REFLECTIONS ON THE HISTORY OF ENGINEERING IN THE UNITED STATES: A PREFACE TO ENGINEERING ETHICS

GTE Lecture
Center for Academic Ethics & College of Engineering
Wayne State University
Detroit, Michigan
19 November 1992

Professions like to trace their origins back to ancient times. So, for example, the American Medical Association's Principles of Medical Ethics cites certain provisions of Hammurabi's Code (about 2000 BC) as the earliest known code of medical ethics.[1] There is, of course, some truth in such going-back. The healers of ancient Babylonia resemble today's physicians in many ways. There are, however, many differences as well; and, for our purposes, the differences are more important. We will understand professions better if we start their history with the rise of modern markets about two centuries ago, the accompanying dissolution of the old distinction between trades and "liberal professions", and the slow emergence of something new.

By 1850, especially in England, we begin to see the modern pattern. The professions are connected both with a formal curriculum, ending with an examination and certification of some sort, and explicit standards of practice, a code of ethics.[2] Admittedly, those creating this new pattern seem unaware of doing something new. But there can be little doubt that they misunderstood their own actions. Even some of the terms they used were new. For example, the term "medical ethics" seems to have been coined in 1803 by a physician, Thomas Percival, for a book he thought was on an old topic.[3]

All this is by way of introduction. My concern here is not the history of professions in general, but only a small part of it, the history of engineering in the United States. Yet, since I am a philosopher, not a historian, even this narrow field belongs to others. I shall be trespassing, with the risk that entails.

I am taking the risk for four reasons. First, I believe that reading history can lead to philosophical insights. The past gives the present context. Second, I believe that some historians, those I have been reading, sometimes miss the obvious--or, at least, get the emphasis wrong--and therefore tend to mislead those trying to understand engineering. Third, though I will be trespassing, I have precedent on my side. Philosophers have long made a nuisance of themselves by pointing out the obvious in fields not their own--which is pretty much what I intend to do. The fourth reason for trespassing on the historian's field, the most important, is that the pay-off should justify it. A better understanding of the history of engineering should yield a better understanding of engineering and, in consequence, a better understanding of engineering ethics.

I. The Beginnings of Engineering in the United States

The first engineers in the United States were officers in the Revolutionary War; the first school of engineering here was a military academy, West Point.[4] This connection between engineering and the military was no accident.

Engineering began with the great army Louis XIV built after 1661. Though engineers were soon called upon for civilian projects--to build roads, bridges, and canals, to construct mines and oversee their operation, or to construct ships--, most of the training of these "civil engineers" was identical to that of military engineers. So, for example, when the French reorganized engineering education in 1794, creating the École Polytechnique, they put students of military and civilian engineering side by side for three years, separating them only in their fourth (and final) year of training, when they were sent to one or another school of "application" (the school of military engineering, the school of bridges and roads, and so on). All students at the

École Polytechnique wore uniforms and lived under military discipline.[5]

Establishing an engineering school in the United States in the first years of the republic was not easy. The first attempt occurred when George Washington was still only a general. Other attempts followed. Even with an Act of Congress in 1802, more than a decade passed before West Point had examinations, grades, or even a settled curriculum. The curriculum settled on, four years in length, was derived from the École Polytechnique. Along with the curriculum came a small library, recitations, examinations, one French officer, and several textbooks.[6]

Though another two decades would pass before anyone successfully copied West Point, the first attempt came soon. Alden Partridge had graduated from West Point in 1805, taught mathematics there for the next fourteen years, and briefly served as superintendent, leaving under a cloud. In 1820, he opened his own school--the American Literary, Scientific, and Military Academy--in his home town, Norwich, Vermont, to train officers for the army and engineers for public works.[7] In 1824, he moved the academy to Connecticut; and in 1829, back to Vermont. In 1834, the academy became Norwich University, apparently without any change of purpose, and so remains to this day, an experiment complete and forgotten.

Though Captain Partridge's school seems to have enrolled almost as many students as West Point for the period between 1820 and 1840, it did not do nearly as well as a engineering school. Of West Point graduates through 1837, 231 became civil engineers; of Norwich graduates during the same period, only about 30 did (and these seem generally to have held less responsible positions).[8]

The 1830s were more hospitable to copies of West Point than the 1820s; the next decade, even more so. The Virginia Military Institute was founded in 1839; the Citadel, South Carolina's

Military College, in 1842; and the Naval Academy at Annapolis, in 1845.[9] What was true of engineering education in general was certainly true of civil engineering. The late 1830s mark the real beginning.

The age of Rensselear Polytechnic Institute, our oldest school of civil engineering, may seem to refute this claim. But Rensselear, founded in 1823, is in fact the exception that proves the rule.

Rensselear was founded without either "Polytechnic" or "Institute" in its name. Like Norwich, it went through several changes, though it never moved. Stephen Van Rensselear, a gentleman farmer with a Harvard degree, gave the school both his name and money in order to train <u>teachers</u> of agriculture and mechanical arts for the grammar schools of his locale. The original curriculum was a single year (as one would expect of a normal school of the day).

