the American Society for Engineering Education, at the suggestion and with the cooperation of the Department of Defense Research and Development Board. It was completed under the direction of the Research Council's Committee on Relations with Military Research Agencies, of which Dean A. F. Spilhaus of the University of Minnesota is chairman.[1] The first report of results was made by Dean Spilhaus at the 1951 annual meeting of the ASEE.[2]

To compile a national inventory of college and university research potential, the Committee sought data from all four-year educational institutions on the numbers of faculty available, their present research commitments, and their special interests and qualifications. Though aware of the shortcomings of the questionnaire process, the Committee adopted that method as being the only possible way to meet the recommended time schedule and to yield data suitable for mechanical processing and comparison.

Only 250 of the nation's 1000 four-year colleges and universities failed to make specific reports on personnel, present research commitments, and special interests. An informal review of this list of schools from which no replies were received suggests to the committee that "substantially all" of the national potential for research in colleges and universities in the physical and engineering sciences is reported.

Of the 750 colleges replying, 513 listed personnel qualified for research in one or more of the physical and engineering sciences. The remaining 237 replied that their staffs were not active in any of these fields. The totals, from the 513 schools, are given in Table 1. In summary, they show:

1. Nearly 25,000 faculty members in all physical and engineering sciences.
2. Of these 20,000 are considered qualified to participate in research.
3. At least 12,700 of these are now active in research.

[1] Members of the Committee, in addition to Dean Spilhaus, are Dr. A. P. Colburn, University of Delaware; Dean W. L. Everitt, University of Illinois; Professor F. B. Farquharson, University of Washington; Dr. C. W. Good, University of Michigan; Dr. Paul E. Klopsteg, Northwestern University; President J. R. Van Pelt, Montana School of Mines; and Dean Eric A. Walker, Pennsylvania State College. Dr. Gerald A. Rosselot, Georgia Institute of Technology, is chairman of the Council.

[2] Spilhaus, A. F., and Mattill, John I., "Summary of Resources for University Research," *Journal of Engineering Education*, Vol. 42, No. 5 (January 1952), pp. 270–97.

	Total number of faculty and full-time research personnel	Number of (A) considered qualified to do research	Number of (A) now engaged in research	Number of full-time research workers to which (C) is equivalent	Number of research workers in (D) now engaged in research for national defense	Number of graduate students and assistants now engaged in research	Number of full-time research workers to which (F) is equivalent
	A	B	C	D	E	F	G
Aeronautical Engineering	652	597	437	289.7	236.8	566	284.2
Astronomy	279.3	246.8	159.8	105.3	39.5	225	130.1
Ceramics	216	200	156	108.8	42	215	122
Chemical Engineering	735.5	701.5	564	279.8	99.4	1699	807.4
Chemistry	3711	3319.5	2435.7	1316.1	506.2	6949	3468.4
Civil and Sanitary Engineering	1698	1429	654	313.6	112.1	936	443.1
Earth Sciences	1447.8	1322	964.2	452.4	172	2086	861.5
Electrical Engineering	1497	1237.5	601.5	288.1	219.1	1125	456.5
Electronics	1119.4	1032	625.6	387.2	313.8	1107	557.8
Food Technology	755.2	634	420	272.6	52.6	692	346.7
Industrial Engineering	535.5	421	173.5	77.1	14.1	352	108.9
Marine Engineering	78	71	35	17.7	12.5	24.2	13.9
Mathematics	3297.3	2261.8	1167.3	570	209.3	1496	640.7
Mechanical Engineering	2002.5	1660.5	716	327.1	150.5	1119.5	434.5
Mechanics	963.7	820.5	424.7	213.3	119.3	557.2	244.6
Metallurgical Engineering	487.5	458.5	349.2	187.6	131.7	757	387.7
Mining Engineering	135.5	128.5	82	44.4	11	129	50
Petroleum and Fuels Engineering	209	195	112	72.7	12.5	197.2	81.7
Physics	2628.4	2271.9	1546	866.6	609.3	3392	1562.1
Psychology and Human Resources	2432.4	2029.2	1242	554.7	227.1	3161.5	1141
TOTALS	24881	21037.2	12865.5	6744.8	3290.8	24785.6	12142.8

Table 1. More defense research is now being carried out in physics than in any of the other physical or engineering sciences, according to these figures compiled by the Engineering College Research Council.

4. An average of 27% of all faculty time is spent on research.

5. At least 45% of this research time is already devoted to defense projects—studies sponsored by military agencies, the Atomic Energy Commission, or their industrial contractors.

