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Engineering National Defense

Technical Education at Land-Grant Institutions during World War II

Amy Sue Bix

Like other national institutions, most colleges in the United States had faced difficult times during the 1930s. Economic depression forced many students to drop out and strained school budgets to the limits. Yet again, like the rest of the country, international events toward decade's end distracted people on campus from domestic issues. Students and faculty closely observed the developing conflict in Europe, debating political and practical questions of American intervention.

During the debate over American preparedness, engineering education came to the forefront. It seemed obvious that as modern warfare came to rely on increasingly complex weaponry, countries must call on those with advanced technical skills and knowledge. Despite the image of academia as an ivory tower, a sense of national emergency hung over engineering programs as early as the fall of 1940. Especially at land-grant schools such as Iowa State, Penn State, and Cornell, where engineering had historically been a central component of the institution's educational mission, issues of America's military and industrial readiness acquired new importance. Once the United States entered World War II, military images filled engineering departments. Celebrating their annual "Engineers' Day" in 1942, Minnesota students portrayed themselves as "engineers going to bat for Uncle Sam." They produced special buttons showing an American eagle with its chest thrust out aggressively, a slide rule hanging prominently on its belt.[1]

After the attack on Pearl Harbor, the Society for the Promotion of Engineering Education issued a statement saying that America's declaration of war "undoubtedly requires an increase in the speed and extent of the preparedness program. The demand for engineers in both military and civilian service will grow correspondingly." The SPEE polled administrators of engineering colleges about whether academic schedules should be accelerated so that students could enter the workforce or military sooner. After studying responses from 125 schools, the SPEE

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concluded that "the present senior class in engineering [should] be graduated as early as possible consistent with the maintenance of a sound engineering educational program." It recommended that schools should add summer sessions so that juniors could graduate three months earlier and sophomores eight months ahead of time.[2]

Many land-grant colleges and other schools accordingly compressed academic calendars, shortening or eliminating normal vacations. Citing wartime urgency, Cornell required all engineering students to attend class three semesters per year, letting them finish four-year degrees in three years and five-year programs in four. New freshmen began class in summer, rather than waiting until September. Some administrators had protested that forcing engineering students to attend class year-round would deprive them of the summer earnings many counted on for tuition. When Cornell switched to an accelerated program, its trustees readjusted scholarships and loans to provide additional financial assistance.

In contrast to the 1930s, when graduating engineers feared they might not find work, Cornell's wartime students knew their future:

> In any typical group of engineering seniors, two out of three are enrolled in the advanced ROTC or in the US Naval Reserve, ready to go on active duty . . . immediately after Commencement. Of the 218 members of the Engineering Class of 1942, 83 will become second lieutenants in the Army; 38 have been commissioned in the Naval Reserve, and at least 25 more will be commissioned and ready for active service in the Navy before . . . June. Most of the rest will go to positions in industries or in engineering concerns working on war contracts.[3]

Further complicating the situation, college officials engaged in battle with local draft boards. Selective Service often refused to grant engineering students a deferment, despite the appeals of school administrators and engineering societies that pointed out that intelligent young men would serve their country better as trained engineers than in the ranks. By 1943, male civilian enrollment on campuses across the country plunged.

Engineering Training for the Military

Low civilian enrollment did not mean that engineering programs became idle. West Point alone could not turn out enough technical specialists for the military, so in 1942, the Army created plans to fill that shortage as soon as possible. The Army Specialized Training Program sent soldiers with superior educational backgrounds and test scores to colleges across the country, where they took prescribed courses in engineering, science, and math. The basic phase of ASTP condensed the first one-and-a-half years of college into nine months. Advanced ASTP gave soldiers accelerated training in aeronautical, chemical, civil, electrical, mechanical, and sanitary engineering, plus surveying, communications, marine transportation, acoustics and optics, and more. Although ASTP men lived on campus, they remained on active duty under military discipline and received regular army wages. Upon completing courses, ASTP men were assigned to technicians' and specialists' posts in the army, the Corps of Engineers, Chemical Warfare Service, Signal Corps, or Ordnance Department. By late 1943, the army had set up ASTP units at over two hundred colleges and universities. At Penn State, almost eight hundred men arrived at once.[4]

The navy similarly sent hundreds of men to Cornell, Penn State, North Carolina, Iowa State, and other colleges to study engineering, communication, electrical systems, and other technical fields. The U.S. Naval Training School at Cornell alone trained 2,001 officers in diesel engineering and 695 in marine steam engineering. The navy paid to build a new wing on Cornell's engineering lab and stocked it with almost every ship engine available. To teach navy men, Cornell brought men from engine manufacturing companies to join regular engineering faculty. Trainees gained both theoretical knowledge and hands-on expertise in diesel power, engine and hull construction, propeller design, and engineering physics. After finishing the four-month course, they were detailed as engineering officers at cargo and repair bases or on patrol vessels, mine sweepers, and other small craft. Navy public relations bragged that Cornell had transformed a "doctor of jurisprudence, just out of Harvard Law School . . . into an excellent engineer who is now at sea on a submarine chaser. A man with an LL.B. from the University of Chicago won honors in an examination in thermodynamics."[5]

The federal government provided a number of other programs through which military personnel entered wartime engineering studies. Purdue, for example, gave air corps engineering officers a three-month training course in aircraft maintenance. Military men arrived in such numbers and so fast that it stretched campus facilities to the limit. Cornell and Purdue converted dorms, fraternity houses, and even faculty residences into army and navy housing, squeezing in extra cots to accommodate still more. Civilian students were pushed into off-campus housing. At Iowa State, by September 1943, students in the armed forces outnumbered civilians by more than seven hundred. Civilian enrollment had fallen by more than 1,000 since spring, but the arrival of 2,314 navy men, 876 army men, and 91 special female engineering students kept total enrollment almost normal. Iowa State observers marveled at the visible changes wartime wrought on the engineering campus:

> New London and San Diego were names [formerly] connected with technical training for . . . the Navy—not Ames, Iowa! But . . . Iowa State has become one of the largest college Navy bases in the country. . . . V-12's pack engineering library and classrooms during all hours. . . . Naval Air Cadets have classes at night, burning the midnight oil to learn more about navigation and codes. Platoons of Army men are seen marching to and from mess. . . . Instead of the usual eight or ten sections of a pre-war statics class, civilian students are limited to two or three.[6]

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The campus paper editorialized with pride that war programs brought new recognition to Iowa State engineering, underlining the growing importance of technical education in the twentieth century. "Looking to the future, we . . . are told that peace will bring . . . new technology—greater and more comprehensive than anything the world has yet known or imagined. Believing this is to believe in a brighter future for the nation—and for the technical school."[7]

Engineering Training for Defense Workers

As substantial as the programs to give military personnel technical training on college campuses were, government efforts to spread engineering education also extended to almost two million civilians. In the spring of 1940, with the continued advance of Nazi forces, the U.S. Office of Education began considering what part it might play in a future military emergency. Congress soon approved a program to extend *vocational* training, but John Studebaker, Commissioner of Education, foresaw a deeper problem in higher education. He worried about a straightforward crisis of supply and demand; colleges simply weren't graduating enough engineers to fill personnel shortages which already appeared as defense-related industries expanded production. Studebaker asked Andrey A. Potter, Purdue's dean of engineering, to join his staff as a consultant. Potter wholeheartedly embraced the idea of expanding federally-funded training to college engineering, writing, "Irrespective of the outcome of the war in Europe, there is bound to be in the near future keen industrial competition. Our country must meet this competition by more scientific and technological knowledge. . . . Higher education, particularly in science and technology, is also a major essential in our military defense . . . [which] depends upon ships, airplanes, tanks, gunpowder, and other manufactured products."[8]