But by the 1830s, Rensselear had become a kind of scientific finishing school for graduates of colleges of liberal arts like Harvard or Dartmouth. It may, in fact, rightfully claim to be the first American graduate school. Many of the graduates of this period became important in American geology, botany, and geography.[10]

But Rensselear was not yet an engineering school. It did not award a degree in civil engineering until 1835 and did not have a distinct engineering curriculum until the late 1840s.[11] That curriculum, three years in length, along with the school's present name, seems to owe much to an 1847 trip to Europe by the school's director, young Benjamin Franklin Greene (who had himself graduated from Rensselaer in 1842 with a degree in engineering).[12] The addition of "polytechnic" to Rensselear's name did not signal any direct connection with the <u>École Polytechnique</u>. By then, Europe had many polytechnics.[13] What the new name did signal was that thereafter Rensselear would focus on training engineers rather than scientists and that French schools, rather than American or English, had provided the models.[14]

Why did the first engineering schools in the United States use French models? The answer is that the French then provided the only practical models. The English, though already leading Europe in manufacture in 1800, would not have a respected school of engineering until well after mid-century[15]; and, whether we even say the English had civilian engineers in 1800 depends on how close we judge the analogy between the skills of the mostly self-taught mechanics, industrialists, and builders of England and the French "civil engineers" whom they admired and studied.[16] The English did well with what was, in effect, training through apprenticeship. In 1800, the United States was almost without engineers to whom apprentices could be sent.[17] So, like most of Europe, the United States copied France.

All our early engineering schools shared a focus on mathematics, physics, chemistry, and drawing. There was also a good deal of bookkeeping, surveying, measurement, and other practical subjects. There was little of the Latin, Greek, or Hebrew, classical literature, or rhetoric characteristic of the liberal arts college of the day, though there might be enough French or German to read untranslated texts.

The difference between these early engineering schools and the liberal arts colleges of the day was not, however, that the engineering schools taught science while the liberal arts colleges did not. By 1800 Harvard, Brown, William and Mary, North Carolina, and the other important colleges already had professors of mathematics and natural science.[18] The early engineering schools differed from the liberal arts colleges primarily in offering an education that was explicitly practical in a way that the college education of the day was not. But practical for what? The historian Charles O'Connell tells a story suggesting an answer:

In 1825, James Shiver led a team of civilians to survey the route for an extension of the National Road in Ohio. Since the Road was a project of the Army Corps of Engineers, Shiver reported to Colonel Macomb, the Army's chief engineer, in Washington. Shiver was soon reporting that his team found it impossible to use the Army's standard forms. Macomb wrote back that the forms "were conceived to be more full and distinct, and consequently better adapted to the fulfillment of the purposes for which they were intended" than what Shiver proposed instead. But, because Macomb had dealt with civilians before, he made allowances. The "civilian brigade" could use Shiver's simpler forms for now, but should switch to the Army's forms "as soon as they shall be understood".[19]

Shiver was a competent civilian used to working the way civilians then did. Macomb spoke for an organization more complex than any other in the United States. In truth, the Army's ways made sense only in the Army. The United States was then largely rural, with most citizens living in towns under 2500. Its industry, though already inventive, still consisted almost entirely of small companies. Such companies did not need, or even understand, the standardization the Army took for granted.[20]

Even a major project like a canal could still be undertaken without engineers. Indeed, the greatest of them all, the Erie Canal, was begun about the time West Point settled on a curriculum (1817) and completed about the time Rensselear was founded (1825). Though often called "America's first engineering school", the Erie was mostly a school of hard-knocks. Those in responsible charge were surveyors, lawyers, or gentleman farmers. They learned as they went, sometimes from visits to other canals or from books, and sometimes from experience.[21] Whether these "canal engineers" are properly engineers at all is, like the analogous question about the British engineers of the same period, one that can be answered either way, depending on whether one chooses to emphasize the analogies with today's engineers (what they built) or the disanalogies (their training and methods).

What was true of the early canals was not true of the early railroads. Even the Baltimore & Ohio Railroad, often compared to the Erie canal and called "America's first school of railroad engineering", employed school-trained, especially West-Point-trained, engineers from the time work began in 1824.[22]

What explains this difference between the canals and the railroads? At least four factors seem relevant: First, while canals were an old technology, railroads were not. Insofar as railroads were a new technology, experience counted for less and a knowledge of fundamental principles for more. Second, railroads required more centralized planning than did canals. The chief economic advantage railroads had over canals was speed. Speed was possible only if lines were clear, water and wood were available at set distances, repair crews could be sent out quickly, and so on. Third, by 1824, West Point had been in existence long enough for its graduates to prove themselves likely to be useful to railroads. Fourth, West Point graduates brought with them styles of organization that suited engineers. So, for example, in 1829, Lieutenant Colonel Long, having worked on the B&O for five years, published the first Rail Road Manual, a book upon which later railroad engineers, schooled or not, would rely.[23] There are many striking similarities between this manual and the Army's.[24]

Even so, the railroads of the 1820s or 1830s were not the domain of engineers they would become. The true achievements of American engineers of this period are of a different order. For example, between 1825 and 1840, the Army's Arsenal in

Springfield, Massachusetts developed procedures eventually much admired in Europe as "the American System". This system made weapons parts interchangeable to a degree never before achieved; it also subjected skilled workers to a new discipline, including the substitution of an hourly wage for the traditional piece rate. The Arsenal was a model for later mass production.[25]

In 1850, the first year the census counted engineers, only about two thousand Americans identified themselves as non-military engineers, two thousand in a population of about twenty-three million.[26] Today, in a population barely ten times larger, we have a thousand times that number of engineers. Engineers are numerous only where there are large organizations to employ them. In 1850, the United States still had few such organizations.

Engineering is sometimes described as a "captive profession" because most engineers work in large organizations.[27] Engineering is contrasted with "free professions", like law and medicine, where most members practice as individuals or in small groups (or, at least, did so until recently). Unfortunately, the term "captive" gives the wrong emphasis to an important insight.

Engineering is no more a captive of large organizations than the heart is a captive of the body. The relation between engineering and certain large organizations, like that between the heart and the body, is symbiotic. Work in large organizations is not a nightmare from which engineers will some day wake; it is their natural habitat. We don't need the skills of engineers to do what machinists, draftsmen, architects, carpenters, millwrights, and the like can do alone or in small groups. We need engineers for the vast undertakings typical of large organizations.

