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Low Cost, Mass Use: American Engineers and the Metrics of Progress

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This paper examines initiatives in engineering formation in the USA as, in part, responses to dominant territorial identities defining what counts as progress. The absence of a primary method of engineering formation during the antebellum period suggests that no metric of progress had yet scaled up to a level of dominance. Robert Thurston's efforts in the 1890s to scale up school-based formation without liberal education did not fit a country that emphasized high-volume production at low costs. The attempts of the Wickenden study in the 1920s to achieve coordination did not fit a country highlighting self-realization through consumption. The 1955 Grinter Report achieved great success when the sudden appearance of Sputnik scaled up a new territorial identity for the USA. Overall, by responding to the evolving metric of low cost, mass use, advocates of engineering formation have designed engineers to serve the country.

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> The American 'style' of engineering that emerged in the 19th century placed more emphasis on reducing labor costs and on economy of construction … and placed less emphasis on strength, permanency, aesthetic appeal, and safety.[1]
>
> Perhaps the most constant feature of American engineering education has been the demand for change.[2]

A Question of Fit?

In 1893, Cornell University engineering professor Robert Thurston (1839–1903) published the nearly 200-page paper, 'Technical Education in the United States', in the *Transactions of the American Society of Mechanical Engineering* (ASME).[3] It was actually more of a report. Thurston had been the ASME's first president when it was formed in 1880 and by 1893 he held a privileged position as the country's leading educator in

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mechanical engineering. For Thurston to take the unusual steps of drafting a lengthy report and publishing it in the transactions of his professional society indicated a profound sense of urgency, a sense built into the report's subtitle: 'Its Social, Industrial, and Economic Relations to Our Progress'.

In his still-influential 1967 study of the shift from 'shop culture' to 'school culture' among late 19th-century mechanical engineers in the USA, Monte Calvert positions Thurston as a savvy architect and advocate of school culture. Tracing the shift by following the competitive struggle among engineering leaders, Calvert shows how Thurston served as an effective mediator of the transition. Although not himself a product of shop culture, Thurston built a school-based enterprise that the entrepreneurial shop culture elite, who largely controlled the ASME, could tolerate. As other historians have affirmed, Thurston was an intellectual and institutional visionary whose creative initiatives made him a strategic agent in the stabilization of engineering formation in schools.

It is instructive, however, that Thurston's 1893 report, which summarized his model for school-based education for engineers, was largely a failure. Key dimensions were rejected by colleagues at other institutions. In particular, his approach focused solely on technical education, including a mix of class-work and shop-work, and explicitly excluded education in the liberal arts, which Thurston considered to be a distraction.[4] Yet US engineering educators quickly made liberal education an integral and continuing component, albeit in peripheral positions.[5] In addition, Thurston's report culminated in an impassioned argument for a national system of technical education led and coordinated by a technical university in Washington, DC.[6] This idea never had a chance.

Thurston appears as an innovative, even heroic, leader to the extent one focuses on his successful actions and discounts the unsuccessful ones. Calvert thoroughly describes how Thurston instituted new methods of shop and classroom instruction, negotiated significant expansions of funding, increased the size of his faculty from seven to 43 members, and himself published research bringing mathematical theory to engineering practice.[7] However, he does not attempt to account for Thurston's failures except to alert readers that his approach to engineering education was 'a blend of French and German ideas' and that, as an individual, Thurston was 'bureaucratically oriented'.[8]

Was Thurston creative only sometimes and not other times? He himself likely considered his work an integrated corpus. Distinguishing Thurston's successful actions from his unsuccessful ones shifts the focus of analysis away from Thurston's creative agency and individual style and onto the responses of his audiences. That is, Thurston's successes became so when other engineering educators adopted or otherwise accepted them. Their adaptations in turn became successful only when still others accepted them, including most importantly prospective engineering students and their families. In other words, the accomplishment of leadership was also simultaneously the achievement of acceptance. Key agencies were enacted by both leaders and followers, and success involved the establishment of educational mechanisms that produced engineers who somehow evidently fit. What, then, enabled some of Thurston's ideas about technical education to achieve wide acceptance, while others did not and what exactly did the emergent engineers fit?

Territorial Identity and Professional Formation

Historians of engineering and other researchers in engineering studies have regularly shown that who counts as an engineer and what engineers have valued as their knowledge have varied significantly over time and from place to place. One way of accounting for such differences is to point to historical contingency. Fields of engineering emerged differently in different places because people making situated judgments in contrasting contexts enacted contingent practices and produced variable outcomes. However, an overemphasis on contingency and localized difference can carry the danger of hiding significant patterns across contexts. In a previous contribution to this journal, Juan Lucena and I summarize work by historians and historical sociologists that finds differences among engineers and engineering knowledge to be linked to differences among countries.[9] Also, presenting brief examples from France, Germany, the UK and the USA, that account suggests that engineering advocates have built mechanisms of formation in response to patterned concepts of progress.[10]

The idea of progress is sometimes treated in academic circles as labeling one thing, an ideological commitment to societal advancement through new technologies and industries. Indeed, new technologies and industries have often been championed in popular arenas as progress in just this sense. In advancing the concept of 'metrics of progress', however, Lucena and I suggest that dominant images of societal advancement, i.e. the indicators of positive change in society that people actually come to take for granted, have varied significantly in content. As lived, progress has been many things.

This study takes the above preliminary research a step further by inquiring through a selective case study of developments in one country the extent to which the evolution of professional formation in that country may be linked to changing metrics of progress. Taking this step entails examining how metrics of progress live not only as images or codes inside people's heads but also as material conditions of existence. To the extent a metric of progress is a material phenomenon linked to a country, it is likely to change as the material circumstances of the country change.