The Office of Education launched surveys in New York City, Chicago, California, and Pennsylvania to gauge regional personnel needs. After conferring with company managers, educators, and engineering societies in more than forty communities, Penn State's extension service concluded that the state needed 7,500 new technical specialists, mainly qualified engineers. Studebaker summoned presidents and deans from the nation's leading engineering colleges to Washington, to meet representatives from the army, navy, and Office of Education. To their dismay, educators heard that the United States already faced "a marked shortage in naval architects, ship draftsmen, marine engineers, engineers skilled in airplane structures, airplane power plants and airplane instruments."[9]

Technical knowledge represented a limited national resource. Lehigh president C. C. Williams wrote, "Colleges have no synthetic chemistry in sight that will make engineers out of air and coal." But though schools could not instantly expand their classes of graduating engineers, they began thinking about ways to supplement regular undergraduate and graduate programs. The hope was to create specialized crash training which could eliminate potential personnel bottlenecks in critical defense industries. Drawing up initial plans, the Office of Education calculated that during the present year alone, the government, the navy, and the aviation industry could use at least 2,500 more people familiar with airplane structures, power plants, and stress analysis. Airplane and ship builders could also absorb at least four thousand engineering draftsmen, according to the Civil Service Commission. Studebaker and Potter figured that engineering freshmen or high-school graduates with shop experience could easily pick up mechanical drawing, freehand detailing, and structural analysis in twelve or sixteen weeks. If one hundred colleges each put together one such class, the nation would have five thousand additional draftsmen available within four months. Experts also worried particularly about a shortage of ship draftsmen. Normally, only three schools (MIT, Michigan, and Webb Institute) even taught naval architecture. Those places had graduated just fifty-one students in 1940, but within two years, the navy and shipbuilders might well need four thousand marine engineers. To supply that brainpower, educators suggested retooling civil, mechanical, electrical, or architectural engineers through a twelve-week course in ship geometry, theory of navigation, marine engineering, and special design problems.[10]

In October 1940, Congress passed a bill along lines recommended by Studebaker and Potter, appropriating nine million dollars to establish the new Engineering Defense Training program, based in the U.S. Office of Education. That legislation defined EDT's mission as "providing short intensive courses on the engineering college level in fields essential to national defense . . . where a shortage of trained personnel prevails at present or is almost certain to occur if steps are not soon taken." Potter, a former president of the SPEE, the American Society of Mechanical Engineers, and the American Engineering Council, would chair EDT's national advisory committee of engineering educators. Dean R. A. Seaton of Kansas State came to Washington to direct day-to-day administration.

Studebaker knew that EDT would not succeed without the public commitment of major technical institutions. Accordingly, he appointed prominent engineering deans (including H. P. Hammond from Penn State and Gill Gilchrist of Texas A&M) to serve as national advisors. Deans from Cornell, Ohio State, Michigan State, Kansas State, Maryland, and the University of Texas became regional advisors, acting as liaisons between the U.S. Office of Education and their region's engineering colleges and defense industries. Those representatives immediately brought their own schools on board and appealed to colleagues at neighboring institutions to sign on. Any institution with accredited engineering curricula could sponsor EDT courses, and most were pressured to do so by Washington headquarters and the SPEE. The new program would be a "cooperative effort in which the federal government furnishe[s] the funds and the colleges furnish the working . . . facilities."[11]

Under the system set up, college officials were expected to identify existing and anticipated personnel shortages in local defense industries, then propose ways

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of meeting those needs. Schools were to plan both full-time and part-time courses, each "designed to train for a specific activity of *immediate* application." Full-time ("pre-employment") courses were intended to teach unemployed men with some technical ability to become engineering assistants, technicians, and draftsmen. RPI president William Hotchkiss explained, "There is a large reservoir of persons . . . partly trained, . . . who have had science courses in liberal arts colleges, or who have had to drop out of engineering courses before graduation, who could be quickly prepared for service in a few weeks or months." EDT also hoped to retrain men who already held engineering degrees to handle new fields. "A civil engineer, through a four-months intensive course, may be prepared to design airplane structures, or a mechanical engineer . . . qualified for airplane engine design." Part-time ("in-service") courses would provide after-hours training, upgrading men already in defense work to positions of more responsibility and improving their technique.[12]

Regulations stipulated that EDT courses must run at "college-grade," which meant anything from freshman level to graduate work. Participants would be required to hold a high school diploma; advanced courses might specify two years of college or even a degree as prerequisites. Courses would be entirely free to qualified students, with the government paying all tuition and lab fees. Seaton stressed that "[c]ompletion of an EDT course should prepare a trainee for immediate employment in a defense activity, if he is not already so employed, and he should be immediately available for such employment after he completes the course."[13]

Isador Lubin, commissioner of the Bureau of Labor Statistics, warned the EDT office that defense expansion threatened to overwhelm company personnel offices. The government had already awarded more than eight billion dollars' worth of defense contracts, entailing an extra four and half million man-years of labor. "New products not hitherto manufactured in this country require new skills that must be developed by training. In normal industry only 20% of workers are skilled; in defense industries this will rise to 40% to 60%." EDT officials realized they must "anticipate the needs of industry [since] it will take three or six months before our trainees are ready. It isn't enough to wait until the need is immediate." Harassed superintendents tended to wait until the last minute, then search colleges for "nice clean-cut-looking [engineering] lads with flat feet or dependents, who won't be drafted."[14]

Training efforts started off slowly in areas distant from defense activity, such as Iowa, Arizona, and Arkansas. The University of New Mexico, Idaho, and Montana State College attempted to organize drafting classes, as requested by national advisors, but failed to secure enough qualified students. With rapid expansion of airplane and ship building, however, California, Washington, and the Northeast saw immediate demand for well-trained employees. By the end of 1940, the national office had approved 418 courses at 84 institutions for more than 29,000 trainees. Most courses met two or three evenings per week, generally for twelve to sixteen weeks. Subjects most in demand included production supervision, with 6,641 students; engineering drawing, with 4,614 students; production engineering, with 3,364; materials inspection and testing, with 3,152; metallurgy, with 2,646; tool engineering, with 2,059; and machine design, with 1,889. EDT staff feared that initial enrollments still fell "far short of meeting requirements, especially in . . . aeronautical engineering, explosives, machine design, naval architecture and marine engineering." Washington encouraged colleges to add more such courses, since plans for expanding the nation's shipyards were underway, and "we must not allow the shortage of engineers to delay this program."[15]

SPEE president Donald Prentice brought out statistics to document this manpower gap. Estimates suggested that government and industry would need 40,000 or 50,000 new engineers in 1941, yet only about 12,000 students were on track to complete engineering degrees in June. Moreover, one-third of graduates would not be available for civilian employment; approximately 4,000 would be given ROTC commissions, drafted, or recruited as naval reserve officers and pilots. Penn State reported that 1941 was already "the most hectic recruiting season we have ever experienced." Major corporations were "hoping to secure not only their usual quota of graduates, but a much enlarged one," while "there will also be many requests from industries who haven't made requests for a long while and some who have never before." Eager employers had begun a bidding war, sending up engineers' salaries considerably. "It is evident that there is going to be a very wide gap between the supply of young engineers and the demand for them," Dean Hammond concluded. "Twice as many wouldn't be too many." On the opposite coast, placement officers at the University of California declared, "We cannot find even one engineer to refer to the dozens of employers who are clamoring for them. . . . [I]n sheer desperation employers come personally to explain their needs. One firm not in existence six months ago has 200 employees today and tells us they will need 2000 within another month."[16]

The Office of Education publicized its new program extensively. An NBC radio show entitled "Engineers for Defense" described training opportunities to a nationwide audience. Colleges broadcast announcements of their own classes, advertised in local papers, and sent information booklets and posters to the area's major employers. In some cases, a flood of subsequent inquiries overwhelmed coordinators; the University of Detroit fielded 1,500 requests for enrollment in its first courses.