II. Middle Period: The "Fragmenting" of Engineering

In the United States of 1850, civilian engineers still formed a single occupation. In 1867, when a few hundred of them established the first national engineering society, the American Society of Civil Engineers (ASCE), any civilian engineer could join.[28] But, even then, engineering had begun the branching into specialties that would, by 1920, produce five major societies (for civil, mining, mechanical, electrical, and chemical engineering), and many smaller organizations, each with membership requirements excluding most other engineers.[29]

The history of the half century from 1870 to 1920 can be read as tragedy, the loss of the primal unity of engineering under the impact of industrialization. One history of mechanical engineering even titles its chapter on this period "Engineering: The Fragmented Profession".[30] There are at least three reasons not to read history this way.

First, the whole history of engineering, not just of this period, is a history of such branching. The first branching was between military and civil engineering in the middle of the 1700s.

A second reason not to read history this way is that the half century after 1870 was a period of great success for engineering. In 1880, the United States, with a population of 40 million, counted 7000 civilian engineers--more than triple the number in 1850 (while the general population barely doubled). Yet, this impressive increase gave no indication of what would happen during the next four decades. The 1920 census reported 136,000 engineers, twenty times the number in 1880 (in a population that had again barely doubled).[31]

A third reason not to read the history of engineering after the Civil War as tragedy is that the enormous branching of engineering is inevitable given the enormous growth of industries that rely on engineers.

Engineering has an important connection with mathematics and natural science, as the similarity between early engineering curricula and today's suggests. But engineering is more than mathematics and natural science. Much of what engineers know are ways of organizing work, giving instructions, and checking outcomes. These vary from industry to industry. So, for example, a civil engineer designing pipes that ordinary plumbers are to install should <u>not</u> use tolerances an aerospace engineer could use without a second's thought.[32]

This field-specific knowledge is largely the result of experience, originally the experience of individual engineers, "field experience" as well as the results of running tests in a laboratory or pilot plant. Because engineers routinely record and report their experience in the same way, this individual knowledge gets passed on to other engineers with whom they work. Eventually, much of it ends up in the tables and formulas that fill the manuals written for those in the field. From there, it works its way into customer specifications, government regulations, and courses taught those entering the field. Though this knowledge generally takes the form of graphs, equations, mathematical formulas, and drawings of things, it has little to do with natural science. It is congealed experience of how humans and things work together.

Engineers often complain that when new technology works--think, for example, of the space shuttle--scientists get the credit; but, when it fails, engineers get the blame. While engineers are, I think, right about how praise and blame are usually distributed, I don't think they should complain. That distribution is a compliment to engineers--though one given with the back of the hand. It implies that scientists only <u>experiment</u> and experiments generally fail, while engineers <u>engineer</u> and engineering generally succeeds. An engineer's failure is noteworthy for the same reason a scientist's success is--it is unexpected.[33]

What makes engineers so likely to succeed is not their knowledge of mathematics and natural science. That they share with scientists. What makes them so likely to succeed is their knowledge of particular industries, what works and what does not work there, what engineers call "engineering science". Such knowledge is not the domain of any natural science. It is sociological knowledge, a knowledge of how people and tools work together; but it is nonetheless engineering knowledge. Only engineers know much about such matters.

Here we reach a second insight into engineering. Though engineers often describe themselves as applying natural science to practical problems, they could just as easily, and more accurately, describe themselves as applying knowledge of how people work in a certain industry. Engineering is at least as much management as it is natural science. All engineers share the ability to give mathematical structure to the problems they encounter, the ability to draw on the natural sciences for help in developing solutions, and the ability to state each solution as "a design" or set of useful specifications. But these designs or specification are, in effect, rules governing someone's work.[34] Engineering is, and always has been, technical management.[35]

Technical management requires detailed knowledge of particular techniques. When such knowledge becomes so great that no one can learn it all, knowledge of techniques in one industry will exclude similar knowledge of techniques in other industries. Engineers will have to specialize and that specialization will tend to break along industry lines.

But (it will be said) other occupations--law and medicine, for example--have specialized without fragmenting in the way engineering has. Lawyers have the American Bar Association; physicians, the American Medical Association. Why then should engineers not have an American Engineering Association rather than so many interlinking societies, boards, councils, joint committees, and institutes that no engineer knows more than a part? The branching of engineering may have been inevitable; this fragmentation was not.

While I agree that the fragmentation of engineering was not inevitable, I think comparison with law and medicine will help to explain what made it likely. Until recently, a majority of lawyers and physicians worked alone. Their employers, the client or patient, might come in with any sort of problem. That unspecialized practice maintained a common body of experience in law and medicine for which engineering has had no counterpart since well before 1900.

Today, of course, <u>that</u> common experience has largely disappeared. Both lawyers and physicians now commonly specialize. But they still do not work the way engineers long have. Though they now commonly work in groups just as engineers do, they do not work in the same kind of group. Engineers generally work with engineers in their own field: civils, with civils; mechanicals, with mechanicals; and so on. A team of attorneys or physicians is, in contrast, likely to be made up of specialists in different fields. The client or patient still provides a common experience for lawyers or physicians, something those employing engineers generally do not. The very name of most engineering fields is also the name of a kind of employer, the industry in which engineers of that kind predominate. Engineering could remain a single occupation only where engineers had so little to do that they had little reason to specialize.

III. Who is an Engineer?

Almost from the beginning of engineering, engineers have disagreed about the relative importance of the scientific (especially, mathematical) knowledge engineers share and the specific practical knowledge that tends to divide them. Those emphasizing practice have tended to take an interest in professional ethics; those emphasizing science have not.[36] We shall learn a good deal about what engineering is--or at least what it has become--by taking a look at how this disagreement has affected the education of engineers.