The term 'territorial identity' is offered here as a label for an asserted connection between an entity and a geography, e.g. the existence of a country or the fact of membership or inclusion in a country.[11] Thurston and his readers, for example, were not only engineers and engineering educators but also Americans. They were identified territorially with the USA.[12]

A specific territorial identity becomes dominant to the extent it becomes accepted and, hence, taken for granted. For example, most readers will likely have experienced in their lifetimes the decline of the Cold War during the 1980s and rise of economic competitiveness as a framework for mapping relations among countries in the world. During this period, the dominant territorial identity of the USA as a country shifted in the sense that the long-feared threat from Communism, which was both external and internal to the country, was replaced by the wholly external threat of economic competition from other countries. For people identified with the USA, the material reality of the world changed as the old image of Cold War was taken for granted by fewer and fewer people less and less often while a new image of economic competitiveness was taken for granted by more and more people more and more often. In other words, one territorial identity scaled down while another scaled up.

To the extent a territorial identity scales up and becomes a given, it also serves as a source of influence. Drawing again on the example of economic competitiveness, as the new image gained legitimacy and became a given condition of the contemporary world, it posed an increasing challenge to people to act in ways that fit or were consistent with it. One could certainly ignore or deny the new reality, for response to challenge is not the same thing as causal determination, but to do so carried consequences. Thus, as the Cold War declined, government officials who continued to define themselves in terms of a Cold War identity were increasingly ignored as anachronistic. At the same time, the early 1980s government-sponsored report, *A Nation at Risk*, was increasingly judged as prescient because it mapped the country's present and future in terms of economic competitiveness before the new image had scaled up.[13]

This paper offers a brief case investigation into the scaling up of new ideas about engineering formation in the USA during four historical periods. It inquires into the extent to which the creative agencies of innovators in engineering formation may be seen as, in part, responses to dominant territorial identities that defined what counted as societal advancement, i.e. metrics of progress. The account begins by describing an initial period of diversity and then offers interpretations of three initiatives in the development of engineering formation: Thurston's 1893 report, the so-called Wickenden reports of the 1930s, and the Grinter Report of 1955. It inquires if the genesis, course of development, and outcomes of those initiatives correlated in any way with specific changes or continuities in dominant territorial identities and, hence, metrics of progress. The documentation of correlations raises the possibility that the construction of the engineering profession in the USA has included a patterned process of making engineering formation fit the evolving country in specific ways.

Initial Diversity

The stabilization of school-based education for engineers was especially remarkable given the diversity in engineering training during the 'early national' period prior to the Civil War. In the oft-told story, the initial domestic production of engineers was of civil engineers, achieved mainly through apprenticeships in the field or office, with the 1816–1824 Erie Canal project a key stimulus. Meanwhile, school-based training to produce state engineers working in government, especially the military, was initiated but experienced limited growth. West Point began training engineers in 1817, and other military schools were established at the state level in the decades prior to 1850. Finally, Rensselaer became the most prominent of a handful of independent polytechnics. Drawing on a thorough archival search, Terry Reynolds identifies four additional patterns within classical colleges, ranging from a few courses to autonomous scientific schools, most of which came and went with little public notice. Finally, Calvert's 'shop culture' points to a distinct version of the apprenticeship model to produce mechanical engineers.

One way of mapping the contrasts in these approaches to the formation of engineers is to extrapolate their efforts and imagine what the country would have to have been for each to scale up to dominance and achieve long-term success. The apprenticeship model, for example, was supplying engineers to a society that foregrounded the realities of social class. Apprenticeship training for engineers has sometimes been described as based on a 'British model' or drawn from a 'British tradition'. Such terms can be misleading. One danger is that they risk presupposing the existence and status of the apprenticeship system as a kind of portable object in the very process of trying to account for it. Recent research on technology transfer illustrates how the travel of an object tends to transform it by relocating it in new sets of relationships.[14] Also, multiple models of engineering education have co-existed in every country, competing with one another even if one gains a dominant position. Selecting one to stand for a country both hides the others and risks replacing dominance with essence. The apprenticeship model in the USA is thus better seen as an American model built on American understandings of the British.

The outputs of apprenticeship were civil engineers designed to function as professional gentlemen in a hierarchical class system with the distinctive responsibility of materially linking together the inhabitants of the country, at least within states. Indeed, through their work supervising the construction of bridges, roads, canals, and, later, railroads, civil engineers working primarily as consultants and on commissions received significant recognition.[15] One could reasonably project a glorious future for a profession built on the production of infrastructure.

The national military school, West Point, initially founded in 1802, supplied engineers whose scientific knowledge would justify leadership in government.[16] This model was understood as French. The school employed instructors from France and used textbooks written in French. If such national academies had multiplied, one could reasonably envision their graduates assuming leadership positions in an expanding administrative bureaucracy, but such a country could never have developed. As Peter Meiksins points out, 'Americans were suspicious of large, centralized, state-sponsored public works'.[17] The idea of large numbers of engineers leading a strong state was not going to resonate in the USA.

The independent polytechnic was a unique development for a country in which elite status for civil engineers in the private sector would be justified by an educational alternative to the classical college. Rensselaer Polytechnic Institute, which was founded in 1824 and began awarding degrees in civil engineering in 1835, drew justification from the French Ecole Centrale des Arts et Manufactures, which had been established in the private sector in 1829. However, Rensselaer did not adopt the Ecole Centrale's mission to produce engineers for industry rather than for infrastructure and did not emulate the Ecole Centrale when it successfully petitioned to join the state system in 1857.[18]

The several approaches within classical colleges were aimed at contributing technically-trained graduates to a world that allocated societal leadership and elite status through cultivation, even while contesting what should count as cultivation. Extrapolating these efforts produces the image of a country in which progress is celebrated as cultural advancement and technical workers are valued as cultural leaders. Although informed Americans were watching such a scenario unfold in Germany, especially after unification in 1870, building a United States that explicitly allocated leadership through cultivation would have required massive rearrangements.

