Individuals, Organizations, and Engineering

U.S. Army Officers and the American Railroads, 1827–1838

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Creative individuals and controlling organizations, subjects long familiar to historians of technology, often clash in military settings. Military establishments, favoring uniformity, order, and control, make difficult environments for innovative spirits, particularly during eras of rapid technological change and increasing institutional complexity. The U.S. Army officers who surveyed early American railroads struggled to maintain their autonomy as they grappled with a protean new technology and a burgeoning bureaucracy. Their story provides insight into two important questions: First, does the bureaucratic need for order and uniformity limit the independence of creative spirits? Second, does military patronage define, for better or worse, the character of a technology?

The backers of early American railroads consistently emphasized the military value of railroads to promote their projects. They claimed that the all-weather, rapid-transport capabilities of railroads were ideally suited to repelling invasions, pacifying Native Americans, suppressing slaves, and moving troops, supplies, and commercial goods in wartime. When Secretary of War James Barbour explained his decision to provide army engineers for the survey of the Baltimore and Ohio Railroad in 1827 by citing the military benefits the road would provide, the military value of railroads appeared to win acceptance. Army officers participated heavily in railroad development for over a decade.[1]

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1. On railroad advocates' efforts to promote their projects by citing their military

The U.S. Army's participation in railroad surveying was just one aspect of a much broader military contribution to American economic development during the antebellum era. Soldiers built roads along the frontier to encourage settlement, while members of the Army Corps of Engineers brought science and central planning to their work on water projects. Army topographical engineers made invaluable cultural and scientific discoveries as they explored and mapped the trans-Mississippi West. The Ordnance Department played an innovative role in the development of the production methods known as the "American system of manufactures" by providing a conceptual and institutional framework for developing and disseminating the new technologies.[2]

The officers who participated in these projects were members of one of the most complex, hierarchical, bureaucratic organizations of its day. Administrative and logistical difficulties during the War of 1812 prompted a series of organizational reforms in the army from 1818 to 1825. Secretary of War John C. Calhoun centralized power within the War Department in Washington, where he created a functionally specialized administrative hierarchy that enforced responsibility and accountability through the use of detailed rules and procedures. The rise of system and uniformity as

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value, see E. G. Campbell, "Railroads in National Defense, 1829–1848," *Mississippi Valley Historical Review* 27 (December 1940): 361–78; and James A. Ward, *Railroads and the Character of America, 1820–1887* (Knoxville, Tenn., 1986), chap. 3. The key work on the army's participation in railroad development remains Forest G. Hill, *Roads, Rails, and Waterways: The Army Engineers and Early Transportation* (Norman, Okla., 1957). Hill's book, however, focuses more on description than analysis. It lists the railroads that army engineers surveyed and the dates the surveys were conducted, but does not offer a detailed study of the engineers' principles and methods. Colleen Dunlavy has noted this omission and urged a close examination of the subject; see *Politics and Industrialization: Early Railroads in the United States and Prussia* (Princeton, N.J., 1994), 48 n. 6, 63, and "Politics and Industrialization: Early Railroads in the United States and Prussia" (Ph.D. diss., Massachusetts Institute of Technology, 1988), 147.

2. On army road building, see Francis Paul Prucha, *Broadax and Bayonet: The Role of the United States Army in the Development of the Northwest, 1815–1860* (Lincoln, Nebr., 1953), and *The Sword of the Republic: The United States Army on the Frontier, 1783–1846* (New York, 1969); Harold L. Nelson, "Military Roads for War and Peace, 1791–1836," *Military Affairs* 19 (spring 1955): 1–14; and Thomas E. Kelly, "The Concrete Road to MIC: Defense and Federal Highways," in *War, Business, and American Society: Historical Perspectives on the Military-Industrial Complex*, ed. Benjamin Franklin Cooling (Port Washington, N.Y., 1977). On the army's role in water projects, see Todd Shallat, *Structures in the Stream: Water, Science, and the Rise of the U.S. Army Corps of Engineers* (Austin, Tex., 1994). On the expeditions of the army's topographical engineers, see William H. Goetzmann, *Army Exploration in the American West, 1803–1863* (New Haven, Conn., 1959; reprint, with a new introduction, Austin, Tex., 1991). On the Ordnance Department, see Merritt Roe Smith, *Harper's Ferry Armory and the New Technology: The Challenge of Change* (Ithaca, N.Y., 1977), and "Army Ordnance and the 'American System' of Manufacturing, 1815–1861," in *Military Enterprise and Technological Change* (Cambridge, Mass., 1985).