By June 1941, Washington had approved proposals for 2,350 courses at 144 schools, reaching 136,618 students. Building on the administrative infrastructure already in place for its regular extension program, Penn State alone opened EDT courses for over 10,000 workers in fifty cities in response to local companies' requests for help. When Piper Aircraft expressed a need for trained draftsmen and junior engineers, Penn State set up classes in aircraft layout, operations inspection, aircraft structure, metallurgy of welding, aircraft drafting, time and motion study, fundamentals of engineering, and aerodynamics. By 1944, 65 percent of the personnel in Piper's engineering department had completed at least one course through Penn State. A supervisor-mechanic who took engineering drafting had been promoted to chief design engineer in the experimental department. A former shoe clerk in Piper's sewing department became assistant chief draftsman. A shop employee had risen to work on plant layout and scheduling efficiency in Piper's new methods engineering department.[17]

Arranging EDT courses consumed substantial time and effort for school administrators. By the spring of 1941, the University of Florida was devoting more resources to EDT than to its regular engineering program. The University of Cincinnati stated its willingness to double EDT offerings, but warned that finding good teachers for extra classes could prove difficult since "our university teaching staff is taxed to the utmost." On balance, D. V. Terrell of the University of Kentucky spoke for many when he observed that after the first round of EDT training, "[i]t is sometimes difficult to say just where the national defense program is benefiting. However, it may be said that such education will be reflected in future needs for men trained to go direct into the defense industries, or to fill gaps left by those who do go into such industries."[18]

EDT courses soon won praise from companies such as Lockheed, which had at least 575 workers enrolled in courses run through Caltech. "This program has filled a need which we have long felt but about which we were able to do little because of the expense involved in . . . regular university extension classes." Cadillac's staff observed that automakers were being asked to turn out new products for which "the tolerances are more exacting and the inspection more rigid than in our normal manufacture. We will have to do training ourselves, but the more foundation we have on which to build, the better off we will be. Training in engineering colleges and the EDT should be increased . . . to relieve industry of this burden."[19]

Some firms reported that having workers participate in EDT classes had already yielded direct benefits in production. At the American Can Company, workers learning time and motion study had pointed out sources of waste in routing materials and suggested ways to improve floor plans. The availability of training had convinced the First Sterling Steel Company to adopt new processes. As the University of Pittsburgh reported, "An employee . . . taking the course in x-ray testing brought the director of research as a visitor. . . . As a result, the company is planning to buy equipment for radiographic examination of their products."[20]

EDT students themselves appreciated EDT as "a common-sense safeguard" for military readiness. One man taking a photogrammetry class wrote, "This subject is fast becoming important in defense mapping and there are few up to date text books available. I am becoming skilled in the use of laboratory equipment which would be impossible to see or use in any other way. I registered . . . with the thought . . . that engineers might soon be conscripted for all defense measures,

and the training I am receiving will enable me to do my share in this important phase of work." Another explained, "I took the course in water supply and sanitation because I had time to spare and it never hurts to keep brushed up. . . . Courses . . . keep the 'white collar' man in condition the same way the army camp keeps the soldier in condition."[21]

Participants also anticipated personal benefit from training. Although family obligations or economic constraints might have prevented workers from seeking education in peacetime, EDT training could finally qualify them for promotion. One Michigan student commented, "Being a tool and die maker that came up the hard way with no education . . . your courses have kindled a fire in me for more. . . . I was a die maker from the old school and with the aid of your course I am now able to go ahead." One goal of the U.S. Office of Education had been to give jobless people engineering training which could help them land employment. While the program's overall success along those lines was difficult to rate, Penn State reported that almost two thousand students who were unemployed upon beginning class had since found positions. One still out of work felt "sure that this course is adding much toward placing me in the near future. . . . [It] gives me the feeling that I am one of the very few learning an entirely new branch of engineering."[22]

Although EDT had been created and implemented by leading engineering educators, some inside that community remained ambivalent. Critics worried about setting a dangerous precedent which could give the government an excuse to control engineering education. If America entered the war, they feared, the emergency might well bring an "insistence that the army run everything." The military might be tempted to convert colleges into something resembling West Point and Annapolis, which would be "horrible . . . for the training of civilian technical men."[23]

Another threat soon appeared: hoping to get in on the action, junior colleges, technical institutes, liberal arts colleges, and schools of commerce lobbied Congress to let them offer courses. The prospect of turning training over to outsiders horrified EDT advisors, who considered many proprietary schools illegitimate and pointed out that most junior colleges didn't even have engineers on their faculty. EDT's board passed a motion declaring that "in order to protect professional engineering training," standards and procedures must "remain in the hands of the engineering colleges."[24]

Lehigh's C. C. Williams warned further that over-expansion of EDT created "a danger of 'inflation' in engineering education." He declared, "To stamp a large number of men as having had engineering training who are not trained engineers [is like] . . . running the printing presses to turn out paper currency. . . . We are in danger of depreciating or destroying the value of the real thing." Williams and others feared that trainees might consider themselves "graduates" of Cornell or Penn State after taking one or two EDT courses through those schools. EDT organizers emphasized that the program did not teach men with a liberal arts background to "become engineers in three easy lessons."

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Though EDT was run through the nation's leading engineering departments, most institutions did not give participants credit toward degrees. After all, EDT courses were "not given as integrated parts of an [engineering] education." Training classes were expected to reflect "an academic standard customarily required of college and university students in the same field"; however, the approach was not identical. EDT studies were "[o]rdinarily . . . of a more intensive and applied character in order to give specific training for a particular field of war work." The Engineers' Council for Professional Development warned that if instructors began modifying specialized course content to satisfy demands for academic credit, it would interfere with EDT's primary objective, preparation for national defense. For that reason, both the ECPD and EDT's regional advisors passed resolutions recommending that colleges refrain from giving credit for war training. Instead, schools such as Texas A&M issued participants a certificate and wallet card, testifying that they had completed courses in airplane drafting, industrial safety, or other subjects.[25]