The state-level military academies produced engineers for a country that was understood to be a collection of states. They were found, not surprisingly, mainly in the South. Prior to the Civil War, it was not yet established whether the country's primary boundaries were external boundaries with other countries or internal boundaries separating states and regions. The War would settle the issue, forcing Southern states to accept an integrated whole and limiting the wider value of the military academies.

Finally, one model that did scale up substantially in the 1840s and 1850s was shop training for the then-emergent mechanical engineer. Built around the apprenticeship, shop training produced an entrepreneurial elite of gentlemen in industry. Because shop training was designed to identify engineers who were born, not made, an extrapolation of this model imagined a country led by natural technical leaders, yet in a system that was not a technocracy because their initiatives were wholly in the private sector.

Although each of these models of engineering formation could be found in antebellum United States, none of the territorial identities justifying them scaled up sufficiently to achieve a level of dominance. Engineering educators could not come to consensus on how to serve the country because the country had not yet figured out what it was. Furthermore, one distinctive feature of all these models was the focus on producing people who were clearly special and deserving of elite status. Such would not be the future for engineers in the USA.

Stabilization in Schools

In analyzing the founding of the Georgia School of Technology, James Brittain and Robert McMath explain that by the 1880s 'overt opposition to industrialization had abated somewhat in the South' and was replaced by an emergent view holding that 'the key to recovery, modernization, and restoration of Southern power within the Union lay in industrialization'.[19] Georgia Tech was founded to provide technically-trained workers for industries drawing on the significant natural resources of the South. Prior to the War, industrialism was a Northern preoccupation contested in the South by a dominant agrarian image of societal improvement. By the 1880s, however, the new metric had scaled up throughout the country.

Industrialization was not a generic process. In sharp contrast with European countries, the rapid construction and spread of new industries in post-Civil War USA included an emphasis on providing increased material comfort to mass populations. The supporters of US industry were similar to their counterparts in Britain and unlike the French and Germans in measuring the progress of the country in terms of improvements in material comfort.[20] They differed from the British by assigning the site of societal progress to the 'masses', a label that stood out because it ignored class differences and included members of the working class in its purview. For the first time in the history of the USA, by 1880 Americans were taking it for granted that the country was progressing when the masses experienced increased material comfort.

The main method for increasing the material comfort of the masses was the high-volume production of goods at low costs. Only through low costs could members of the lower classes gain access to market consumption. David Hounshell reports that between 1874 and 1880 the annual production of sewing machines by the Singer Manufacturing Company doubled from 250,000 to over 500,000. '[T]he company', Hounshell explains, 'was feeling the pressures of mass consumption to an extent unknown to most American manufacturers of that time.'[21] Thomas Misa describes how the steel industry responded to rapidly increasing demand in the 1870s and 1880s by adapting the Bessemer process 'to yield the reckless mass production of steel rails'. Indeed, the 'emphasis on high-volume, low-quality production … distinguished the US steel industry in size and character from its European rivals'.[22] Overall, as Terry Reynolds reports in the epigraph to his article on the engineer in 19th-century America, the dominant American approach to manufacturing differed from European versions by emphasizing 'reducing labor costs' and 'economy of construction' rather than 'strength, permanency, aesthetic appeal, and safety'. Although exceptions existed and struggle continued, a metric of low-cost, mass use had successfully scaled up to dominance.

None of the pre-War models for engineering formation fit a country focused on high-volume industrial production at low costs. Industry was not a primary home for civil engineers, regardless of whether they were trained in apprenticeships or elite polytechnics. The national or state military academies could not produce engineers for private industry without raising fears about government interference. Industry was also not a place for the cultivated graduates of classical colleges. Ultimately, as Monte Calvert recounts, industries built on mass production and aimed at low labor costs would not be places for shop-trained entrepreneurial elites.

During the Civil War, Congress passed the Morrill Land Grant Act authorizing federal financial support for schools devoted to agriculture and the mechanic arts while preserving state authority over how and where to spend the money. The model was explicitly designed to help expand and provide upward mobility to the 'industrial classes'. While it was not clear until the 1890s that the term 'mechanic arts' could be construed as 'mechanical engineering', it was clear from the beginning that this type of school culture differed from shop culture by building rather than revealing abilities. As Calvert put it, the new technical education was for 'average' students, large numbers of them.[23]

The dominant themes of the land-grant story are rapid expansion and increased service to industry. '[T]he number of academic engineering programs in the United States shot up sharply,' Reynolds reports, 'reaching seventy by 1872 and eighty-four by 1880.'[24] Although each story had its unique features, by the 1890s land-grant schools across the country were placing great emphasis on educating mechanical engineers for high-volume production. '[B]y 1902,' Calvert reports, 'an engineering professor at the University of Illinois could state with some truthfulness that technical education could now be regarded as a prerequisite to the "proper practice of the engineering profession."'[25] The focus on high-volume production applied to engineers as well. By 1900 the country had 40,000 engineering practitioners, and engineers had moved from the shop to the office. By 1920, the USA had 134,000 engineers working to realize a country built around low cost, mass use. 'The American state', Meiksins summarizes, 'helped to sponsor the development of American engineering education. … [I]n so doing, it appeared to be responding to industry, not leading it.'[26]

In his 1893 report to the ASME, Robert Thurston built his argument for technical education upon a clear articulation of what he called the 'two lines of progress'. The first line of progress was 'the cheapening of all essential … elements of … civilization'. The second was the 'application of the powers … and … intellect of man to … production … in … forms most useful to the mass of mankind'.[27] Low cost, mass use.