organizing principles within the army paralleled the growth of modern management.[3]

Members of similar military bureaucracies have, on other occasions, dramatically influenced the course of technological development. Ken Alder demonstrated that in the eighteenth century scientifically trained engineers in the French artillery corps conducted a sophisticated political campaign to implement their vision of how to organize the nation's technological life. They sought not only to transform the way France fought but also to introduce science, precision, and planning to private industry in the service of a rational, centralized state. Their pursuit of a system of uniformity in gun manufacturing created new forms of technological knowledge, established new institutional structures, and defined the state's relationship to the productive order.[4]

The agenda and impact of the French military engineers bear comparison to the role of the military-industrial complex in the United States during the cold war. Once again, military organizations cooperated closely with scientists and engineers, shaping policies that extended well beyond the military or technical realms. The potential threat this collaboration posed to the integrity and autonomy of science and engineering and the distribution of political power alarmed many scholars. Paul Forman argued that military imperatives restricted the independence of quantum physicists and distorted their research agenda. In Paul Edwards's reading, the politics of the cold war permeated computer technology, even at the level of technical design. David Noble found that the military's emphasis on uniformity, command, and modernity in technology imposed unnecessary and undesirable economic and social costs.[5]

3. On the organizational development of the U.S. Army during the antebellum period, see Samuel P. Huntington, *The Soldier and the State: The Theory and Politics of Civil-Military Relations* (Cambridge, Mass., 1957), 214–17; Leonard White, *The Jeffersonians* (New York, 1959), 211–64; William B. Skelton, *An American Profession of Arms: The Army Officer Corps, 1784–1861* (Lawrence, Kans., 1992); Charles F. O'Connell Jr., "The United States Army and the Origins of Modern Management, 1818–1860" (Ph.D. diss., Ohio State University, 1982), and "The Corps of Engineers and the Rise of Modern Management, 1827–1860," in Smith, *Military Enterprise and Technological Change*. For a brief overview of army structure from 1815 to 1846, perhaps most valuable for its extensive bibliography, see Paul A. C. Koistinen, *Beating Plowshares into Swords: The Political Economy of American Warfare, 1606–1865* (Lawrence, Kans., 1996), 81–86.

4. Ken Alder, *Engineering the Revolution: Arms and Enlightenment in France, 1763–1815* (Princeton, N.J., 1997).

5. Paul Forman, "Behind Quantum Electronics: National Security as the Basis for Physical Research in the United States, 1940–1960," *Historical Studies in the Physical and Biological Sciences* 18 (1987): 149–229; Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, Mass., 1996); David F. Noble, *Forces of Production: A Social History of Industrial Automation* (New York, 1984), and "Command Performance: A Perspective on the Social and Economic Consequences

This study tests whether the experience of army engineers surveying early American railroads resembled the interplay of individual goals and organizational imperatives described in these literatures. It explores whether the officers' membership in a complex, hierarchical bureaucracy and the constant emphasis on the military value of railroads produced a distinctive military technological style. It also asks whether these nineteenth-century American engineers exhibited the hegemonic ambitions of the eighteenth-century French artillerists or the distorting influence of the cold war American military.[6]