Despite such misgivings, engineering programs gained tangible advantages from participating in EDT. At a time when both industrial recruitment and the draft threatened to steal away college staff, EDT justified keeping faculty intact. Educators argued that any attempt to prepare technical workers should come through them, saying, "Just as the medical school is responsible for the training of medical technicians, so must the engineering school assume responsibility for the training of those who are to assist engineers." Furthermore, in addition to paying all course costs, the federal government gave schools an additional twenty percent to cover overhead expenses and purchase extra teaching supplies. Program rules allowed schools to keep new equipment, so that government money helped expand college labs in fields such as electronics. Ultimately, growing evidence of a nationwide manpower crisis overpowered lingering doubts. One company president noted, "It is almost impossible to get ready made engineers and it is going to be increasingly more difficult."[26]

Although initial legislation limited EDT's jurisdiction to engineering, that boundary proved hard to maintain. Classes in chemical engineering shaded near pure chemistry; students of airplane design needed to learn meteorology. Companies wanted supervisors to learn business administration, industrial methods, and accounting so that they could cope with the problems created by rapidly expanding production. Moreover, regulations stipulating that only engineering programs could run courses made it harder for schools to find teachers. The engineering dean at Virginia Polytechnic complained, "Some liberality in interpretation of *engineering* might be helpful. We might make more use of departments of physics and chemistry if we were not afraid to."[27]

NYU engineering dean Thorndike Saville worried that legislators would force engineers to cede control of EDT. "[I]t will be a great mistake to open up the gates to schools of commerce and business," he warned. Though business schools taught courses titled industrial engineering, the substance differed radically since "engineers have a background of a totally different experience from the men in the schools of commerce." Saville continued:

> Dean Seaton intimated that a good deal of pressure has been applied to have the law permit business schools . . . to participate in this program. . . . [I]t is just this matter of political pressure which has concerned a great many of the engineering and other college administrators with respect to the Office of Education programs. Many of us have contended from the outset that it will be impossible to avoid political pressures as the federal government more and more gets into education administration on the college level. This is a direct evidence that we were correct.[28]

Despite such criticism, Congress appropriated seventeen million dollars in July 1941 to add training in chemistry, physics, and production supervision to the program accordingly renamed "Engineering, Science, and Management Defense Training" (ESMDT).

Japan's December 1941 attack on Pearl Harbor lent new urgency to defense training. The Office of Education called for "universal war-mindedness," declaring, "Employed people . . . must be constantly trained for greater responsibilities." Its program changed names one last time, becoming "Engineering, Science, and Management War Training" (ESMWT). The Office of Production Management told engineering and science programs, "We need everything you can give us, as of yesterday."[29]

By now, training extended nationwide. Penn State had established the single largest program; in 1941–42, it enrolled almost 55,000 students in 150 different cities, one-eighth the national total. Since some locations did not have good teaching facilities, Penn State created three "auto-labs," trucks filled with scientific equipment. Those "chemistry and physics labs on wheels" traveled from town to town, demonstrating principles of electricity, mechanics, and matter to introductory science and engineering pupils. The full list of ESMWT courses taught through Penn State included:

> Advanced Inspection Methods, Aerodynamics, Air Conditioning, Aircraft Engines, Analysis of Solid and Gaseous Fuels, Applied Engineering Math, Applied Mechanics, Auditing, Ceramic Engineering, Chemical Thermodynamics, Chemistry of Engineering Materials, Chemistry of Explosives, Chemistry of Metals and Alloys, Coal Distillation, Combustion of Liquid and Gaseous Fuels, Corporation and Manufacturing Accounting, Cost Accounting for War Production, Cost Control, Die Design, Electric Meters and Instruments, Electric Motor Control, Elements of Radio Communication, Engineering Drafting, Foremanship, Foundations of Engineering, Fundamentals of Railway Signaling, Glass Technology, Heat Treatment for Tool Engineers, Heat Treatment of Steel I, II, and III, Industrial Electrics, Metallographic Laboratory Technique, Methods Engineer-

ing, Motor Freight Management, Industrial Supervision and Inspection for Women, Ordnance Inspection, Personnel Management, Petroleum Laboratory Technique, Physical Testing of Materials, Plastics Design and Machining, Production Control, Pyrometry, Qualifying Math for Engineering Courses, Safety Engineering, Shaping of Steel, Steam Power Plants, Surveying and Mapping, Time and Motion Study, Tool Design I and II, and more.[30]

Some subjects taught in ESMWT represented elementary material. When the York company requested help in finding drafting personnel, Penn State recruited twenty-three girls just out of high school for a full-time, 100-hour engineering fundamentals course. Twenty subsequently took posts as junior draftsmen at York. Ultimately, Penn State took 1,945 young people through introductory engineering, and 1,164 reportedly found work immediately. Typically, classes in "foundations of engineering" combined freshman-level math and physics with use of the slide rule and other basic engineering methods. The course description for prospective students explained, "Make no mistake. This course isn't a quick, easy way to become an expert engineer. It provides . . . powerful instruments of immediate practical utility to help you do a better job in industry. . . . What you build on it in the future is up to you."[31] Other training approached graduate-level science and engineering. Caltech's classes for people in petroleum refining introduced sophisticated principles and the use of infrared and ultra-iolet spectrophotometers.

Many ESMWT courses set out to fill specific manpower gaps. With schedules calling for production of smokeless powder alone to rise from fifty to one thousand tons per day, the army and industry desperately needed skilled explosives inspectors. Few colleges could hold training classes in explosives, since they did not have professors familiar with the subject. Accordingly, the Office of Education held special training for organic chemistry faculty from thirty-three institutions, who returned home to organize local courses on the chemistry of powder. One subsequently noted, "We never get an opportunity to complete a class," since arsenals and munitions companies "take them away from us before they finish."[32]

Building on that success, the Office of Education organized similar efforts to train experts in new radar technology. Electrical engineering and physics professors from forty schools met with army and navy officials in 1941 to outline a common course covering cathode ray tubes, amplification, oscillation, modulation and demodulation, receivers and transmitters, radiation, and more. After taking an intensive refresher course themselves at MIT, instructors brought training in ultra-high-frequency theory and methods to institutions such as Penn State. After Pearl Harbor, Iowa State required all electrical engineering seniors to take the two-quarter pre-radar course (waiving normal ESMWT rules to give them full degree credit). For teaching purposes, the government sent colleges thousands of dollars' worth of very special equipment.[33]

As the war accelerated, defense manufacturers were under great pressure. Large firms especially demanded ESMWT classes tailored to their exact work and

limited to their own employees. Initially, the national advisory committee resisted; engineering educators felt that companies with such specific expectations should handle training themselves. Yet the urgency was apparent, and managers at companies such as Bethlehem Steel reported seeing the most satisfactory results from courses which industry people had helped plan. Industries repeatedly urged "extreme caution to prevent these courses from becoming too academic." Confirming such opinions, a study of Connecticut's entire EDT program revealed that different schools achieved varying success rates (defined as the percentage of trainees subsequently able to assume greater responsibility at work). The college with the highest proportion of successful students was the one with the closest coordination with the businesses being served.[34]

Even when educators feared losing academic rigor, they faced the hard fact that college faculty simply could not handle all the additional ESMWT courses on top of their regular teaching load. Out of both necessity and desire, many ESMWT courses were taught by men from industry (under supervision of academics). At Penn State, 83 percent of instructors were working engineers, and as one plant superintendent explained, "We like these courses . . . especially because the instructors are practical men from industry."[35]

Both companies and the government boasted about links between employee training and improved performance. One Indiana machine manufacturer wrote, "We had trouble in getting good manganese bronze castings so we began making them ourselves. We [sent] test bars . . . with our men when they went to the [metallurgy] class, . . . and we are now making better castings than we can get anywhere else." West Coast airplane manufacturers claimed that sending people to courses on "quality control by statistical methods" had saved $800 on every bomber. The Rustless Iron and Steel Corporation staffed its new spectrographic laboratory entirely with employees who received their training through the program; their introduction of new techniques sped up analysis and thereby saved critical metals.[36]

Since the national office reviewed course offerings each year, the program maintained valuable flexibility. Toward war's end, changing defense priorities called for fewer courses on explosives and more in plastics, synthetic rubber, and petroleum refining. Colleges focused on serving regional needs. The University of Washington emphasized naval architecture, and USC and the Illinois Institute of Technology organized courses in the chemistry of food dehydration. Serving the state's oil industry, Penn State set up courses in petroleum laboratory techniques to train badly-needed technicians. One such class placed four unemployed women, two former secretaries, and one ex-salesclerk in the Pennzoil labs; another retrained two female soda fountain operators as core analysts.