The practical emphasis in engineering education has long appealed to practitioners, especially those who began as apprentices rather than students: Teach engineers what they need to know to do the job they are going to do (the extremist would say). Forget theory. Get the engineer into the shop as soon as possible.[37]

At this extreme, the practical approach would exclude not only courses in the humanities, social sciences, and other typical elements of a liberal education but also much engineering science. It would, in effect, substitute vocational training for the university education that has long been the norm for training engineers.[38]

The early history of engineering in the United States includes many experiments with practical education in a college or other academic institution, all more or less short-lived. For example, Amos Eaton, who taught civil engineering at Rensselear in the 1830's, described its program in this way: "The cloister begins to give way to the field, where things, not words, are studied." Eaton claimed that no mathematics more advanced than arithmetic was necessary to teach engineering, that the most important part of engineering could not be learned from any book, and that the civil engineering text used at West Point was good only for "closet reading".[39] Yet, during Amos' tenure, Rennselear was no more successful at training engineers than was

Norwich.[40] And, when Greene replaced Amos, Rensselear moved much closer to the scientific extreme which, by the standard of the times, West Point represented.[41]

Beginning with the Erie Canal, many large undertakings in the United States tried the practical approach as a way of supplying technical skill not obtainable in any other way. Whether these count as attempts to train engineers in the shop is an open question. I will give just one (late) example.

During the 1890s, General Electric offered a course in "practical engineering" for $100. To be eligible, one had to be a "young man" at least 21 years old and have either a degree in civil, mechanical, or electrical engineering or two years experience in practical electrical work or two years in a machine shop. The course of study, a year long, consisted of rotating through various departments of GE's Lynn Works: four weeks in the Shop Plant doing wiring, two weeks in the Arc Department assembling arc lamps, and so on. There was no formal instruction.[42]

What are we to make of this shop training? Notice that, for this course in "practical engineering", two years of work experience was considered equal to a college degree in engineering. By the 1890s, a first degree in engineering would have required four years, just as it does today. So, at GE, practice was not only a substitute for formal education, it was, it seems, considered, year for year, twice as good. This is a striking attitude, especially in a company which, like GE, was then among the technologically most advanced. What explains GE's attitude?

We must, I think, recognize that our understanding of "engineer" (and of "engineering") has changed over time. The term "engineer" was vague in 1890 and, though less vague than it used to be, is still pretty vague today. But it is not confused.

A term is confused when any case to which it is thought to apply is disputable. A confused term, such as "round square", has inconsistent criteria of application. "Engineer" is not like that. There are clear cases. On the one hand, someone with a degree in civil or mechanical engineering and several years of successful practice, is certainly an engineer. On the other hand, a train operator or boiler tender, though still called "engineer", clearly is not an engineer in the sense relevant here. Such "technicians" are engineers only in a sense belonging to an earlier age.

Though not confused, "engineer", like other terms, is still vague. In addition to the clear cases, there are disputed cases. One contemporary dispute concerns whether one can, by getting the right experience, become an engineer without a degree in engineering (for example, with only a degree in physics or chemistry). Complicating this dispute is a subsidiary dispute concerning which experiences are of the right kind. Is supervising engineering work for a decade or so the right kind? Or must you actually do some engineering yourself? And what constitutes "doing engineering"? The boundaries of engineering remain quite fuzzy.

Back in the 1890s, the boundaries were even fuzzier. Then mechanical engineers were still at pains to distinguish themselves from "mere mechanics"[43]; electrical engineers had a similar problem distinguishing themselves from "mere electricians"[44]; and so on. What GE then meant by "practical engineering" might today be identified by a two- or four-year degree in "technology" rather than "engineering". But, back in the 1890s, that was not an option. Engineers had to find other ways to explain how they differed from mechanics, electricians, and other craftsmen with whom they shared some tasks and much technical knowledge. Engineers found only two ways to explain the difference. Both emphasized the scientific element in engineering.

One way to distinguish engineers from craftsmen was to understand engineering as a kind of management.[45] Engineers issue orders; those with technical skills merely carry them out. Engineers are officers in the army of production.

This way of distinguishing engineers from craftsmen is plainly inadequate. It fails to explain why engineers should be in charge. The explanation cannot simply be that the employers so ordains. If being put in charge of engineering work is all that distinguishes engineers from other employees, anyone put in charge of engineering work would be an engineer. Engineers have generally supposed that engineering requires more than that.[46]

Engineers seem, then, pushed to claim that engineering requires knowledge craftsmen do not have: Engineers can give orders to craftsmen because engineers know things that mere craftsmen do not. This claim, though plausible, is plausible only if the knowledge in question depends, at least in part, on training outside the shop. Knowledge of natural science and advanced mathematics certainly is such knowledge. Hardly anyone would suppose much of those subjects could be learned in the shop.

That is one advantage of understanding engineering as fundamentally "scientific" (rather than "practical"). There are at least two other advantages. First, a common academic training is generally considered one crucial mark of a profession. If engineering is ever to be a profession like law or medicine, engineers cannot let being an engineer depend on how an employer happens to define one's job. Credentials, not employment, must define the engineer. Second, engineering's unity, insofar as it survives, depends heavily on all engineers having an education that they share with each other. Emphasis on what goes on in the shop stresses just those features of engineering that threaten to divide engineering into many mutually incomprehensible occupations. In contrast, engineering-as-science seems to confirm the sense most engineers have that, for all the immense differences between fields, virtually all engineers share something that distinguishes them both from ordinary workers and from ordinary managers.[47]

The question "Who is an engineer?" sounds like a philosopher's question--and it is. But it is also a practical question: Every engineering society that decides, as most do, to limit membership (or a certain category of membership) to "engineers" will have to define "engineer" with more or less precision. The historian Edwin Layton has taught us much about the consequences of adopting various definitions. Definitions close to the practical pole tend to turn engineering societies into trade associations; definitions close to the scientific, to exclude many who shape the projects engineers carry out and do much to maintain discipline among engineers.[48]

