I. THE MAGNITUDE, IMPACT, AND CAUSES OF THE UNDERGRADUATE INSTRUCTIONAL EQUIPMENT PROBLEM: VIEWS OF EDUCATORS AND SCIENTISTS

Scientific and engineering equipment is required in undergraduate education for two different purposes: to teach the phenomena of physical principles, and to demonstrate the capability and power of modern instrumentation for problem solving. There appears to be consensus among educators and scientists about the deficiency of instrumentation and equipment for undergraduate science and engineering education. However, there is no consensus on the implications of the deficiencies, the extent to which the deficiencies affect the quality of graduates, and means for alleviating concerns.

The current concern over the state of scientific equipment in academia reflects several important scientific developments over the past two decades. Advances in computers and microprocessors have affected every aspect of the scientific laboratory, making it possible to collect and analyze data in a matter of minutes; an analysis that might previously have taken weeks. The speed and precision contributed by computers to scientific observation have, some educators say, permitted undergraduates to leapfrog through the curriculum at an accelerated pace compared to the previous generation. The educational value or effectiveness of this leapfrogging is not yet documented. Other advances in instruments, not related to computers, have permitted scientists to analyze weaker spectra and smaller particles of matter. The use of improved Nuclear Magnetic Resonance instruments in chemistry is one example. The improved analytical range of this instrument has permitted the field to move forward in its understanding of matter. In many fields, students at the introductory level are required to learn information that was not available with the instruments of a previous generation and to understand how the modern instruments make such information available.

Most educators look back upon the decade following the launch of the Soviet satellite Sputnik in 1957 as the last period of serious national concern for science education. In the 1960s, a vast flow of Federal funding permitted universities and colleges to equip their scientific laboratories with modern instruments. During this same period, a variety of Federal programs were established to improve the quality of undergraduate science courses through seminars for teachers, financing equipment grants, and assisting with curriculum development.

According to a 1985 report by the Association of American Universities, the National Association of State Universities and Land-Grant Colleges, and the Council on Governmental Relations, Federal support for academic research, including equipment, increased by an average of 15.7 percent per year from 1953 to 1967. From 1968 to 1983, Federal funding increased at an annual average of 1.6 percent.[1] In addition, two programs that provided funds for improving facilities, the Graduate Research Laboratory Program and the Institutional Grants for Science Program, were eliminated in the 1970s. This has caused financial difficulties for research institutions. While these programs were aimed at research activities, they had a "trickle down" effect of improving all university facilities and freeing up equipment for undergraduate use. Some analysts believe that research support at universities has been sustained at the cost of cutbacks in undergraduate equipment. The result, academics say, is equipment that is old, in disrepair, or obsolete. A number of professors told OTA that alumni who visit their college laboratories frequently express surprise that the equipment is unchanged since their years in school. In many cases, the equipment in use is older than the students.

Faculty members from a wide variety of institutions stated that their equipment is either obsolete or in disrepair owing to a combination of events that have occurred over the past 15 to 20 years:

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1. Association of American Universities, National Association of State Universities and Land-Grant Colleges, Council on Governmental Relations, Financing and Managing University Research Equipment (Washington, DC: 1985), p. 15.

- inflation;
- escalating equipment costs (rising at a rate faster than general inflation);
- the increasing sophistication of scientific and engineering equipment over the past decade;
- breakthroughs in both equipment and scientific fields;
- a rapid pace of technological change in equipment, particularly computers;
- an increasingly sophisticated curriculum, especially for junior and senior level science majors;
- declining Federal funds for undergraduate science education;
- tight budgets at State funded institutions, because of State fiscal policies;
- an increase in student enrollments in engineering schools over the past decade, which has placed pressure on laboratories designed for smaller numbers of students; and
- a decrease in enrollment at small private colleges with corresponding budget strains.

In addition, faculty and administrators frequently commented that during budget crises, equipment repairs or replacements were the first items to be deferred. Faculty salaries have been, and at many schools remain, the first priority in terms of budget needs. One engineering dean stated that he expected to divert money from his equipment fund to boost salary offers in his effort to attract new faculty members. At the same time, he called the engineering college's equipment budget inadequate: it represents about half of the total amount that his department chairmen were requesting for new instruments.

A general concern is that new science and engineering graduates have spent much less time in the laboratory during the course of their education than was common a decade ago. Some industry employers stated that their new employees appeared to have a more theoretical and less hands-on education than the employers had expected. Thus, they require more on-the-job training.

Several educators report that lab requirements and offerings are being reduced because the equipment requirements are so expensive. Some small colleges are dropping certain majors — such as physics — because of the high cost of equipment.[2] However, there is disagreement among academics as to whether the trend toward reduced laboratory experience was caused by the rising cost of equipment or by other factors.

Bassam Z. Shakhashiri, Assistant Director for Science and Engineering Education with the National Science Foundation, stated that many universities have dropped the lab component of their first semester introductory science courses because of a lack of funds for equipment, chemicals, and staff. He said that many universities justify this trendon the grounds that it will give students a theoretical basis in the first semester, to be followed by a lab course in the second semester. In reality, he contended, this approach weeds out many talented students by the end of the first semester, because they have not experienced the challenge and excitement of the discipline in its laboratory setting. The trend toward eliminating lab experience, Shakhashiri said, borders on the criminal.[3]

Many academics said that the decline in laboratory offerings could also be attributed to the lack of credit toward tenure given to young faculty for participating in laboratory teaching, compared to research and paper-writing. This is unsung work,[v] noted George Dieter, Dean of the University of Maryland Engineering College. Others attributed the reduced laboratory experience to declining interest on the part of students. According to Massachusetts Institute of Technology (MIT) physics professor John King, it was student dislike, together with lack of faculty interest, that caused the demise of the lab requirements for the introductory physics courses at MIT. Over a 20-year period, MIT experimented with a variety of lab courses that would hold greater interest for the student. Today, each student is required to take a projectlab~ in which the student defines a question and develops an experiment. Unlike the original

2. Violet Meek, Council of Independent Colleges, Washington, DC, interview, 1985.
3. All unreferenced quotations are taken from interviews conducted by an OTA contractor during 1985. See Appendix A for a complete list of interviewees.

introductory physics requirement, however, the student may choose from several science departments for location of the project. King expressed concern that students are displaying a “white collar trend away from experiments. [4]

4. John King, Massachusetts Institute of Technology, interview 1985.