The best example of how ESMWT served regional wartime demands came on the West Coast. The University of California ran the most courses of any institution, about one thousand, many targeted to aid airplane manufacture. School administrators explained, "At the present time the aircraft industries in the Los

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Angeles area have great numbers of persons in the engineering departments who are capable only of the most elementary types of engineering activity. Approximately half of the people in this lower level must be upgraded to the second level. The places they vacate must then be filled by persons . . . from the outside." To help upgrade workers, the university taught aircraft lofting, aircraft plastics, metals in aircraft design, aircraft development layout, stress analysis for aircraft designers, flutter prevention in aircraft, aerodynamics for designers, aircraft weight control, electrical engineering for aircraft, and aircraft industry administration. Enrollment in most of those relatively advanced courses required at least six months' experience in airplane manufacture. In order to bring new workers into industry, the university ran full-time drafting classes. After one such course in 1942, at least 107 out of 132 students (mostly female) found war-related work, 70 percent with either the Douglas, Ryan, Consolidated, or Vega airplane companies.[37]

California ESMWT staff had no reservations about getting too close to business. The university developed sixty-six classes for Lockheed staff at that company's request; Lockheed supplied both teachers and instructional material. Similarly, the Jacobs Aircraft Engine Company wrote, "The fact that you have worked with us in setting up a special course built around our particular engine . . . [makes it] more effective." The University of Southern California put together twenty-five sections of a tool engineering course to meet at two o'clock in the morning for swing-shift employees. After gasoline rationing made it hard for workers to travel to campus, ESMWT moved courses directly into airplane plants. More than nine hundred workers at Consolidated-Vultee went through an in-plant ESMWT course on aircraft production control. "All students in the class are studying with the same frame of reference, their training needs are more narrowly definable, and illustrative examples are readily available in their common experience."[38]

Given rapid changes in airplane design, companies appreciated courses to help employees keep on top of new ideas. Curtiss-Wright found particular value in advanced training covering problems of airplane flutter and vibration. One aeronautical engineer requested a class on airfoils, since "this subject is changing so fast that not only our new employees but also our older ones not in direct contact with this work do not appreciate the present status."[39]

Initially, companies feared employees might not take ESMWT training seriously, since courses were free. Just the opposite; 60 or 70 percent of trainees completed class, attending regularly despite demands of late-shift employment and overtime. Virginia Polytechnic's engineering dean observed, "I never saw as serious a group of students in all my years." Students felt proud that new training helped them speed up war production. One wrote, "As a layout draftsman in the wing group of Consolidated's Engineering Department . . . , a day hasn't past [*sic*] that I haven't applied analytic solutions [learned in ESMWT] to layout [*sic*] problems that would otherwise have been a nightmare." A former history major, who used a course on circuits and electric machinery to land a job at Boeing, reported, "It's a grand feeling to be serving one's country in a technical way." Some found new knowledge exciting for its own sake. One wrote, "Before, . . . my job meant nothing to me but monotonous routine. Now with a better understanding of what happens [in] heat-treating, I find my work much more interesting and my superiors have noticed it. I am anxious to delve more deeply, working toward being a metallurgist."[40]

As the war began winding down, ESMWT ended in the summer of 1945. All told, 227 colleges and universities in every state (plus Alaska, Hawaii, and Puerto Rico) had offered courses. At a cost of about 94 million dollars, the federal government had paid to train 1,795,716 American men and women. More than 1.3 million had enrolled in various types of engineering: 207,618 had studied general engineering, 161,460 aeronautical engineering, 52,020 chemical engineering, 70,908 civil engineering, 250,563 electrical engineering, 184,977 industrial engineering, 43,762 marine engineering, 175,596 mechanical engineering, and 64,859 metallurgical engineering. Penn State alone had taught more than 140,000 people in 224 communities. Cornell trained 30,144 war workers through classes in Ithaca, Binghamton, Buffalo, Corning, Elmira, Endicott, Niagara Falls, and sixteen other locations.

Although ESMWT and its predecessors were the creations of wartime, their impact on American engineering lasted far longer.

ESMWT represented a unique episode, the most intense centralization of science and engineering education effort up to that time. With the United States facing an international crisis, university administrators grabbed at government support for extending and promoting engineering and science training. That immense commitment of public funds and professional effort helped pave the way for postwar policy developments. Although important differences exist, ESMWT in many ways foreshadowed the Cold War's National Defense Education Act. The 1950s once again brought announcements that the United States was not educating sufficient numbers of engineers and scientists. Experts warned that lack of brainpower could seriously compromise the race against communism. Extension education again took on new importance; in a 1956 speech to the American Institute of Electrical Engineers, U.S. Steel chairman Roger Blough praised evening classes as a means of upgrading shopfloor workers and technicians to great responsibility, as engineers. "The whole work force moves forward a notch or two, and that is another way to take care of an ever-increasingly mechanized America."[41] ESMWT had underlined the significance of engineering training to modern America's military readiness and industrial strength. It brought the university closer to the government and engineering programs closer to the military, trends which would only continue over the decades.

Engineering Training for Women

Wartime programs carried an even greater significance in the way they affected women's access to engineering training. For decades, formal barriers had maintained engineering as a primarily male preserve. Up to World War II and beyond, some of the nation's foremost technically oriented institutions (such as RPI, Georgia Tech, and Caltech) refused to enroll female undergraduates. Many male students, faculty, officials, and alumni at those elite schools openly criticized or ridiculed the idea of women engineers. Unwritten rules also discouraged women from attempting engineering education. The few coeds admitted to MIT struggled against a hostile intellectual and social environment. Long-standing school traditions tied technical expertise to masculinity.[42] World War II marked a brief break in such conditions, a window of opportunity which challenged assumptions about gender and engineering. Although at first glance it seems as if that window of opportunity closed all too suddenly at war's end, that temporary break paved the way for a long-term redefinition of women's place in college engineering departments.

Back in the late 1800s and early 1900s, a handful of women had established a small but significant place in engineering studies, attending mainly land-grant colleges or small technical schools. For instance, Olive Dennis received a civil engineering degree in 1920 from Cornell, then worked for over thirty years at the Baltimore and Ohio Railroad. Women such as Dennis got a certain amount of attention, since they were a rarity, a curiosity. A 1920s article remarking on that female presence was headlined, "Three Coeds Invade Engineering Courses and Compete With Men at Cornell University: Stand Well in Their Studies." Similarly, a 1925 article in the University of Minnesota's engineering publication bore the title, "Coed Engineers: Man's Domains are Again Invaded."