Thurston was fearful of economic competition from Germany. Since unification in 1870, the country not only appeared to have made a firm commitment to industry but this commitment was backed by a multilevel, coherently organized national system of technical education. The urgency in Thurston's report appears in its regular assertions that the USA was trailing Germany and other European nations 'in a race in which they have many years the start of us'.[28] All readers understood that the race was about production. Thurston documents in detail what he considered to be the 'somewhat intimidating comparison' between the national system of technical education supporting production in Germany and the woeful infrastructure in technical education in the USA.[29]

Thurston's proposals were evidently responding as much to his understanding of the German system as to domestic pressure for low-cost, mass use, if not more so. His goal was to produce a new kind of cultural elite built on technical education. He advocated an integrated system of technical training that would culminate in graduation from a national technical university in Washington that would produce cultural leaders. '[A] difficulty arises here [at Cornell]', he complained to a friend, 'from the evident and indisputable intention of the founders of the University to make it useful to the masses.'[30]

That Thurston's recommendations were perhaps more German than American was illustrated by the insistence of colleagues at other institutions on including education in the liberal arts. A proposal to omit liberal education made little sense when engineering formation produced managers of people and a proposal to centralize engineering education could not be accepted if progress depended upon the maximization of individual initiative.

Preparing Engineers for Corporate Industry

In 1923, the Society for the Promotion of Engineering Education initiated an ambitious study of engineering education in the USA. Taking school-based formation as a given, the project voiced concerns about a national system of engineering education whose focus on college-level instruction had 'grown up sporadically in America and … never been thought out as a whole'. Also, the multiplication of degree-granting colleges had produced a situation in which 'one third of their number fall below a satisfactory standard'. One fear guiding the project was that inadequate 'non-college technical training' would make US industry fall behind Europe, where '[i]n every other advanced country this type of technical education is very generously provided for'. A second was that too much disparity in the quality of engineering education would undermine the status of the profession. 'It would be wholly regrettable', wrote project Director William Wickenden in a preliminary report, 'if the present occasion … should pass without constructive steps toward a better balanced program.'[31]

By the time publication of the 1300 page study involving 700 faculty at 150 schools was completed in 1934, Wickenden was forced to admit that 'No big transforming idea [had been] discovered'.[32] In other words, the engineering education system as it existed at that time should remain largely the same. The major material outcomes were summer schools for engineering teachers and endorsement of a new professional organization to accredit engineering curricula. Alternative outcomes had indeed been possible, but scaling them up successfully would have required building a different country than the one that confronted them.

The late 19th century emphasis on high-volume production had been wildly successful. However, after 1900 and prior to World War I, a broad array of concerns emerged around the implications of this headlong drive. While the character of the concerns was not new to the period, the scale and level of legitimacy they achieved definitely was. Noble reports, for example, that 'a number of engineers began to perceive a contradiction between socially beneficial … progress and corporate control of the material and human means to that progress'.[33] They were far from alone. Historians use the term Progressivist Period (1900–1914) to name an era in which Americans were wrestling with a production-based orientation that appeared to many as disorderly, inefficient, and/or a source of significant inequality, depending on one's point of view.

Stories of the Progressivist Period are typically accounts of the expansion of governmental involvement in industrial production, including growth in mechanisms of regulation. The principal new image to emerge was the idea was that material comfort for the masses could somehow be managed by a society that intelligently appealed to and applied the insights of science. Since the private sector was by definition the site of unregulated individual volition, the image of management necessarily invoked the material participation of government in industrial production. Perhaps representative government could be deployed to deliver low cost, mass use both efficiently, to insure fulfillment, and fairly, to reduce unequal distribution.[34]

By the 1920s, however, the romance with governmental management had ended. As Lynn Dumenil explains:

> In contrast to the progressive era, the 1920s were characterized by strong hostility to government, especially federal, power. … Critics of federal power emphasized bureaucracy, using the word as shorthand to invoke images of a pervasive and pernicious federal presence that strangled local and individual initiative. … [T]hey argued that at worst this trend would lead to Prussianism or Bolshevism.[35]

The optimistic expansion of governmental management of low cost, mass use since 1900 had been halted abruptly by the government-mandated entrance of the USA into the war in Europe. US participation in World War I provided new evidence for the position that governments impose themselves on people rather than representing them.

David Noble reports a post-War shift to 'consumption-based economy'.[36] For example, Henry Ford's approach to high volume and low cost lost legitimacy. As David Hounshell explains, 'Automobile consumption in the late 1920s called for a new kind of mass production, a system that could accommodate frequent change and was no longer wedded to the idea of maximum production at minimum cost.' As a result, 'General Motors, not Ford, proved to be in tune with changes in American consumption with its explicit policy of "a car for every purpose and every purse", its unwritten policy of annual change, and its encouragement of "trading up" to a more expensive car.'[37]

What scaled up during the 1920s was not just the fact of consumption but the kind of advancement one accomplished by means of it. As Dumenil puts it, the 19th century '"production" ethos of work, restraint, and order' was being replaced by an ethos that 'embrace[d] leisure, consumption, and self-expression as vehicles for individual satisfaction'. The rise of leisure activities, including especially the participatory sports of golf and tennis and the explosion of magazines, movies and newspapers, all marked a shift of emphasis from 'character' to 'personality' in which even working-class Americans participated. 'Rising prosperity, consumer goods, and increased leisure time', Dumenil summarizes, 'offered new venues for meaning.' That is, 'one could seek satisfaction and definition in the personal realm of leisure and consumption'.[38]

During the 1920s, industrial corporations successfully positioned themselves as vehicles of progress by facilitating consumption and self-realization. Dumenil shows how '[t]he idea that prosperity depended upon giving business free rein' had become dominant by 1924, grounding the election of Calvin Coolidge.[39] David Nye shows how General Electric used industrial advertising to make itself 'appear the guarantor of low electrical costs' and, as such, 'an integral part of the culture, which could later claim, "Progress is our most important product"'.[40] The most prominent indicator of the link between private industry and progressive self-realization was achieved by the General Motors' success in segmenting the market. By the 1940s, it was commonly said that 'what is good for G.M. is good for America'.

