Appendix C. — Science and Engineering Graduate Study and Credentials in Other Nations

The U.S. system of university-based graduate education, combining research and training, is admired throughout the world for the quality of researchers it produces. However, it is not the only model for training and certification of researchers. Other nations take different approaches to training graduate-level scientists and engineers for academic and industry research and development (R&D), reflecting major social, administrative, legislative, and economic differences in university systems, in where and how R&D is conducted and funded, and where scientists and engineers are employed in that country.[1] Higher education in other countries generally is more science- and engineering-intensive, particularly in Japan, Soviet Union, and West Germany.

There is no "best" model for graduate education. The U.S. university system is decentralized, with a large high-quality private sector; many other nations have much more centralized systems. Most developed countries have reformed university education in the past decade, often modeling U.S. successes. These reforms have been driven and accompanied by a move to mass higher education, problems of overexpansion in the face of declining young populations, worries about quality, and retrenching in tight budgets.

Japan.[2] Although Japan awards more science and engineering doctorates on a per capita basis than does the United States, far fewer of these are obtained through formal university graduate studies. Students follow two paths to the doctorate. Students may earn a "course doctorate" *(katei hakushi)* in one of the major universities, similar to the United States, with courses, 5 years or so of research, and an oral defense of the dissertation. Graduate students conduct research for their professor and do not serve as teaching assistants. These graduates usually stay in the universities after completion of the doctorate.

A greater number of "dissertation doctorates" *(ronbun **hakushi)*** **are** awarded not to graduate students, but to researchers who submit a dissertation based on research conducted outside the university. Many of these are industry employees, and their

1. S. Blume and O. Amsterdamska, *Post-Graduate Education in the 1980s* (Paris, France: Organisation for Economic Co-operation and Development, 1987).
2. Lawrence P. Grayson, "Technology in Japan, Part 1: Graduate Education," *Engineering Education,* April/May 1987, pp. 687-696; and William K. Cummings, "Japan's Science and Engineering Pipeline: Structure, Policies, and Trends," OTA contractor report, October 1987.

dissertation research usually is geared toward their industry work. Few academic Ph.D.s work in industry. Companies prefer to hire young, broadly-educated college graduates and train them (often sending them overseas for graduate training). Many complete graduate studies at the university, but do not receive a degree; some may later earn a "dissertation doctorate." Japanese institutions offer a 2-year master's degree, and, as in the United States, the number of students receiving this degree has grown rapidly. The Japanese are placing ever more importance on graduate education as a potential source of creative researchers for building industry R&D, and the Ministry of Education has announced expansion plans.

Parents are a more important source of financial support for graduate students in Japan than in other countries. Overall, about 40 percent of support comes from parents, about 30 percent from scholarships, and about 30 percent from job earnings.[3]

West Germany. The German doctorate is fairly similar to the U.S. Ph.D., although graduate training generally takes longer and involves more formal study and less independent research than in the United States. A graduate student may spend several years in formal studies, do a modest thesis, and then spend another 3 or 4 years on dissertation research. The doctorate recipient is often over 30, and may have spent time in military service or in industry. The *Doktor Habilitation* is a postdoctoral degree considered necessary for receiving an academic post. Compared to the United States, there are relatively few graduate students in West Germany.

In engineering, the *universität* offers a 5-year *Diplome Ingenieur* (between a B.S. and a master's), which includes 1 year of work in industry. The average age of Dip. Ing. recipients is 25. While university training is preferred for research or academic engineers, most people working as production, design, or line engineers are trained through formal apprenticeships or have a 3- or 4-year engineering degree from a *Fachhochschule,* similar to British polytechnics or the best U.S. engineering technology programs. Graduate students and researchers come through the universities rather than the *Fachhochschulen.*[4]

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3. Blumeand Amsterdamska, op. cit, footnote 1, p. 32.
4. Lawrence P. Grayson, "EE Education Around the World," *IEEE Spectrum, November 1984,* p. 66; and Joseph Mintzes and William Tash, *Comparison of Scientific and Technical Personnel Trends in the United States, France, West Germany, and the United Kingdom Since 1970,* NSF 84-335 (Washington, DC: National Science Foundation, 1984), pp. 147-157.

Great Britain. The university D. Phil. is awarded earlier in Great Britain than in the United States, at age 25 or 26, usually after 3 years of study (beyond a 3- or 4-year undergraduate course). With necessary coursework, this leaves little time for research. The universities are primarily government-supported and essentially all students are supported by nontaxable government studentships, and thus are less tied to fluctuating university needs for teaching and research assistants. Great Britain also has a large polytechnics and colleges sector geared to undergraduate education, including engineering.

France. French universities are centralized and government-supported. Students often hold teaching or research assistantships. Graduate education and college education are quite different and are less distinct in France than they are in the United States (and secondary education extends slightly longer in France); "graduate" education really consists of the latter years of higher education. Following 2 years of general study and 2 years of specialized study leading to a maitrise or an engineering degree, or to a university *Diplome d'Etudes* (between a bachelor's and a master's), graduate-level scientists and engineers can follow two paths: entry to the small and prestigious Grand Ecoles, which concentrate on engineering, applied sciences, and technical management; or the entry into universities, which enroll the vast majority of students and have a longer and broader curriculum.

The Grandes Ecole degree, the elite *Diplome d'Ingenieur,* is roughly equivalent to a U.S. master's of engineering management. It is essentially all formal classroom learning (most students spend a few months in work assignments out of 5 years), and is general rather than technically specialized. Those few graduates of the Grandes Ecoles who go into research (rather than industry or government) often go to university laboratories for several more years of thesis research, and may receive the doctorate.