There was plenty of joking about women attempting to penetrate masculine territory. In 1938, Justin DuPrat White, vice chairman of Cornell's board of trustees, told the school's Society of Engineers, "When I entered Cornell in 1886 ... two years before, ... there had been a woman who had had the temerity to register as an undergraduate in Sibley College. I want to congratulate ... the College of Engineering for their great tolerance, in these days of intolerance throughout the world, [in welcoming] the entrance of women.... Lord knows that the lawyers have almost been swamped with the influx of women in their profession." In fact, by 1938, more than twenty women had received engineering degrees from Cornell, one by one over the years. Isolation made the experience hard. One such "Slide Rule Sadie" (as they were nicknamed) said:

> A girl has to want ... pretty badly to go through with the course in spite of the unconscious brutality of the young men who will be her classmates.... She must be ready to be misunderstood, as ... many ... will conclude that she took engineering ... to catch a husband. She must be ready to do alone the work the men do in groups ... lab reports, etc., because in general men who are willing to face the scorn of their peers and ... work with her are far more interested in flirting than in checking computations. She must be prepared for a pretty lonely academic career.... [43]

Before World War II, simply being a woman studying engineering was unique enough to get your picture on the front page of campus papers at Iowa State, Minnesota, and elsewhere. Those discussions of female engineering majors treated each one individually, as if each case were unusual—which it was. For instance, under a typically cutesy headline, "Beauty Meets Resistance," the *Penn State Engineer* noted that Olga Smith had become the school's first woman enrolled in electrical engineering. Yet beneath the joking, women's presence stirred controversy. In 1935, the *Iowa Engineer* commented:

> Things have reached a pretty pass when the girls can come over to the engineering side of the campus and beat the boys at what is theoretically their own game. Somehow it just doesn't seem to be quite right. But after all, honor to those to whom honor is due. At the Fall Honors Day Convocation, ... a girl ... walked off with the show. Alice Churchill, E.E. junior, received both the Pi Mu Epsilon calculus award and the Phi Kappa Phi high scholarship award. Perhaps this will serve as a stimulant to ... embryo engineers of the opposite sex ... to exert themselves a little more to uphold their much boasted "superiority" in such matters as engineering.[44]

Female engineering students themselves talked about their experiences in the singular—they simply didn't know enough others to refer to themselves as a group. Charlotte Bennett, who studied chemical engineering at Purdue in the 1930s, wrote, "I have surprised a good many people who thought I could not stick it out ... [and] I would make the same choice" again.[45]

That image of women as solitary invaders venturing onto masculine ground came to the forefront with World War II, when there simply weren't enough male engineers available. Just as manufacturers turned to "Rosie the Riveter" on the shop floor, companies sought to begin employing women at drawing boards and in engineering shops. But of course, managers soon encountered the obvious problem—they couldn't find enough women with relevant training ready to move into engineering positions.

War provided a rationalization for giving more women access to engineering education. Purdue civil engineering student Ellen Ziegler wrote in 1942, "Think of the vast reserve of engineers we might have if we had been training women ... during the past few years." The idea of women studying technical subjects suddenly acquired patriotic value. One month after Pearl Harbor, the University of Texas newspaper ran a photo showing the school's five female engineering majors working slide rules. The caption read, "No knitting or other sissy stuff for these five girls—they're doing their bit for national defense in a manly way."[46]

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University announcements and campus publications were filled with bulletins urging women to take up engineering and science. Purdue's paper bemoaned reports that fewer than thirty percent of 1942's female college graduates had majored in fields needed for national defense. "The slide rule is only part of engineering, but those who can handle one well are needed to fill the vacancies left by the draft.... A yen to build bridges or to know why an engine goes round is even more useful today than yesterday."[47]

To demonstrate to coeds how much potential they had, Purdue required all 1,300 female students to take a math and science aptitude test in December 1942. That announcement spread dismay across campus, with rumors that only women who scored well would be permitted to reenroll in spring. Administrators hastened to assure coeds that individual performances would not be held against them. Results were being compiled for national policy, "to find the percentage of college women who could be depended upon to replace men in jobs requiring some technical training." Meanwhile, Purdue handed out material promoting its science and math courses, emphasizing that all coeds with ability should select studies which would "equip them to fill a position ... in case the crisis becomes so acute that the national interest demands their services."[48]

The U.S. Office of Education, conscious of a growing manpower crisis, had wanted to draw women into war training from the beginning. Experts worried that "on the average women will require more training than men" since they had less technical backgrounds. As one Cornell instructor put it, women were "handicapped to the extent that by tradition their experiences have been womanly.... They have not had the advantage of playing with Erector Sets and tinkering with Model T's. They have the rather tough job of catching up on things mechanical ... in a relatively brief ... time." But there seemed no other way to meet industry's personnel needs.[49]

In 1943, fifteen colleges across the country offered ESMWT courses entitled "Engineering Fundamentals for Women," intended to help women with bachelor's degrees qualify for junior engineer positions with the navy, War Department, or other civil service. Those courses involved 320 hours' worth of work in engineering math, drawing theory and practice, mechanics of materials, surveying, and shop processes. When Westinghouse realized in 1944 that several of its draftsmen were about to be called into the forces, managers immediately hired fifteen female college graduates and put them through a six-month full-time ESMWT course.

The number of women with degrees in math and science was limited, and the WAACs and WAVES also sought to recruit such women. Schools ran newspaper advertisements and drummed up publicity to interest college students in war training. At Penn State, at least sixty-five women (most majoring in liberal arts, education, or home economics) signed up for classes in airplane and ship drafting. The campus paper editorialized, "We think [that free training of] six hours a week with a definite goal ahead, including an enviable salary, would be worth consideration of any coed.... [T]here's much to gain and little to lose by enrolling in these defense courses." Indeed, employers competed to attract participants; during one ESMWT course at Illinois Institute of Technology, companies hired all sixty women enrolled before they even finished class.[50]

In yet another government initiative, the Signal Corps trained over two hundred women for radio engineer jobs in the civil service. Women went to Purdue, Missouri, Illinois, Minnesota, Kansas, and other participating schools for a six-month course in radio theory, the physics of sound, electrical lab work, shop practice, math, drafting, and engineering materials. The women were paid standard wages for forty hours of classwork per week, plus overtime for Saturday study. The "under-engineer trainees," as the women were known, were then assigned to the Aircraft Radio Laboratory at Wright Field in Dayton, Ohio, center of the latest secret radio and radar development. Federal education experts took pride in their success at cultivating women for wartime technical work. One reported, "From talks I have had with young women who are in ... or finished training, it occurs to me that, although in many cases they are slightly overwhelmed with their first view of the engineering field, they feel that they are getting a much firmer grip upon this man's world into which they are being forced."