Layton has, however, taught us that while failing to make clear how hard it is to say what an engineer is. In particular, he has failed to notice that, at its extreme, engineering-as-science can be as disastrous for engineering as engineering-as-practice. Training engineers as scientists, if only as "applied scientists", tends to turn out scientists rather than engineers.[49] Consider, for example, the Lawrence Scientific School, founded in 1847 as part of Harvard, to teach: "1st, Engineering; 2d, Mining, in its extended sense, including metallurgy; 3d, the invention and manufacture of machinery."[50] By 1866, Lawrence had graduated 147 students: 94 of these became professors or teachers; 5 became college presidents; but only 41 actually became engineers (as against 126 from Rensselaer during the same twenty years).[51] The Massachusetts Institute of Technology opened in Boston in 1865 in large part because Lawrence had failed as a school of engineering.[52]

Nonetheless, during much of this century, especially after World War II, engineering education moved ever closer to the scientific extreme. Programs in specialized fields of engineering--everything from agricultural engineering to telephone engineering--disappeared from the undergraduate curriculum, leaving only the larger divisions--civil, chemical, electrical, and the like. And even courses in these fields tended more and more to emphasize general principles, calculations, and laboratory work. Students were left to learn the art of engineering after graduation, if at all.[53]

Only recently have engineering schools begun to move back toward practice. They have done so largely under pressure from industry and the board that accredits engineering schools. This counter-movement has, however, <u>not</u> meant a return to the shop. Engineering schools have, instead, begun to think of engineering in a new way, that is, as fundamentally concerned with design. Some results of this new thinking are already in place, for example, senior courses in engineering design. Others results are only now showing up, for example, as design elements in junior or even sophomore courses in engineering science. And some results are only at the stage of talk or experiment, for example, as attempts to include in design courses everything from the ethical issues a design might raise to the practical problems of getting colleagues and superiors to adopt one's design.

In retrospect, these recent developments seem both sound and overdue. The stereotype of engineering as the logical or, rather, mechanical solution of practical problems by deduction from scientific principles misses the creative side of much engineering, something that should have been obvious from the striking newness of so much of what engineers have produced, whether the bridges early railroad engineers built or the bewildering variety of today's computers.

Of course, engineering is not only inventiveness, just as it is not only science or only management. We have come to want engineering rather than mere invention in many departments of life in part because engineers work within restraints other inventors--whether architects, industrial designers, or mere handymen--do not. Engineers have distinctive routines for assuring safety, economy, reliability, durability, manufacturability, and so on. These routines, and the engineering science behind them, are subordinate to engineering design. But, though subordinate, they are fundamental to engineering, much as a certain pattern of rhyme and meter is to making a sonnet.

Who, then, is an engineer? Today we must answer: anyone who can design as engineers do.[54] Unfortunately, we have only the roughest idea of what engineering design is. Today, the philosophy of engineering is where the philosophy of science was a hundred years ago. We have barely begun to understand that there is a question.[55]

IV. Ethics and the Profession of Engineering

I have so far spoken of engineering as an "occupation", not a "profession". I had a reason. While the old expression, "liberal profession", referred to any occupation suitable for gentlemen, the modern use of "profession" requires more--organization, with standards of admission, including both training and character.[56] In 1850, engineering was still not a profession in this sense; nor was it so even in 1900. Today, it is. What explains the change?

Until this century, engineering societies were primarily scientific associations. So, for example, the American Society of Civil Engineers was established with the purpose of "advancing knowledge, science and practical experience among its members, by an exchange of thoughts, studies, and experience."[57] There was no suggestion either of improving the formal education of engineers or of setting standards of conduct.

Indeed, the first efforts to set minimum standards for engineering education came from the engineering schools, not from practicing engineers. In 1893, at the Columbian Exposition in Chicago, a few feet from where I now live, seventy engineering teachers organized the Society for the Promotion of Engineering Education (SPEE), later to become the American Society of Engineering Education (ASEE).[58] While the SPEE undertook a number of valuable studies of engineering education, making many influential recommendations, not until 1932 did the major engineering societies establish the Engineers' Council for Professional Development (ECPD) to accredit engineering curricula.[59]

The adoption of standards of conduct began earlier. Indeed, in one sense, it began when engineers first distinguished themselves from those unable to work the way engineers do. Engineering can be defined (in part) by standards of competence. But that is true of every skilled occupation. Ethical standards, not standards of competence, distinguish professions from other skilled occupations.

Engineers in the United States lacked distinctive ethical standards until the second decade of this century. Why did they not adopt such standards earlier? Why did they adopt them then? I will venture a guess. Engineers did not adopt ethical standards earlier for the same reason that most of today's professions, including law and teaching, did not. They did not see the need.[60]

Until this century, engineering was a clubby affair. There were relatively few engineers and those few worked in a small world in which gossip maintained what discipline was necessary. But, by 1900, that time had passed. Cities had grown up where small towns had been. The big cities of 1850 or 1870 had tripled, quadrupled, or quintupled in size. The same thing had happened to the companies for which most engineers worked.[61] And engineering itself had grown enormously. The few thousand engineers of 1870 had become more than a hundred thousand and seemed likely to continue to increase rapidly. By 1900, most engineers were young. College or technical school was, or at least soon would be, the primary route to a career in engineering. Old systems of apprenticeship were being swamped.

The old men of the profession naturally sought new means to do what they could no longer do by the old. A formal code of ethics must have seemed one way to help the young understand what was expected of them. So, early in this century, each of the major engineering societies set up a committee to draft a code of engineering ethics. The drafting proved harder than expected. The committees found that they agreed on less than they had supposed. Even determining what that little was took much effort.[62] The societies were not only writing down what they agreed on, they were also hammering out new agreements. What began as an attempt to preserve the past ended in a new profession.