Reviewing the surveyors' reports reveals that they proposed diverse railroad construction styles, many of which sacrificed performance in order to keep expenses low. Individual engineers retained their creative independence because political, economic, and social forces outweighed military considerations during the army's involvement in early American railroads. These factors included a political culture that fostered an instrumentalist view of government yet feared vested power, a relationship between the officers as individuals and the army as an organization that encouraged the officers to shape their recommendations to the individual railroad companies' needs, and a new technology constantly in flux. The army engineers' multifarious technical recommendations thus not only provide insight into early American railroad engineering but also suggest that military institutions do not always pursue a uniform approach to technology and that military patronage need not define the character of an innovation.[7]

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of Military Enterprise," in Smith, *Military Enterprise and Technological Change.* Before the cold war even began, Lewis Mumford noted that the symbiotic relationship between modern industrialism and large-scale military operations forced the pace of technological innovation, generating standardization and mass production; see *Technics and Civilization* (New York, 1934), 84–94. For a critique of historians' tendency to focus on the military-industrial complex whenever they write about the history of technology and the military, see Alex Roland, "Science, Technology, and War," *Technology and Culture* 35 (1995): S84–S89.

6. Merritt Roe Smith and others have called for additional studies of the relationship between the military and industry before the twentieth century: see Everett Mendelsohn, Merritt Roe Smith, and Peter Weingart, "Science and the Military: Setting the Problem," in *Science, Technology, and the Military* (Dordrecht, Neth., 1988), xiv; Lewis Pyenson, "On the Military and the Exact Sciences in France," in *National Military Establishments and the Advancement of Science and Technology: Studies in Twentieth-Century History*, ed. Paul Forman and José M. Sanchez-Ron (Dordrecht, Neth., 1996), 136, 149 n. 6.

7. For an eyewitness description of the diversity of antebellum railroads, see Franz Anton Ritter von Gerstner, *Early American Railroads: Franz Anton Ritter von Gerstner's "Die Innern Communicationen," 1842–1843*, ed. Frederick C. Gamst, trans. David J. Diephouse and John C. Decker (Stanford, Calif., 1997). Colleen Dunlavy has also argued that the American style of railroad construction was varied, and cites the influence of political structure on the character of the engineering community as the primary cause of that diversity of styles; see Dunlavy, *Politics and Industrialization* (n. 1 above), 202–34. Although this article does not dispute the importance of institutional structure, it high-

Early American railroad advocates frequently stressed their military value. Railroads, they argued, could move troops rapidly and deliver them to their destination fit and ready for action year-round. Boosters of the South Carolina Railroad in 1828 boasted that their line would convey one thousand troops one hundred miles in twelve hours, while "a New York Citizen" writing in the *American Railroad Journal* asserted that an extensive rail network would transport the country's vast resources to any point of attack "with the speed of the wind." The editors of the *Mercantile Advertiser* added that railroads surpassed steamboats and canals for defense because all the internal water communications froze in winter.[8]

Railroads' rapid, all-weather transport capabilities promised to solve the country's three primary security problems during the antebellum period: foreign invasion, Native American unrest, and slave rebellion. Massachusetts state representative Emory Washburn, speaking in support of the Western Railroad, asserted that railroads would enable the nation to ward off the attack of any invader. The Montgomery Railroad Company, in a petition to Congress, underlined the potential benefits to the government of its line in the event of a future conflict with "the savage hordes upon our South Western frontier." A civil engineer advised a group planning a railroad from Cincinnati to Charleston: "The south, possessing a slave population, whose physical strength increases in a ratio greater than that of their owners, will, no doubt, view this additional bond of union with their white brethren as auspicious of their own safety." One of the road's commissioners from South Carolina agreed, promising that the road would end, once and forever, all fears of slave revolt.[9]

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lights additional reasons why army engineers in particular recommended various styles of railroad construction.

8. *Report of a Special Committee Appointed by the Chamber of Commerce to Inquire into the Cost, Revenue, and Advantages of a Rail Road Communication between the City of Charleston and the Towns of Hamburg and Augusta* (Charleston, 1828), 20; *American Railroad Journal* 4 (17 October 1835): 642; editors of the *Mercantile Advertiser* quoted in *American Railroad Journal* 1 (19 May 1832): 325.