"Putting these figures another way," Dean Spilhaus pointed out, "of the 25,000 faculty members reported, one-half are active in research; these spend about one-half of their time in research, and one-half of this is devoted to military research. This means that one-eighth of the total college effort in these fields of engineering and physical sciences is already devoted to defense research."

More research is now underway in chemistry than in any other of the engineering and physical sciences. But physicists lead in the realm of defense research, with chemistry second. Together, chemistry and physics account for one-third of the defense research total; nearly one-half is in the three areas of chemistry, physics, and electronics. "This," the Committee report notes, "is convincing evidence that colleges and universities are maintaining emphasis on the fundamental sciences. They must continue to resist the temptations to undertake extensive assignments in applied research and development."

Substantial Physics Research Resources

The Engineering College Research Council's figures show 2628 faculty members and full-time senior research personnel in physics in 445 schools. Of these, 2272 are judged qualified to participate in research projects, and 1546 of them are now engaged in research. This effort is equivalent to the work of a full-time research staff of 867, and of these "equivalents" 609 would be engaged in defense projects for military agencies or their contractors.

These figures seem to show that research accounts for one-third of the total college effort in physics; and of this research nearly 70% is devoted to studies for defense. This means that, on an average, 23% of today's total college effort in physics is expended on defense research. In some schools with heavy defense assignments this figure is far higher—perhaps to the detriment of effective teaching.

John I. Mattill, secretary of the Engineering College Research Council of the American Society for Engineering Education, was responsible for editing the report on which this article is based.

Table 2

	Number of schools reporting one or more faculty interested or competent in research.
Physics:	
Ballistics	36
Biophysics	39
Cryogenics	36
Electricity and magnetism	243
Electromagnetic waves	104
Heat and thermodynamics	119
High-energy particles and cosmic rays	70
Mechanics	119
Molecular and atomic physics	124
Neutron physics	51
Nuclear physics	157
Photography	79
Radioactivity and isotopes	117
Solid state physics	75
Sound and acoustics	94
Theoretical physics	143
Ultrasonics	44
Underwater sound	43
X-rays	99
Radiation and Optics:	
Infrared methods and applications	63
Physical optics	135
Physiological optics	11
Photoelectric phenomena	82
Spectroscopy	168
X-ray methods and applications	99
Electronics:	
Antennas and wave propagation	106
Communication theory	133
Components	62
Countermeasures	24
Electro-acoustics	61
Electromagnetic waves	86
Electronic circuits and theory	201
Electronic computers	54
Electronic control equipment	125
Electron theory	108
Electron tubes	114
Microwave circuits	101
Mineature and printed circuits	19
Navigation aids and direction-finding	41
Radar	97
Radio communication	147
Radio interference	57
Radiosonde	20
Speech security and scrambling	17
Television	50

A total of 3392 graduate students and assistants in physics research was reported by the survey, equivalent to the full-time work of 1562 junior research staff members. The ratio of junior to senior staff (3392 to 2628) is higher in physics than in many of the engineering and physical sciences covered, but not so high as in chemistry, chemical engineering, earth sciences, and metallurgy.

In addition, other physicists—as well as some electrical engineers—were reported to the Research Council under the "electronics" catagory. Here the totals show 1119 faculty and full-time senior research staff members, of whom 1032 are qualified for research and 625 have projects underway. Their research is equivalent to a full-time staff of 387, of which 314 would be engaged by defense projects. In addition, there are 1107 graduate students and junior staff in electronics research, equivalent to a full-time junior staff of 588.

More than 200 colleges and universities reported at least one faculty member interested in and qualified for research in electronics, and nearly 100 schools indicated substantial resources in that field.

Nevertheless, electronics today stands second only to aeronautical engineering as a critical research area, in the sense that 80% of today's electronics research in educational institutions is already defense research, and the pressure is on for still further increases. At least 82% of aeronautical engineering research is now under military sponsorship.