During the Progressivist period, the major professional societies in engineering rejected a collection of efforts to re-form engineering as an autonomous profession directly serving society, either by means of government or through authoritative relations with mass publics. The story of what Edwin Layton called the *Revolt of the Engineers* is told by him as a victory of engineering leaders associated with industry, by Noble as a victory of corporate capital, and by Meiksins as the product of a temporary alliance between elite reformers and rank and file engineers who accepted locations within companies but sought to increase income.[41] All narrate the failure of the reformers as the success of a model taking for granted that engineers would spend their careers in corporate industry.

Noble reports that direct cooperation with industry was relatively infrequent prior to 1910. After that date, however, the Society for Promotion of Engineering Education took preparing engineers for corporate industry to be its main mission. Examples of the expansion of curricular connections with industry include the 'cooperative education' program at such schools as University of Cincinnati, MIT and University of Pittsburgh, Purdue's overarching interest in 'bringing the man and the job together' and even the establishment of the new field of chemical engineering around the 'unit operations' of industrial processes.[42]

After World War I, figuring out what to do with engineering education necessarily involved figuring out how to make room for engineers in a country defined by industry-led consumption. Note that the Wickenden study was conducted by the Board of Investigation and Coordination. To them, the crucial problem was the contrast between the increasing organization of industry and government on the one side and the woeful disorganization of engineering education on the other. 'It is plain', the Board pointed out in a preliminary report, 'that technical education has grown up sporadically in America and has never been thought out as a whole.' Furthermore, of the more than 100 schools then conferring degrees in engineering, 'approximately one-third of their number fall below a satisfactory standard'. Not only has there been 'almost no coordination of effort', asserted the Board Chairman, but 'there is lack of agreement on even fundamental objectives'.[43]

The central objectives of the Investigation were thus clarification and coordination: 'to clarify the educational functions and responsibilities of the colleges of engineering' and 'to indicate how engineering curricula may be coordinated more effectively with the needs of industry and the requirements of engineering practice'. Crucially, the image of coordination referred to coordination both with one another and with corporate-based industry. Modes of engineering formation that did not serve industry had little prospect of successfully serving America. The Society maximized the possibility of fit between engineering education and the country when they chose as Director of the study a charismatic man who had not only taught at both the University of Wisconsin and MIT but was also Assistant Vice President of AT&T, responsible for the educational activities of the Bell system. William Wickenden would understand the needs of industry since his job was to articulate them.[44]

In the United States, coordination without explicit authority and direction from government is not easy to accomplish. The study considered but rejected recommending a variety of proposals to produce a more organized system, including redefining curricula in terms of functional positions in industry, lengthening study to five years, establishing a two-step program that began with education in the liberal arts, distinguishing programs by level and merit, establishing a single threshold for entrance into the profession, and innumerable specific strategies in curriculum and pedagogy. Wickenden himself performed the tension between a desire for coordination and a resistance to standardization, administering a massive study yet taking care to avoid any steps that inhibited individual action. 'The present investigation', wrote Wickenden in an early report, 'has revealed a strong mood for concerted action among the colleges, provided their final autonomy is fully safeguarded. What is desired is not standardization but concerted initiative. … What is wanted is effective collaboration, and not the dictation of any group to the others.'[45]

The establishment of summer schools for teachers of engineering was a way of improving instruction in engineering at the weaker schools without presuming to control their curricula. The establishment of a new organization to accredit engineering programs was acceptable because it emerged from a consensus of professional engineering organizations, led especially by the American Society for Engineering Education. In his final report in 1933, Wickenden used a navigational metaphor to assert that '[t]he facts brought out in these investigations are fairly reassuring to the pilots both as to present position and course' and '[t]he ships may proceed with renewed confidence'.[46] No change was necessary. In a separate article published the same year, Wickenden's assistant Director, Harry Hammond, summarized the work by asserting, 'In no other division of higher education has more effort been expended to bring scholastic work into line with the changing needs of … industry'.[47]

The massive Wickenden study typically gets relatively little mention in the historical record. Noble's account in particular, which analyzes in great detail many developments in engineering education, gives the Wickenden report only two pages. Perhaps the important point here is precisely that the Wickenden report was a massive accomplishment of a continuity, not a change. The continuity was affirmation that engineering as a profession or occupation must channel its service to society by operating within private industry, even when private industry was run by large corporations. By the 1920s, the earlier enthusiasm for high-volume production had shifted to acceptance and legitimacy for the high-volume producers who facilitated self-realization through consumption.