9. Emory Washburn, *Speech of Emory Washburn, Delivered in the House of Representatives of Massachusetts, Feb. 14, 1838, on the Bill to Aid the Construction of the Western Rail Road* (Springfield, Mass., 1838), 27; Montgomery Railroad Company, 26 December 1836 [referred 30 January 1837], file SEN 24A-G17.2, Petitions and Memorials Referred to the Committee on Roads and Canals, Various Subjects, Record Group 46, Records of the U.S. Senate, National Archives, Washington, D.C. [hereafter NA]; J. S. Williams to Daniel Drake, *American Railroad Journal* 4 (19 December 1835): 787; Robert Y. Hayne, *Address in behalf of the Knoxville Convention to the Citizens of the Several States Interested in the Proposed Louisville, Cincinnati, and Charleston Rail Road* (Charleston, 1836), 24. Walter Gwynn, a former member of the Corps of Engineers who left the army to work as a railroad engineer, advised the president and directors of the Wilmington and Raleigh Railroad Company that "one of the most happy results of the Railway system" in the South would be its ability "to put down, if not entirely suppress and remove all

Railroad backers also claimed that their lines would transport soldiers and supplies safely and inexpensively and enable internal commerce to continue in the event that war with a superior naval power halted seaborne trade. The citizens of Adams County, Illinois, argued that a railroad from Buffalo, New York, to their county would lower the government's costs for transporting military supplies for the western posts and the Indian department by over 75 percent. The editor of *Niles' Weekly Register* asserted that the entire cost of a railroad from New York to Washington would be less than the additional charges that had been incurred when British naval superiority blocked seaborne transport between the two cities during the War of 1812. One supporter of a railroad from Boston to Albany claimed that poor transportation during the war had increased the cost of flour and bread in those cities enough to pay for the entire construction of the road. Backers of the Louisville, Cincinnati, and Charleston Railroad promised that their line would ensure the continued shipment of the Southeast's products in wartime.[10]

Although railroad promoters sought any assistance they could get from the government, more than simple boosterism motivated them to stress the military importance of their projects. The scarcity of capital in antebellum America forced backers to advertise their road's stature and potential revenue in order to attract investment. By suggesting that the army might use its line to move troops and supplies, a railroad not only enhanced its prestige but also raised the prospect of a steady flow of income that might make the difference between financial success or failure.[11]

A shortage of academically trained engineers also encouraged railroad advocates to accentuate their projects' military worth. Demand for skilled civil engineers far outstripped supply in the early republic. The United States Military Academy, however, produced more engineers than the army could employ. To remedy the problem, Congress passed the General Survey Act of 1824, which authorized the president to assign army engineers to

apprehensions of servile disturbances and insurrections"; *American Railroad Journal* 5 (17 September 1836): 581–82.

10. Citizens of Adams Co., Ill., 28 November 1831 [referred 10 January 1832, referred again 3 March 1834], file SEN 23A-G17, Petitions and Memorials Referred to the Committee on Roads and Canals, RG 46, NA; comments of the editor of *Niles' Weekly Register* reprinted in *Railroad Advocate* 1 (7 June 1832): 194; William Jackson, *Lecture on Railroads, delivered January 12, 1829, before the Massachusetts Charitable Mechanics Association* (Boston, 1829), 19–20; *Proceedings of the Knoxville Convention, in Relation to the Proposed Louisville, Cincinnati, and Charleston Rail-Road* (Knoxville, Tenn., 1836), 12.