After World War I, there was a smaller round of code writing; after World War II, another; and then, starting in the 1970s, the largest round yet. All this code writing has produced much coordination among major engineering societies and substantial agreement on what a code of ethics should contain. Today, engineers have relatively clear standards of conduct they can cite when offering advice to one another, when criticizing one another's work, or when seeking to prevent certain conduct. What engineers still lack is a systematic way to protect members of their profession who act ethically when an employer or client wants something else. As with other professions, so with engineering: ethics is unfinished business.

V. Concluding Remarks

We all have a tendency to see institutions, professions, and even people as more or less complete, as Platonic Ideas dropped into history. This is plainly a mistake when trying to understand people. We all know that, however smooth the surface we show the world, we are beings ever changing or, at least, ever capable of change.

Since I believe this to be true of professions as well, I have tried to describe engineering as an evolving institution, one that people much like us have made, not always intending what they achieved, imperfect, as all human works are, and therefore capable of improvement. I believe that thinking of engineering in this way will help engineers both to understand and to resolve the ethical problems they face. I also believe that thinking of engineering in this way will help the rest of us understand engineering. It is in this belief that I offer this talk as a preface to engineering ethics.

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NOTES

I should like to thank Tom Misa and Sid Guralnick for many helpful comments upon an earlier draft.

1. "Principles of Medical Ethics", in Codes of Professional Responsibility, edited by Rena A. Gorlin (Bureau of National Affairs: Washington, DC, 1986), p. 99.

2. The first of these modern professions was the Apothecaries, who reorganized in 1815. The other liberal professions followed only slowly, beginning with the solicitors in the 1830s. See, W. J. Reader, Professional Men: The Rise of the Professional Classes in Nineteenth-Century England (Basic Books: New York, 1966), especially, pp. 51-55.

3. Thomas Percival, Medical Ethics; or A Code of Institutes and Precepts Adapted to the Professional Conduct of Physicians and Surgeons (1803).

4. See, for example, Lawrence P. Grayson, "The American Revolution and the 'Want of Engineers'", Engineering Educations __ (February 1985): 268-276.

5. I defend this claim in "Technology, Values, and Ethics", forthcoming.

6. "Sylvanus P. Thayer was appointed director in 1817, by which time enrolment and teaching staff had increased to 250 cadets and 15 professors covering mathematics, 'engineering', and natural philosophy, recently joined by Claude Crozet (1790-1864, a graduate of the École Polytechnique, who introduced the teaching of descriptive geometry to the college, and in 1821 published the first textbook on the subject...Thayer graduated from Dartmouth in 1807, and from the Military Academy in 1808. He had studied military engineering developments in France and this influence was evident in his reorganization of the curriculum and mode of instruction at West Point. He used texts employed at the École Polytechnique, divided classes into small sections, required weekly class reports, and developed a grading system." George S. Emmerson, Engineering Education: A Social History (Crane, Russak & Company: New York, 1973), p.140-141.

7. Though Patridge did now and then teach a course in civil engineering, he was not a civil engineer (and, apparently, was barely qualified to teach the course). The West Point he tried to reproduce was the pre-1817 version. He rejected most of the innovations his successor as Superintendent, Sylvanius Thayer, introduced. For more on this, see Thomas J. Fleming, West Point: The men and Times of the United States Military Academy (William Morrow & Company, Inc.: New York, 1969), esp. pp. 3-14 and 34.

8. Daniel Hovey Calhoun, The American Civil Engineer: Origins and Conflict (Technology Press (MIT): Cambridge, Massachusetts, 1960), p. 45. Compare James Gregory McGivern, First Hundred Years of Engineering Education in the United States (1807-1907) (Gonzaga University Press: Spokane, Washington, 1960), pp. 42-45 and 38; and Emmerson, 141-142.

9. All the histories of engineering education cited here ignore both the Virginia Military Institute and the Citadel. Most also ignore both Annapolis and the impact of naval engineers on the development of mechanical engineering in the land-grant schools after the Civil War. (For one who does not, see Monte A. Calvert, The Mechanical Engineer in America, 1830-1910 (Johns Hopkins Press: Baltimore, 1967), esp. pp. 48-51.) A surprising number of engineering schools were--like Texas A&M--virtually military academies until the 1960s. All this leads me to suspect that the relation between engineering and military education has, until quite recently, been a lot closer than the histories of engineering education indicate. That relationship might explain much about the characteristic attitudes of American engineers in times past--and why many of these have begun to fade in recent years.

10. McGivern, 50-51. See also Ray Palmer Baker, A Chapter in American Education: Rensselear Polytechnic Institute, 1824-1924 (______________: New York, 1924), pp. 48-56.

11. Baker, 35 and 44-46. But about 25 of its graduates from the period before 1840 did eventually become engineers. Calhoun, 45.

12. "Though Eaton [the school's first director] had insisted that most colleges attempted to teach so many subjects that they could teach none of them well, and that Rensselaer should limit its activities primarily to the sciences, progress in them had been so rapid that Greene [the new director in 1847] concluded

that it was again time [for the school] to narrow its field." Baker, p. 39-40.

13. Frederick B. Artz, <u>The Development of Technical Education in France, 1500-1850</u> (MIT Press: Cambridge, Mass., 1966), pp.______.

14. Emmerson states that Rensselear's new curriculum was modeled not on that of the <u>École Polytechnique</u> but on the <u>École Centrale</u> of Paris. Emmerson, pp. 148 and 153-156. McGivern says the same, p. 59. But neither tries to explain the change of name.

15. The British did, it is true, establish a school of military engineering at Woolwich in 1741. The school retained a number of notable applied mathematicians who wrote some textbooks engineers found useful. Emmerson, 33. Yet, unlike West Point, Woolwich seems to have had little influence on engineering generally, or on engineering education in particular, even in England, until the second half of the nineteenth-century, that is, after talent replaced patronage as the primary means of gaining entry. Reader, 96-97.