War even fostered appreciation of the potential talent of women in home economics, especially those majoring in domestic technology. For years, Iowa State had required household equipment students to take math, physics, and electrical work. In 1942, after Naval Research Lab recruiters came to interview those majors, the home economics department added a five-hour calculus course to help its women enter engineering. At industry's recommendation, the college also organized a special electrical engineering class to prepare home equipment majors for defense employment. Students who signed up were nicknamed WIRES, "Women Interested in Real Electrical Subjects." Professors originally planned to give "these girls ... elementary background [as] a gentle transition from biscuit baking," but as one instructor wrote, anyone "who expect[ed] to see the girls changing a fuse or repairing a toaster cord [ended up] sadly disappointed. Baby stuff! They learned those things in their own equipment lab when they were freshmen." WIRES were ready for "more rugged topics" such as magnetic circuits, vector diagrams, transformers, and synchronous motors. Though the program turned out only a handful of graduates, those women immediately entered into wartime testing and design work for Western Electric, General Motors, and General Electric.[51]

Desperate for skilled personnel, a number of companies established classes specifically to steer female students into their employ. At the request of Grumman Aircraft, ESMWT instituted an engineering aides' training course at Columbia University in 1942. That course was given five times, and 251 women completed it. The company's recruiting booklet read:

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> You probably never thought of yourself in engineering—that has long been considered a man's forte. Only a few years ago, we too considered it so. But every day the improbable becomes possible, and we have discovered that a girl with certain qualifications ... can be trained in a relatively short time.... With a dearth of available engineers, we are looking for young women to assist the men we have.... Their satisfactory handling of sub-professional assignments [leaves] our graduate engineers free to concentrate on more complex problems of aircraft design and production.

Grumman accepted women with college degrees in any major (though it preferred math, science, architecture or business) and paid each thirty dollars a week during training. Once women finished at Columbia and entered Grumman shops, they spent three afternoons per week getting additional training in aircraft structural layout.

Other airplane companies soon arranged similar programs. At Penn State, the Hamilton Standard Propellers Division of United Aircraft set up both six-month and year-long courses, training over 130 women as engineering aides. The "Hamilton Propeller Girls," as they were known, were enrolled in Penn State's engineering school, where they studied engineering design, aerodynamics, and metallurgy. At Rutgers, the Eastern Aircraft Division of General Motors ran three sessions of a three-month course in mechanical engineering, metallurgy, math, and shop. Eastern trained about fifty young women, one of whom described the opportunity as "one in a million."

Given the success of training women for aircraft engineering, other industries got into the act. Through Purdue, the Radio Corporation of America ran two eleven-month programs training over 140 women as engineering aides in radio design and quality control. Those trainees worked in Purdue's machine shops, observed RCA's Indianapolis plant, and studied engineering math, materials, electronics, radio circuits, shop practice, and drafting. One faculty member admitted that teaching RCA Cadettes changed his mind; while "three years ago [he] wouldn't have thought so," he came to believe that women definitely had a place in engineering.[52]

General Electric, in an advertisement headlined "Girls, Girls, Girls," announced that it was "hiring young college women to do work formerly done by male engineers ... [to] make computations, chart graphs, and calibrate fine instruments for use in the machine-tool industry.... Although no one expects these girls to become full-fledged engineers, most of them will be given the Company's famous 'test' course." GE recruited women with degrees in math or physics for its on-the-job training, but that pool was limited. Firms began reaching down further, to draw women still in college.

That was the aim of the Curtiss-Wright company, whose planes were a mainstay of the war and which was having trouble meeting production targets. In 1942, the firm developed a plan for training female engineering aides, whom it called "Curtiss-Wright Cadettes." The company chose seven colleges—Cornell, Penn State, Purdue, Minnesota, Texas, Iowa State, and Rensselaer Polytechnic Institute—to teach a special technical curriculum to a total of more than seven hundred women. Program representatives advertised in college papers and visited schools across the East and Midwest to recruit sophomore, junior, and senior coeds. Curtiss-Wright offered "a unique opportunity to participate in the war effort"; Cadettes would receive $10 per week during their tuition-free, intensive training. Once they were assigned to Curtiss-Wright research, testing, drafting, and production divisions, the women could earn about $140 a month.

A few women selected already had some experience with technical studies (for instance, studying architecture), but most, liberal arts or home economics majors, started cold. Cadettes underwent a ten-month immersion in aviation technology and science. Their course in flight theory taught fundamental aerodynamics, while the strongest students learned engineering math up through calculus. In drafting class, Cadettes practiced detailing actual airplane parts, following Curtiss-Wright standards and typical company blueprints. Studying engineering mechanics and materials, Cadettes used the same textbook as regular students, except that their problems in statics, dynamics, and structural analysis emphasized practical knowledge of airplane construction. To familiarize the women with company procedures, Curtiss-Wright created a class in job terminology and production methods. Entering school machine shops, Cadettes learned welding, soldering, and machine-tool operation to prepare them for shopfloor liaison work.[53]

At participating land-grant campuses, the Cadette program forced faculty to adjust to the sudden arrival of significant numbers of female engineers. Minnesota Cadettes remembered a "reputedly tough professor who strode into his first class and suddenly burst into uncontrollable laughter, eventually recovering to admit that he had never before faced 25 females wielding slide rules." But Cadettes could claim to be doing their part for the war effort, and on those patriotic terms, they were welcomed. Moreover, some skeptics ended up pleasantly surprised by the women's ability. At Penn State, roughly one-third of Cadettes received grades high enough to qualify for the dean's list. Assistant dean G. M. Gerhardt said such performances proved "that these girls could absorb and apply much more engineering training than anyone had anticipated." Instructors reported that the challenge of teaching women with little previous technical experience improved their classroom technique. One said, "I discovered that many things were not instinctively obvious which I had previously taken for granted.... Now I throw emphasis on really basic and difficult points.... My stock of practical examples ... is appreciably increased."[54]

Cadettes' presence also led male engineering students to reevaluate assumptions linking technical education to masculinity. Purdue's 1943 yearbook noted, "Tradition ... seems destined to vanish as the demand for man power opens careers for women in ... fields heretofore ... practically uninvaded by the fair sex."

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The *Iowa Engineer* went further, editorializing, "Men . . . were on guard for the preservation of the good name of Iowa State's engineering school when Curtiss-Wright . . . brought a group of girls here to study aeronautical engineering. . . . Girls in the wind tunnel lab, in the shop . . . caused the engineers to wonder, then acknowledge, and finally resign themselves to the fact that there would be similar incursions as long as the war continues, and perhaps even after the war."[55]

Schools benefited by participating in the program; when civilian enrollment fell, engineering departments could justify keeping men on staff by assigning them to teach Cadettes. Moreover, the Cadette program made great public relations in a nation pumped up over the war effort. Cadettes proved temptingly photogenic; local papers ran dozens of stories, and *Life* published a special feature. At the end of their crash course, Cadettes received certificates of acknowledgement, then went into Curtiss-Wright plants. Wartime was chaotic; some Cadettes stayed in their initial assignments for only a relatively short time before leaving for other employment or following husbands to a different location. Others remained at Curtiss-Wright for the duration. Though often underused, many appreciated the feeling of contributing to national defense and the relatively decent pay.