Moving Engineering Sciences to the Core

Following the shift from shop to school in the late 19th century, the most profound transformation in the history of engineering education in the USA was the curricular shift to the sciences in the late 1950s and 1960s. Schools of engineering across the country reorganized undergraduate engineering curricula, replacing existing menus of technology-based and practice-based courses in favor of ordered sequences of courses in the 'basic sciences' and 'engineering sciences'. These ordered sequences were paralleled by individual elective courses in the humanities and social sciences and culminated in courses applying the engineering sciences to design. Both engineering educators and historians of engineering education have characterized the change as a shift to a curricular model that has remained dominant to the present. Bruce Seely, for example, described the outcome in 1999 as 'the basic style of engineering education that has dominated American universities for the past three decades'.[48]

By all accounts, the key vision of the new curriculum was articulated in 1955 by the Grinter report. Published as the 'Report of the Committee on Evaluation of Engineering Education' under the auspices of the American Society for Engineering Education (formerly the Society for Promotion of Engineering Education), the document was the final product of a three-year study 'to recommend the pattern or patterns that engineering education should take' both 'to keep pace with the rapid developments in science and technology' and 'to educate men [*sic*] who will be competent to serve the needs of and provide the leadership for the engineering profession over the next quarter-century'.[49] The Report that emerged under the leadership of Linton E. Grinter, engineering dean at the University of Florida, recommended a curricular structure allocating one-quarter each to mathematics and basic sciences, engineering sciences, and analysis/design/systems, with a mix of technical electives and humanities and social science courses contributing the remainder. The Report was also quite explicit in recommending a de-emphasis of practical training, for '[t]he most important background of the professional engineer … lies in the basic sciences and the engineering sciences'.[50] The Grinter Report did indeed articulate a model that was scaled up through follow-up accreditation criteria published by the Engineering Council for Professional Development, but did the 1955 report also have good timing?

Seeley points the way to understanding the remarkably widespread acceptance of this shift by highlighting the dramatic rise in defense funding for engineering research after World War II. '[A]n avalanche of federal money, primarily from the military and the Atomic Energy Commission', Seely explains, 'displaced the smaller industrial research projects that had been conducted by a few engineering colleges before 1940.' The new emphasis on engineering science was, from one point of view, simply scaling up a trend that had been initiated by the immigration of European engineering faculty dating back to the 1920s. However, the combined curricular and research model that actually scaled up during the late 1950s and into the 1960s differed dramatically from what was developing earlier because, as Seely explains, 'the goal was not to serve industry, rather to attract federal research funds.' Indeed by 1968, when the American Society for Engineering Education published a report on the goals of engineering education, 'little talk was heard of seeking support from industry; the only patron that mattered was government'.[51]

A longstanding territorial outcome for engineering education was seemingly disrupted. Rather than emphasizing self-realization through consumption, the elites in engineering education had turned toward a new metric of progress, one that did not highlight low-cost production for mass consumption in the private sector but was led by government. Were Americans no longer suspicious of large, centralized, state-sponsored public works, as Meiksins had characterized the 19th century? Was there no longer strong hostility to government, as Dumenil had described the 1920s? The change in territorial identity was not as fundamental as it might seem. A new dominant metric of progress was indeed scaling up but this was less because of a great change of heart among the masses and more because of sober analyses of external risks.

Science and scientists had become firmly linked to government during the War. The territorial integrity of the USA was put at risk when the Japanese attacked Pearl Harbor. The Manhattan Project and subsequent deployment of atomic weapons were only the most visible examples of wartime activities that made scientists agents of government. After the War, establishment of the Atomic Energy Commission and National Science Foundation were early examples of expanded governmental initiatives that sought to locate areas of connection between the work of scientists and the work of government.

The dramatic change in territorial identity during the 1950s was due to the apparent rapid expansion of Communism. The sense of threat from Communism dated back at least to the Red Scare following the Bolshevik Revolution and end of World War I. It became much more real after World War II with the Soviet occupation of Eastern Europe and detonation of an atomic device in 1949, victory of Maoist Communists in China in 1949, the Korean conflict bifurcating the world into non-Communist and Communist states and McCarthyism confronting Americans with the image of Communists at home. What scaled up the threat of Communism into a present, palpable, territorial reality was the Soviet launch of Sputnik in October 1957 and its regular appearance overhead. Extrapolating their understanding of expanding links between scientists and government, Americans quickly came to understand Sputnik as an achievement of Soviet science, not engineering.[52]

The threat of Communism to the territorial identity of the USA differed from earlier threats of Southern agrarianism, competition in manufacturing from German industry, Axis elimination of market allies, or Japanese-controlled empire. Communism threatened to replace the dominant identity of the country as advancing through enhanced material comfort for the masses achieved through low-cost production in the private sector. The threat was socialism, which was understood as government-defined and government-controlled economic action and read as marking the ultimate loss of individual freedoms.

So obvious was the increasing scale of Communism and so fundamental was its threat that it justified a turn to government in the USA to devise and manage a collective defense. The new indicator of progress was success in stopping the spread of Communism, either by directly undermining it or by out-competing it. With Communism's finest moment understood as a success of science, critical elements in the government response were greatly increased funds for scientific research and a federally-led effort to increase the number of scientists in the USA, the most significant involvement of the federal government in higher education since the Morrill Act of 1862. The percentage of the National Science Foundation budget devoted to education grew rapidly, reaching 45% by 1959.[53]

So rather than redirecting American ideas of progress away from private industry, the government-led response to Communism was actually an affirmation of private industry as the vehicle of low-cost, mass use. Since the 1920s, the dominant identity of corporate industry was that it facilitated self-realization through consumption. The perceived challenge of Communism threatened the entire system of production that had enabled self-realization through consumption to become an indicator of human progress in the first place. It posed the possibility of replacement by a world that granted central government the authority to manage both production and consumption.