A broad range of fields is represented in this physics research manpower. While the Research Council study did not ask individual faculty members to specify their special skills and interests, schools were asked to show areas in which one or more faculty members were experienced and qualified. Table 2 shows the numbers of schools indicating research potential in the various

Table 3. **Distribution of College and University Physics Research**

	Total number of faculty and full-time research personnel	Number of (A) considered qualified to do research	Number of (A) now engaged in research	Number of full-time research workers to which (C) is equivalent	Number of "equivalents" in (D) now engaged in defense research	Proportion of faculty research talent still available for new projects
	A	B	C	D	E	
PHYSICS:						
Eight universities with most defense research in progress	302	300	283	194	175	6%
Ninety-nine other major universities	1314	1160	975	521.8	380.9	16%
Total at 107 major universities	1616	1460	1258	715.8	555.9	14%
Total at 88 smaller universities	422	327	140	55.2	18.75	57%
Total at 250 liberal arts colleges	590	485	148	95.6	34.6	69%
Total at 445 colleges and universities	2628	2272	1546	866.6	609.3	32%
ELECTRONICS:						
Eight universities with most defense research in progress	251	242	216	165.5	154.5	11%
198 other colleges and universities	868.4	790	409.6	221.7	159.3	48%
Total at 206 colleges and universities	1119.4	1032	625.6	387.2	313.8	39%

categories specified; the full report of the project identifies the schools and details the personnel resources reported from each.[3]

The Distribution of Physics Research

Where are these physics research resources? Research now underway in physics shows a distribution which is typical of that in most of the physical and engineering sciences. Expansion of research to meet new national needs seems to depend on more effective decentralization. Of the 2628 physics faculty and senior research workers, 1616 (61%) are at 107 large universities—institutions with extensive professional and graduate schools. Nine out of ten of these teachers are considered qualified to do research, and nine out of ten of these qualified faculty members have research underway. According to the institutions' reports, those teachers who have research underway spend nearly 60% of their time on these studies, more than three-fourths of which are sponsored by defense agencies. (See Table 3.)

At 338 other schools, including smaller universities, teachers colleges, and liberal arts colleges, are 1012 physics faculty members. Eight out of ten of these teachers are considered qualified for research, but hardly more than one-third of those qualified have any research in progress. Those who do have research underway devote about half of their time to it, but less than one-third of this work is for defense needs.

To summarize: over 80% of the college and university physics research is carried on at 107 major universities and is in the hands of just over 60% of the nation's total of qualified faculty members. The other 40% of the qualified physics teachers, at 338 smaller schools, share the remaining one-fifth of all research. The chances appear to be nine in ten that a qualified physicist in a large university will have research opportunities as a part of his academic work. At a smaller institution, only one out of three apparently equally qualified teachers can expect to get research underway.

The Concentration of Defense Research

Physics research under military sponsorship shows a more distinct trend to concentration. The 107 major universities now have 91% of all physics studies made possible by federal defense money.

Eight of these large schools,[4] with 11% of the nation's total qualified faculty members, are doing 29% of all the defense-sponsored physics research in the United States. At these schools, only 17 of the 300 qualified faculty members are without research assignments. Those who have research in progress spend 70% of their time in their laboratories, and 90% of their efforts go to defense studies.

In electronics, defense research responsibilities are even less widely shared. Eight large schools,[5] where research claims the equivalent of 157 full-time senior workers, report more than half of all college and university defense studies in electronics. At these schools are less than one-quarter of all the electronics faculty members in the country; here nearly two-thirds of the *total* teaching and research effort in electronics is devoted to these defense studies.

This is not the whole story, of course; it needs qualification and some reservations. Large universities, with many graduate students, have vastly more resources which are appropriate to advanced research. Where there are many graduate students, the research of these students in meeting their advanced degree requirements involves faculty members. This is recorded as "research time" though it is well within any definition of teaching duties.

Despite these reservations, however, there is obviously an uneven distribution of research opportunities weighted in the direction of the larger institutions.

"One almost inevitable concomitant of government supported research," said Dr. Joseph W. Barker in the 1951 Annual Report of Research Corporation, "is that the government bureaus naturally seek out as contractors the 'going concerns' in our educational and scientific institutions. The bigger and more famous the institution, the greater the pressure upon it to undertake more and more government sponsored programs." [6]

The pressure upon all research resources continues to grow; the Engineering College Research Council's survey was prompted by the hope that lesser-known sources of research talent could be brought to bear in meeting the needs for more fundamental research.

These needs became acute shortly after the start of the Korean war, and since then research and development in the physical and engineering sciences have been limited not by available funds but by the known available research manpower. According to Research and Development Board figures, the total military research and development budget has risen from $500 million before Korea to $1.3 billion in 1952. Colleges and universities were responsible for 9% of the 1951 research and development total; they must have at least this same share of the considerably larger 1952 effort.[7] "Fully effective use of college and university resources," the Engineering College Research Council Committee predicted, "may considerably raise the ceiling placed on research and development progress."