Though the Cadette program was a temporary wartime expedient, it helped break down barriers to women's participation in campus engineering culture. At Penn State, Curtiss-Wright delegates served on the Engineering Student Council, the first time women ever participated there. Since they were enrolled in aeronautical engineering, Iowa State Cadettes were eligible to join the campus chapter of the Institute of Aeronautical Science. Purdue Cadettes and Signal Corps women attended local meetings of the American Institute of Electrical Engineers, which "seemed glad to welcome girls into their organization, perhaps for reasons other than merely insuring a big membership." Cadette Marjorie Allen reported that over cocoa and doughnuts, AIEE men got "busy establishing themselves in the good graces of certain Cadettes." In any case, it marked a milestone, the first time that college meetings of professional engineering societies included a sizable representation of women.[56]

More than that, the Curtiss-Wright program marked the first time that enough women were studying engineering to form their own organizations. Students organized a Cadette Engineering Society on each of the seven campuses, with regular meetings featuring movies about aviation and guest speakers on engineering. Members also built model planes, practiced tearing down and rebuilding airplane engines, and discussed topics such as high-altitude flying.

Still more important, the presence of Cadettes and other women in special wartime training reflected a positive light on the growing number of women studying engineering as a regular college degree. By August 1944, Purdue had more than thirty women enrolled in engineering; by December 1945, about seventy-five. A critical mass made life easier; aeronautics major Helen Hoskinson remarked, "Now that lady engineers are not a novelty on this campus, people no longer stare at the sight of a girl clutching a slide rule." More than that, rising numbers helped validate the notion that women could handle technical subjects. Maxine Baker wrote, "We are not asking the men to . . . give up their places to us. We want only to be accepted as co-workers. . . . Let the feminine voice speak loudly."[57]

It was no coincidence that World War II brought a number of "firsts" for coeds in engineering. In 1944, the *Iowa Engineer* reported, "A woman invaded the Guard of Saint Patrick for the first time in the history of Iowa State College." Civil engineer Ruth Best joined thirty-three men initiated into the scholarly honor society that year. Her selection opened the gate; over the next few years, other female engineering majors also earned membership. Four months later, Eloise Heckert became the first Iowa State woman initiated into Pi Tau Sigma, the honorary mechanical engineering fraternity. In 1945, architectural engineering junior Mary Krumholtz became the first woman to edit Iowa State's engineering magazine. She immediately wrote an editorial saying:

> [S]lide-rule-pushing girls are no longer a rarity. . . . We see them on our own campus and they are not the problem they were once expected to be. In fact, they are a problem only inasmuch as their fellow students and instructors choose to make them one. . . . Obviously there is a long struggle ahead for any woman who presumes to enter a 'man's field.' Men cannot be expected to share the profession voluntarily, and in the dim, distant future when the break does come—and women are accepted rather than tolerated—the concession will be made only as a matter of necessity. Meanwhile we shall continue with our present compromise.[58]

Compromise was a good word for it; growing numbers of female students had not turned engineering departments into a feminist paradise. Some ridicule continued; the 1944 *Cornell Engineer* ran a headline, "WOES (Women of Engineering Schools) Are Here." The piece said, "Rumor has it that 17 woman engineers are at Cornell. Do they build up morale or do they provide distraction? Are they taking advantage of the boy-girl ratio in engineering, are they just trying to help the war effort, or do they want engineering careers?"[59]

Toward war's end, Cornell started to worry about women taking up too much room on campus, as returning veterans tightened up housing. Deans agreed that for the late spring term of 1945, departments should admit no new female undergrads, except in home economics. Cornell's engineering dean had already approved admission of nineteen women; combined with the eighteen women already enrolled, the engineering college thus exceeded its quota of twenty-five women by fifty percent. Cornell's vice president scolded the engineering school for carelessness and stated that absolutely no more female students would be admitted to engineering that semester.[60]

Through the late 1940s and 1950s, students and faculty at schools across the country publicly debated women's place in engineering. In 1955, Penn State engineering dean Eric Walker wrote an article titled "Women Are NOT For Engineering." Walker declared that despite the success of "unusual women" such as Lillian Gilbreth and Edith Clarke, most women did not have the "basic capabilities" needed to handle technical work. He concluded that teaching coeds engineering was not a sound investment, since "[t]he most evident ambition of many women is to get married and raise a family.... Few companies are willing to risk $10,000 on a beautiful blonde engineer, no matter how good she may be at mathematics." Two female engineering students at Florida State jumped to defend their sex, insisting that women's technical skills and professional commitment be respected. In a response headlined "Women Are for Engineering," Wilma Smith pointed out that increasing numbers of women wanted to continue careers after marriage. Penelope Hester added, "If someone can do a job well, why should he or she be denied the right to do that job? An all-male concept of engineering is based on prejudices and old-fashioned ideas.... A woman can be just as devoted to her job as a man, and maybe even more so."[61]

After the war, female engineering students had some momentum behind their claim for recognition. In 1946, about twenty female engineering students at Iowa State organized a local group called "Society of Women Engineers" (four years before the national group of the same name) to assist "in orienting new women students in the division." That same year, female students at Syracuse and Cornell vented their frustration at being excluded from several major engineering honor societies (or restricted to a "woman's badge" instead of full membership). The new honorary society they created, Pi Omicron, soon had chapters at schools around the country. Members held orientations for new female engineering majors and hosted speakers such as Lillian Gilbreth. The mission was "to encourage and reward scholarship and accomplishment... among the women students of engineering...; to promote the advancement and spread of education in... engineering among women." Then in 1950, female engineers on the East Coast began getting together, officially incorporating in 1952 as the Society of Women Engineers. Significantly, many of the group's early leaders had received their engineering degrees either just before or during World War II.[62]

Though women's foothold in engineering departments remained tenuous, World War II programs made a long-term difference. In subsequent years, the Cold War provided further justification for encouraging young women to pursue engineering. Educators, politicians, and government experts warned that in the atomic age, it would be fatal if the U.S. kept wasting half its brainpower. In 1952, Arthur Flemming, manpower chief in the Office of Defense Mobilization, wrote, "[W]e haven't got a chance in the world of taking care of that deficit of engineers ... unless we get women headed in the direction of engineering schools." Flemming warned, "Soviet Russia isn't making this mistake" of ignoring women's talent.

All told, World War II courses for Curtiss-Wright and other aircraft companies trained about 1,670 women as engineering aides. Hundreds more participated in the RCA, GE, and ESMWT programs. True, most of those who completed wartime training did not make lifetime careers out of engineering, but their experience left its mark on American colleges. A Penn State professor later remembered, "We had [two or three] girls in electrical engineering from the time I got here [in 1931] and I guess they had them before.... But to have groups of them like that!" That was the key difference. Before World War II, the one or two women who occasionally chose to pursue engineering at land-grant schools like Penn State were an anomaly, a curiosity. Wartime programs sponsored by government and private companies suddenly brought their ranks up to a critical mass. With several dozen or even a hundred at a time studying technical subjects, the women could provide each other with crucial intellectual and psychological support.

More than that, World War II gave female engineering students at places like Iowa State, Penn State, and Cornell a collective identity and a chance to build up the numbers over succeeding years. In 1949, there were 763 female students enrolled in engineering at schools across the U.S.; by 1957, that total had more than doubled to peak at 1,783. True, given that the number of male engineering students also soared during those years, women remained less than one percent of total engineering enrollment. But at individual institutions, the difference was apparent. As early as 1946, Cornell had 34 women enrolled in engineering, whereas in previous decades there had generally been no more than about four—and in many years, none. True, for years to come, the campus climate for engineering women would remain chilly, discouraging some to the point of dropping out. But those who had earned their degrees during the 1940s insisted that female students in wartime programs had proven that they could survive in modern engineering education.

Notes

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