16. W. H. G. Armytage, <u>Social History of Engineering</u> (Faber and Faber: London, 1961), p. 160-161. Jonathan Williams, the first superintendent of West Point, observed in 1802: "To be merely an <u>Engineer</u>...is one thing, but to be an <u>Officieur du Genie</u> is another. I do not know how it happened but I cannot find any full English Idea to what the French give to the profession." Quoted in Thomas J. Misa, "The Machine in the Academy", unpublished (12 December 1980), p. 18. The irony, of course, is that, when the term "engineer" entered English from the French, it was to refer to what distinguished the officieur du genie from the architects, millwrights, and the like the English already had.

17. For a more or less complete listing of the dozen or so "engineers or quasi-engineers" available for public works in the United States before 1816, see Calhoun, 7-23. Calhoun is also good on what in American culture made it hard for even these few to find employment.

18. McGivern, 15-23.

19. Charles F. O'Connell, Jr., "The Corps of Engineers and the Rise of Modern Management, 1827-1856", in Military Enterprise and Technological Change, edited by Merritt Roe Smith (MIT Press: Cambridge, Massachusetts, 1985), pp. 95-96.

20. Merritt Roe Smith, "Army Ordnance and the 'American system' of Manufacturing, 1815-1861", in Military Enterprise, pp. 40-86.

21. Elting Morison, "The Works of John B. Jervis", in From Know-How to Nowhere, ; and James Kip Finch, The Story of Engineering (Doubleday & Company: Garden City, New York, 1960), pp. 262-265.

22. Finch, 267-269.

23. Finch, 268-269.

24. O'Connell, in Military Enterprise, pp. 100-106. Note, especially, the initial resistence of the civilians to army-style standardization.

25. Smith, in Military Enterprise, 77-78. See also David A. Hounshell, From the American System to Mass Production, 1800-1932: The Development of Manufacturing Technology in the United States Johns Hopkins University Press: Baltimore, 1984).

26. Edwin T. Layton, Jr., The Revolt of the Engineers (Press of Case Western Reserve University: Cleveland, 1971), p. 3. The Census used the term "civil engineer" which, at that time, probably would have included mechanical engineers (and, indeed, all other nonmilitary engineers).

27. The phrase in quotes is Steve Goldman's. See "The Social Captivity of Engineering", in Critical Essays in Engineering and Applied Science, edited by Paul Durbin (Leheigh University Press: Bethlehem, PA, 19__). But the sentiment seems to be widespread. See, for example, David Noble, America by Design (Alfred A. Knopf: New York, 1977). His nostalgia for the lost shop culture seems to confuse inventing in general which, indeed, can exist in small (and even isolated) organizations and engineering (a special kind of inventing: centralizing, standardizing, and so

on) which probably cannot. The shop culture, however admirable, seems to lose out to engineering in certain environments--capitalist or not. Noble has contributed to our understanding of what might give engineering that advantage (while giving it a cast more sinister than necessary on the facts even as he presents them).

28. The ASCE was actually founded in 1852, its membership almost entirely in New York City. It seems, like other attempts at organizing engineers before the Civil War, to have died out within a few years. The connection with the ASCE of 1867 seems to be tenuous, another example of professions trying to add to their lineage. For a bit more on this, see Layton, 28-29.

29. For some of this history, see--beside works cited here--Bruce Sinclair, A centennial History of the American Society of Mechanical Engineers, 1880-1980 (University of Toronto Press: Toronto, 1980); and Terry S. Reynolds, 75 Years of Progress: A History of the American Institute of Chemical Engineers (American Institute of Chemical Engineers: New York, 1983).

30. A. Michal McMahan, The Making of a Profession: A Century of Electrical Engineering in America (Institute of Electrical and Electronic Engineers: New York, 1984), Chapter 11.

31. Layton, 3.

32. Compare Billy Vaughn Koen, "Toward a Definition of the Engineering Method", Engineering Education __ (December 1984): 150-155.

33. Engineers also have a tendency to claim successes for engineering whether the person responsible was in fact an engineer by training. It is this tendency that leads engineers to claim, for example, that the builder of the pyramids or the inventor of the cotton gin was an engineer. There is, it seems to me, considerable unfairness in claiming the successes for engineering while (as generally happens) blaming the failures on others, for example, "managers", "tinkerers", "technicians", or "scientists". I have therefore tried to adopt a concept of engineering that does not fall into this trap.

34. The only exception I know of is recent: in some software engineering, the engineer actually constructs the computer program, thus giving directions not to human workers but to mechanical workers (robots). But, even these engineers should take into account the social environment in which those mechanical workers must operate.

35. Compare Calhoun, pp. 77: "the engineer role was specialized out of the executive role".

36. For example, the most scientific of the major engineering societies, the Institute of Electrical and Electronic Engineering, has also been the only one to forget that it had a code of ethics (rediscovering it in the 1970s only after it had written a new one). For a bit more on this, see my "The Ethics Boom: What and Why", Centennial Review 34 (Spring 1990): 163-186, esp. p. 173-174.

37. For example: "Much time is wasted in our colleges and technical schools over higher mathematics. Every engineer will have to agree with me that the cases where the use of the higher calculus is indispensable are so few in our practice, that its study is not worth the time expended upon it, and we have the highest authority for saying unless its use is constantly kept up we become too rusty to use it at all. Unless the student possesses extraordinary genius for mathematics, I would limit its study to the ordinary analysis." Thomas C. Clarke, "The Education of Civil Engineers," Transactions of the American Society of Civil engineers 3 (1875): 557 (quoted in McGivern, 113).