[3] Copies of this full report, entitled *University Research Potential*, are available from the Secretary of the Engineering College Research Council at Room 7–204, 77 Massachusetts Avenue, Cambridge 39, Massachusetts, at $1.00 each.

[4] The eight are University of Michigan, New York University, Yale University, University of Illinois, University of Chicago, Cornell University, Pennsylvania State College, and University of Texas.

[5] They are the University of Michigan, New York University, University of Pennsylvania, Cornell University, Massachusetts Institute of Technology, Georgia Institute of Technology, Pennsylvania State College, and University of Florida.

[6] *1951 Annual Report*, Research Corporation (405 Lexington Avenue, New York City 17, N. Y.), p. 8.

[7] Walker, Eric A., "Research and Development: The Nation's Balance Sheet in June, 1951," *Journal of Engineering Education*, Vol. 42, No. 3 (November, 1951), pp. 126–133.

Untapped Research Resources

According to the survey's figures, there are 2272 physicists in colleges and universities who are now qualified for research. Of these, 726 have no research in progress. If each of these "unemployed" physics faculty members takes on one-third time research, the total of physics research in these schools will be increased by the equivalent of 242 full-time workers, a growth of 28%.

Of 1032 faculty members qualified for electronics research, only 625 have projects underway; more than 400 teachers still are available for research assignments. If these undertake studies on a one-third time basis, the equivalent of 133 more full-time research scientists is added to the research force—an increase of 34% in a field now considered critically short.

Where is this potential for increased service?

In those universities with the largest share of defense research, only a handful of qualified faculty members have no studies underway. In 107 large universities, including this "big eight" group, are 202 physics faculty members who are qualified but are not now active in research. This is less than 14% of the total number of qualified teachers in these schools.

At 88 smaller universities and technical schools (four-year institutions where there is little emphasis on graduate degrees) only 140 out of 327 qualified physics faculty members have research in progress. The 187 faculty still available here represent 57% of the total research potential at these institutions.

The 250 liberal arts and teachers colleges which contributed to the Research Council's inventory reported 485 qualified physics faculty members, of whom 337 have no studies underway. Here almost three-fourths of the available total remains to be put into research service.

Not all these scientists are equally qualified. It is natural that contractors, both military and industrial, have turned first to the largest institutions where talents in widest variety are available. But today's shortage of research manpower suggests revision of this approach; the Engineering College Research Council figures indicate that would-be contractors may profitably make a more careful search through the rosters of the smaller faculties.

The lack of certain specialized equipment may also limit the research undertakings at smaller schools. But manpower is the most critical need. Where manpower is available, the Research Council Committee believes that necessary equipment to implement research can probably be supplied. And it is far better to move research equipment than to move research scientists—particularly when moving the scientists disrupts their teaching programs.

Nevertheless, the Engineering College Research Council's survey project included a limited inventory of highly specialized research equipment—major facilities which might of necessity influence the location of certain studies. The results further emphasize the possibility of decentralizing physics research. (See Table 4.)

Specialized Equipment for Physics Research

	Number of schools reporting equipment available or in use
Analog computer	27
Anechoic chamber	11
Autocorrelator	6
Betatron	4
Cloud chamber	51
Cryostat	20
Cyclotron	18
Differential analyzer	20
Digital computer	12
Electrophoresis apparatus	35
Electrostatic generator	34
Interprometer	99
Linear accellerator	14
Mass spectrograph	46
Microphotometer	59
Molecular beam apparatus	11
Spectrographs:	
Infrared	73
Micro-	16
Raman	38
Vetraviolet	142
Visible light	165
X-ray	87
Spectrophotometer	176
Synchrotron	6
X-ray diffraction	90

Table 4

The Benefits of Research Expansion

The national interest clearly lies in expanding and broadening the research opportunities at all educational institutions, subject only to the important reservation that the colleges' first purpose and responsibility is their teaching programs. If overemphasized, research can become the tail that wags the dog, pulling teachers out of classrooms and away from their students. Within sensible limits, and properly integrated into academic life, research has important benefits for teachers and their students. Physicists need no itemized list of these gains. Research helps schools give more interesting opportunities and better salaries to competent faculty, while students benefit directly from an acquaintance with research problems and methods and indirectly from the faculty's new outlooks which inevitably are the result of research activity.

College and university research should be an investment that returns double dividends: while the research results contribute to fundamental knowledge, the projects in progress strengthen the teaching programs and promise more and better-qualified scientific manpower for the future. The problem today is to assure that, with the increasing burden of research in colleges and universities, these dividends are not eclipsed but extended.