The main route of advanced study used by most science students is through the universities. Following recent, politically-charged reform, the several doctorate level degrees *(Ingenieurs Docteur,* individual university doctorates awarded mostly to foreigners, *Troiséme* cycle doctorate, and the high-level pinnacle of the *Doctorate d'Etat,* awarded after the *Troiséme* and important for an academic career) were combined into one doctorate requiring 2 to 4 years of additional study, similar to the British Ph.D. In addition, a degree similar to the German *Habilitation* is *is* now awarded in place of the *Doctorate d'Etat,* recognizing advanced research and achievement.[5]

Italy. Italy has no research-oriented Ph.D.-like degree beyond the *Laurea*, a master's level degree usually awarded around age 23. At some point, aspiring faculty members can obtain a title of *Docent* based on their academic achievements, as demonstrated by publications and prepared lectures.

china. China is rapidly rebuilding the infrastructure of research and graduate education that was disrupted by the Cultural Revolution. Universities, colleges, and institutions for engineering and other specialities are examined, authorized, and funded by the state, although many are run by local governments. Graduate enrollments are approved by the state as part of national planning, although universities are being given more discretion in their admissions, hiring, promotion, and spending. Entry, until recent experimental reforms, has been by competitive examination. Universities require about 2½ years of study for a master's degree, a year of which is research. A doctorate takes 3 more years, all devoted to research except for one semester.[6] About 660 doctorates were awarded in all fields in 1987, and over 53,000 master's.[7] New policies encourage part-time graduate study for students with 2 or more years of work experience, and new graduate students to spend a year working before pursuing academic study. Most doctorates go into university teaching to help the country expand higher education, particularly in science and engineering.

Soviet Union.[8] In the Soviet Union, research is concentrated in a few government-run institutes and a few of the leading universities which conduct significant amounts of quality research. Thus many university students do not get intimately involved in research. Universities and various technical institutes (VUZy) are concentrated in a few cities. Approximately 40 percent of Soviet graduate students earn their degrees at scientific research institutes and institutions of the Academy of Sciences rather than at *VUZy*.

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5. Guy R. Neave, "Science and Engineering Work Force Policies: Western Europe,'' OTA contractor report, September 1987, p. 11.
6. Richard De Meis, "Engineers for China's Future," *Aerospace America,* January 1988, pp. 7-9, 56.
7. Meng Yang, " Developments and Reform in Graduate Education in the PRC," *Graduate Education — Communities of Scholars,* Proceedings of the Twenty-Seventh Meeting of the Council of Graduate Schools, Washington, DC, December 1-4, 1987, p. 44. See also Halsey L. Beemer, Jr., ''Chinese Engineering Education: The Development of Graduate and Undergraduate Studies, 'f *Graduate Education — Communities of Scholars,* Proceedings of the Twenty-Seventh Meeting of the Council of Graduate Schools, Washington, DC, December 1-4, 1987, pp. 48-57.
8. Harley D. Balzer, ''Soviet Science and Engineering Education and Work Force Policies: Recent Trends," OTA contractor report, 1987.

There are two major advanced degrees: Candidate of Science *(kandidat nauk)* and Doctor of Science *(Doktor nauk).* The *kandidat* degree is closest to the American Ph. D., although may require less work. There is no direct equivalent of a master's. The *kandidat* recipient is generally earned by younger scholars who have completed their initial period of mandatory employment following graduation from a VUZy. (In unusual cases, a promising student may be permitted to continue study immediately following graduation.) Most graduate students at VUZy have been sent by their employers, with the expectation that they will return after completing their degrees. All graduate students are, of course, state-supported, and receive a modest stipend. The Soviet *Doktor* degree often honors a senior scholar who has already achieved significant status, and is awarded as much for the corpus of work as for a specific dissertation. Most Soviet Doctors of Science are at the level of full professors in American universities.

Soviet reforms are geared toward fostering research creativity and innovation: encouraging early involvement in research, encouraging more students to continue toward advanced degrees without interruption, awarding the *kandidat* degree for "practical" work, and offering greater recognition for outstanding students and faculty.

Natural Science and Engineering (NSE) Doctorate-Level Degrees For Selected Nations, 1984

	No. NSE Ph.D.s	NSE Ph.D.s as % of 27-year olds	Ratio of 1984 NSE Ph.D.s to 1980 NSE B.S. Degrees[a]
U.S. (1985)	12,101	0.3	7
Japan	2,712	0.2	3
West Germany	4,650	0.5	31
France[b]	4,800	0.6	22
U.K.	3,846	0.5	12

NOTE: NSE includes agriculture but not the social sciences.

a The French degree includes the *Troiséme* cycle and *Docteur Ingenieur* degrees, which are somewhat less than a Ph. D., and the *Docteur d'etat,* which is more than a Ph.D. France will grant one Ph.D.-level doctorate in the future.

b Ph.D. data (numerator) from National science Foundation, *International* Science and *Technology Update,* NSF 87-319 (Washington, DC: 1987); B.S. data (denominator) from National Science Board, *Science Indicators: The 1985 Report,* NSB 85-1 (Washington, DC: 1986), p. 192.

SOURCE: National Science Foundation, *International Science and Technology Update,* NSF 87-319 (Washington, DC: 1987), pp. 38, 42.