38. For an interesting discussion of this debate, though largely limited to mechanical engineering, see Calvert, pp. 63-85.

39. Calhoun, 45.

40. Calhoun, 50-53.

41. The practical success of the West Point is easy to underestimate. Consider, then, what was said by Francis Wayland, President of Brown University from 1827-1855. Near the end of his term, which included bringing engineering to Brown, he observed enviously that "the single academy at West Point,

graduating annually a smaller number than many of our colleges, has done more toward the construction of railroads than all our one hundred and twenty colleges united." Quoted in McGivern, 91.

42. McGivern, 152-154.

43. Calvert, 203.

44. McMahan, 33-43.

45. Compare: "The Society would have been a small one and of limited influence had its membership been restricted to the type of consulting or creative engineer alone. The factory engineer is more and more a manager of men....The engineer must be what he is often called, a businessman." Frederick R. Hutton (1907), secretary of the American Society of Mechanical Engineers. Quoted from Layton, 37.

46. Of course, some engineering societies, especially in their early years, admitted into membership persons who, though not school-trained engineers, had been "in responsible charge" of engineering work for a number of years. The criterion was, it should be noted, not simply "being in charge" but being in "responsible charge" for a certain length of time, long enough, presumably, to show that they could do the job. And, even this criterion has come to look more like a political compromise than a natural definition.

47. Compare Layton, esp. pp. 58-60.

48. See, especially, Layton, pp. 25-52. This vagueness may explain why at least one engineering society, the short-lived American Association of Engineers, allowed architects to join. See Peter Meiksins, "Professionalism and Conflict: The Case of the American Association of Engineers", Journal of Social History __ (-- 1983): 403-421, esp. p. 406. The exclusion of rank-and-file workers may indicate a class bias, but I think it indicates more than that. Many people who called themselves engineers, for example, train drivers or scientific tinkerers, would have seemed ignorant of much engineers did have in common, even engineers who had come up through the ranks. What Layton in fact reports is, I think, part of the process by which "engineer" came to mean in

English what it did in French (and what Williams understood by "Officieur du Génie").

49. For an interesting example of how too much emphasis on science can interfere with the practice of engineering, see Bruce E. Seely, "The Scientific Mystique in Engineering: Highway Research at the Bureau of Public Roads, 1918-1940", Technology and Culture 24 (October 1984): 798-831.

50. McGivern, 65. Note that "engineering" here means (what we now call) civil engineering. Though grouped with civil engineering, both (what we call) mining (and metallurgical) engineering and mechanical engineering are yet engineering. That still seems to have been true when Columbia University's School of Mines was established some twenty years later. We should, therefore, probably be more cautious than we have been about thinking of engineering as "fragmenting" during the nineteenth century. We might, with equal basis in fact, be able to tell a story of several different occupations coming together. In this story, higher education would play a crucial part in giving engineering a unity it did not originally have (and might never have achieved otherwise). In this regard, it is worth noting that early civil engineers seem generally to have failed at both mechanical engineering and mining. Calhoun, pp. __________.

51. McGivern, 64-69.

52. McGivern, 79-82.

53. See Lawrence P. Grayson, "A Brief History of Engineering Education in the United States", Engineering Education ___ (December 1977): 246-264, esp. p. 257-261.

54. This is quite clear in, for example, Walter G. Vincenti, What Engineers Know and How They Know It (Johns Hopkins University Press: Baltimore, 1990).

55. For others who have noted the sad state of our understanding of engineering, see: James K. Feibleman, "Pure Science, Applied Science, Technology, Engineering: An Attempt at Definitions", Technology and Culture 2 (_____ 1961): 305-317: M. Asimov, "A Philosophy of Engineering Design", in Friedrich Rapp, ed., Contributions to a Philosophy of Technology (Reidel: Dortrecht-Holland, 1974), pp. 150-157; George Sinclair, "A Call for a Philosophy of Engineering", Technology and Culture 18 (October

1977): 685-689; Taft H. Broome, Jr. "Engineering the Philosophy of Science", Metaphilosophy 16 (January 1985): 47-56; and Paul T. Durbin, "Toward a Philosophy of Engineering and Science in R & D Settings", in Paul Durbin, ed., Technology and Responsibility (Reidel: Dortrecht-Holland, 1987), pp. 309-327.

56. This is, of course, not intended as a definition of "profession", merely as a sketch of one, adequate for our purposes now. For more of what I mean by "profession", see: "The Moral Authority of a Professional Code", NOMOS 29 (1987): 302-337; "The Use of Professions", Business Economics 22 (October 1987): 5-10; "Vocational Teachers, Confidentiality, and Professional Ethics", International Journal of Applied Philosophy 4 (Spring 1988): 11-20; "Professionalism Means Putting Your Profession First", Georgetown Journal of Legal Ethics (Summer 1988): 352-366; "Thinking Like an Engineer: The Place of a Code of Ethics in the Practice of a Profession", Philosophy and Public Affairs 20 (Spring 1991): 150-167; "Do Cops Really Need a Code of Ethics", Criminal Justice Ethics 10 (Summer/Fall 1991): 14-28; and "Codes of Ethics, Professions, and Conflict of Interest", Professional Ethics 1 (Spring/Summer 1992): 179-195.

57. Quoted in McGivern, 106. At the same place, he offers similar examples from American Institute of Mining (1873) and American Society of Mechanical Engineers (1880).

58. Grayson, Brief History, 254.

59. Grayson, Brief History, 258. Today that organization is the Accreditation Board of Engineering and Technology (ABET).

60. For more on this, see my "The Ethics Boom".

61. For a good (if somewhat jaundiced) account of this period, with its effects both on industry and engineering, see Noble, American by Design.

62. The electrical engineers seem to have had the greatest difficulty here (an eight-year process). See McMahan, pp. 112-117.