In addition, note that the key emergence during what became known as the Cold War was a new type of private industry. The US government did not follow the Soviet model and build government-owned enterprise. Americans were indeed still suspicious of government-owned public works. The so-called 'defense contractor' was a clever invention that recruited private corporations to become agents of government without incorporating them into the body of government. Soon dominated, as Meiksins explains, by 'large, vertically-integrated corporations', the defense sector grew rapidly, attracting 'between 20 and 30 per cent of the engineering and scientific workforce' and 'became higher prestige … as the often esoteric, sophisticated kinds of research characteristic of weapons became more attractive than more mundane work in consumer-oriented manufacturing.'[54]

The Grinter Report was completed two years before Sputnik. Although the project was initiated during the Korean War, it included no reference to the external or internal threat of Communism. As Atsushi Akera shows, the Grinter Report did pick up on worries about the status and identity of the engineering profession relative to science raised in a 1952 report from the Engineering Council for Professional Development. Asserting that engineering 'possessed no uniform professional objective', the ECPD report had mapped the internal diversity in engineering education along 'a spectrum of "professional" programs supported by strong science background to "vocational" programs in which only a modest amount of science in included'. Grappling with the emergent prestige of science, the ECPD report focused on the problem of demarcating engineers from technicians.[55]

One possible future for the engineering profession indeed lay in unions. Although 'most members of early "engineering" unions were really draftsmen', Meiksins explains, a burst of organizing activity during the 1930s and 1940s meant that by the mid-1950s roughly 10% of the 500,000 engineers in the USA belonged to unions. Indeed, in 1952, the same year the ECPD report was released and Grinter study initiated, 'the exclusively engineering unions moved to strengthen their collective voice by forming an umbrella organization—the Engineers and Scientists of America'.[56]

The Grinter study became a site for debating how to adjust engineering education to make it fit the industrial realities of post-World War II USA. The Committee asked 'why the basic pattern of engineering education ha[d] remained fixed in its main concepts over a period of forty years and whether new patterns were not required to meet the challenge of rapid developments in science'. The Preliminary Report of the Grinter Committee attempted to formalize the ECPD spectrum into a distinction between what it called 'two functional designations, professional-general and professional-scientific'. The distinction would institutionalize a separation between preparation for consumer industries and preparation for science-based industries, but, as the final Report acknowledged, the 'nearly universal … reaction' by faculties at more than 120 institutions was that 'engineering curricula should not be subdivided into two functional stems'.[57] Resistance came not only from schools that were at risk of being demoted by the distinction. Even MIT faculty, Akera reports, rejected the idea on the grounds that it 'would release lesser institutions from the obligation to augment the scientific content within their academic program'. In other words, engineering education for all industries should be based in science.[58]

Note that the Preliminary Report and a review Interim Report 'failed', as the final Report put it, 'to give adequate emphasis to the graduate phase of engineering education'. This omission was significant. It indicated that in calling for greater emphasis on science, the Committee's first inclination was not to build a system of research and graduate studies for defense purposes. Note also that when the Committee organized a panel of seven industrial leaders to respond to the Preliminary Report it chose production-oriented companies that did not place high priority on research and development, who nonetheless insisted that 'their sales, manufacturing, operations, and maintenance engineers need strong scientific backgrounds just as much as do their research and development engineers'.[59]

In sum, the Grinter Report emerged as a response to one territorial reality but became influential within another. The Report constituted an attempt by intellectual leaders in engineering education to adapt engineering curricula to fit a world of industrial production in which low-cost production for mass consumptions increasingly relied upon the application of knowledge from the sciences. The curricular structure it recommended in 1955 beautifully fit the alternative world created suddenly by the appearance of Sputnik two years later, in which the mass supply of engineering graduates to production-oriented industries would be supplemented by the creation of a whole new pattern of education and research for government-sponsored industry, all in the name of protecting private production and consumption.

By the 1960s, the hierarchy that the Grinter committee sought to formalize had become a *de facto* pattern. 'Engineering educators in the leading schools', report Terry Reynolds and Bruce Seely, 'paid little attention to industry.'[60] The National Science Foundation was fully supporting not only research in the engineering sciences but also graduate traineeships for engineering researchers. As engineering curricula nearly everywhere worked to integrate the basic and engineering sciences, technical institutes moved to fill the curricular space they left behind by expanding two-year technician programs to four-year 'engineering technology' programs and, as Meiksins explains, by 1967 the union movement for engineers had dropped to 20,000 members.[61]

Conclusion

In the four episodes introduced above, advocates for engineering formation were following progress in the sense that they worked to produce engineers who would be well-placed to facilitate societal advancement. Creative innovators of engineering formation endeavored to develop ways of constructing engineers that would enable them to fit the territorial identity of the country. Achieving such fit would help insure both that the country did indeed progress and that engineers could feel secure in the knowledge that their work actually contributed to serving society.

During the antebellum period, the absence of dominance by a specific method of engineering formation indicated that the USA had not yet settled its territorial identity as a country. In the 1870s and 1880s, the stabilization of engineering formation in schools proved to be an effective response to the scaling up of low cost, mass use as a metric of progress. Challenged by this territorial identity, Robert Thurston's creative initiatives gained broader acceptance when they promised to help produce industrial managers committed to high-volume production in the private sector and unsuccessful when they did not. In the 1920s, a sustained attempt by engineering educators to build a more coordinated system of technical education met with significant resistance to the extent it raised the specter of external control. In the end, the most successful initiatives were those that helped prepare engineers for corporate industry and, hence, advanced the dominant territorial project of self-realization through consumption. Finally, the Grinter Report's model of science-based curricula gained currency when Sputnik was judged to pose a fundamental challenge to the American way of life. The subsequent growth of government-sponsored actions, including nurturing of the defense industry, actually affirmed the dominance of low cost, mass use rather than undermining it.

The above accounts draw heavily from published histories of engineering education in the USA. As such, they constitute an attempt to integrate findings from contingent histories in order to call attention to a significant pattern in the midst of those contingencies. They seek to move in a direction opposite to derivative history, i.e. the transformation of nuanced accounts into simplified ones by stripping out situatedness and complexities, by making the case that historical contingencies gain their significance as such in relation to forms of patterned dominance. Thus, for example, Robert Thurston became an interesting and important figure in the emergence of engineering education in the USA not only because he was creative in building a novel educational enterprise at Cornell University but also because that enterprise was positioned materially in relation to the dominant territorial identities of both the USA and Germany. Part of what he did fit a country that took for granted the value of high-volume production at low costs and part did not. Both his individual acts of creation and constructions in negotiated interactions with others included struggle with the challenge of fit.

To thus call attention to the problem of fit with the country as a patterned issue in engineering formation is not to replace contingent practice with causal determination, nuance with simplism, or heterogeneity with homogeneity. Rather it is to advance the view that contingent changes necessarily also achieve continuities and, hence, to make visible the possibility that historical transformations in modes of engineering formation in the USA may have included continuities in the relationship between engineering formation and the country. In analyzing the emergence of engineering in France, Ken Alder asserts that engineers were 'designed to serve'.[62] Although the correlations presented above must be multiplied many times over to move the account from the plausible to the persuasive, taken together they do suggest that advocates of engineering formation design engineers to serve countries.

Finally, extrapolating from these episodes introduces the specific expectation that those initiatives in engineering formation that have succeeded in the USA over the course of its history are likely to be those that responded intelligently to its evolving metric of progress as low cost, mass use.

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Notes

[1] Reynolds, 'The Engineer'.
[2] Seely, 'The Other Re-Engineering'.
[3] Thurston, 'Technical Education', 855.
[4] Ibid., 860–861.
[5] Noble, *America by Design*, 29–32.
[6] Thurston, 'Technical Education', 994–1002.
[7] Calvert, *The Mechanical Engineer*, 49, 94, 102, 45.
[8] Ibid., 47, 177.
[9] Downey and Lucena, 'Knowledge and Professional Identity', 396–399.
[10] Ibid., 402–411.
[11] The concept of territorial identity builds on a general view of identities as projects locating entities in relation to other entities. As such, identities have both conceptual and material dimensions.
[12] This paper does not address the identity politics involved in people from the USA calling themselves Americans to the exclusion of South Americans, Central Americans, and other North Americans.
[13] National Commission on Excellence in Education, *A Nation at Risk*, 5–8.
[14] See, for example, De Laet, *Research in Science.*
[15] Calhoun, *American Civil Engineer*, 182–199.
[16] Reynolds, 'The Engineer', 11.
[17] Meiksins, 'Engineers in the United States', 62.
[18] Weiss, *The Making of Technological Man*, 63.
[19] Brittain and McMath, 'Engineers and the New South Creed', 127, 126.
[20] Downey and Lucena, 'Knowledge and Professional Identity', 404–407.
[21] Hounshell, *From the American System*, 122.
[22] Misa, *Nation of Steel*, xx–xxi.
[23] Calvert, *The Mechanical Engineer*, 278.
[24] Reynolds, 'The Engineer', 21.
[25] Calvert, *The Mechanical Engineer*, 65.
[26] Meiksins, 'Engineers in the United States', 67.
[27] Thurston, 'Technical Education', 862.
[28] Ibid., 856.
[29] Ibid., 859.
[30] Ibid., 103.
[31] Society for the Promotion of Engineering Education, *Report of the Investigation*, 142, 116, 56.
[32] Ibid., 1045.
[33] Noble, *America by Design*, 62.
[34] See, for example, Sklar, *The Corporate Reconstruction*.
[35] Dumenil, *The Modern Temper*, 26–27.
[36] Noble, *America by Design*, 229.
[37] Hounshell, *From the American System*, 12–13.
[38] Dumenil, *The Modern Temper*, 85, 82, 86.

[39] Ibid., 34.
[40] Nye, *Image Worlds*, 132.
[41] Layton, *Revolt of the Engineers*, 124–127; Meiksins, 'The "Revolt of the Engineers"', 420–424; Noble, *America by Design*, 39–44, 277–302.
[42] Noble, *America by Design*, 198, 193, 203.
[43] Society for the Promotion of Engineering Education, *Report of the Investigation*, 142, 115–116, 8.
[44] Ibid., 121.
[45] Ibid., 81.
[46] Ibid., 1045, 1044.
[47] Noble, *America by Design*, 206.
[48] Seely, 'The Other Re-Engineering', 292.
[49] American Society for Engineering Education, 'Report on the Evaluation', 26.
[50] American Society for Engineering Education, 'Report on the Evaluation', 38, 31.
[51] Seely, 'The Other Re-Engineering', 289, 291.
[52] Lucena, *Defending the Nation*, 29.
[53] Ibid., 41.
[54] Meiksins, 'Engineers in the United States', 82.
[55] Akera, 'Practice and Discursive Constructions', 9, 10.
[56] Meiksins, 'Engineers in the United States', 78.
[57] American Society for Engineering Education, 'Report on the Evaluation', 43.
[58] Akera, 'Practice and Discursive Constructions', 23.
[59] American Society for Engineering Education, 'Report on the Evaluation', 27, 44.
[60] Reynolds and Seely, 'Striving for Balance', 143.
[61] Meiksins, 'Engineers in the United States', 78.
[62] Alder, *Engineering the Revolution*, 85.

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