11. Railroads during the period also asked the government for direct investment, land grants, and tariff relief on imported rails. For an explanation of why American railroads found attracting capital difficult, see Dunlavy, *Politics and Industrialization*, 212–14.

civilian projects "of national importance." The act identified military utility as one of the determinants of an undertaking's national importance, prompting railroads to underscore their military advantages in the hope of obtaining military assistance.[12]

Initially, the arguments of railroad backers emphasizing the military value and national importance of railroads appeared effective. When Secretary of War James Barbour agreed to the Baltimore and Ohio Railroad's request for engineering assistance in 1827, his justification for the action followed closely the arguments of railroad advocates who stressed the military importance of railroads. Explaining his decision, Barbour informed Philip E. Thomas, president of the Baltimore and Ohio:

> The successful introduction of Rail-Roads, into this country, is viewed by the Department as of great national importance, and especially any practicable mode of connecting the Atlantic States with the Western; whether by Rail-Roads or Canals, so that the commodities to be found in either can be conveniently and cheaply conveyed to the other, across the barriers which divide them, and which communications, while aiding in the advancement of commercial enterprise, offer the most sure and economical means to the Government to convey, to the different parts of the Union, the means of defense, in the transportation of men and munitions to the seat of war, wherever it shall exist.[13]

For over a decade following Barbour's initial decision to assist the Baltimore and Ohio, army officers participated actively in railroad development. Between 1832 and 1836, they provided assistance to over twenty different railroad companies. In 1835 alone at least fifteen railroads received engineering aid from the army. The army engineers' work prompted Francis Wayland, president of Brown University, to declare in 1850 that "The single academy at West Point has done more toward the construction of railroads than all our . . . colleges united."[14]

12. On the shortage of civil engineers, see Daniel Hovey Calhoun, *The American Civil Engineer: Origins and Conflict* (Cambridge, Mass., 1960), 17–22. On West Point's role in nineteenth-century engineering, see Terry S. Reynolds, "The Engineer in 19th-Century America," in *The Engineer in America: A Historical Anthology from "Technology and Culture"* (Chicago, 1991), 16–17. On the General Survey Act of 1824, see Hill (n. 1 above), 44–47.

13. Barbour to Thomas, 25 June 1827, roll 2, microfilm M-1113, Miscellaneous Letters Sent by the Chief of Engineers, 1812–1869 [hereafter M-1113], NA. Later that year, Barbour again noted in a report to Congress that the railroad "is certainly of great national importance"; see "Showing the Condition of the Military Establishment and Fortifications during the year 1827," 26 November 1827, *American State Papers: Military Affairs*, vol. 3 (Washington, D.C., 1860) 616.

14. Lt. Col. John J. Abert to B. F. Butler, 24 January 1837, roll 2, microfilm M-66, Letters Sent, Topographical Bureau of War Department and Successor Divisions [here-

The antebellum army constituted the most advanced management bureaucracy in the country. Equipment shortages, recruiting shortfalls, and administrative deficiencies had embarrassed the army and the War Department during the War of 1812. John C. Calhoun, secretary of war from 1817 to 1825, campaigned successfully to improve military preparedness and organizational effectiveness.[15]

Calhoun pursued three reform objectives. First, he centralized authority. During the War of 1812 the army's decentralized staff system had placed some departmental headquarters in Washington, scattered several around the country, and lacked others altogether. Soon after assuming his duties as secretary of war, Calhoun secured passage of a bill formalizing the staff system. He subsequently ordered the heads of the staff departments to locate their headquarters in Washington. He then appointed able veterans of the War of 1812 as heads of the bureaus, where they provided him and the army with technical and administrative expertise.[16]

Second, Calhoun and his subordinates standardized reporting and accounting procedures to ensure responsibility and accountability. Field commanders submitted regular returns of the troops and property under their control. Engineers completed frequent expense estimates, equipment inventories, and progress reports. Bureau chiefs prepared detailed reports of their departments' operations. The system that Calhoun and his compatriots implemented enabled the army to function more efficiently, respond to congressional and public requests for information more effectively, and track more accurately the large sums of money and property under its control.[17]

Third, Calhoun established a functionally specialized administrative system governed by rules and procedures. As part of his reorganization of the staff system he created new departments, including the Subsistence Department and the Medical Department, and reorganized existing ones, such as the Quartermaster's Department. He assigned each a clearly defined area of responsibility and, to ensure their efficient functioning, required department heads to develop regulations governing department activities. These regulations, as well as other detailed rules and procedures governing

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after M-66], NA; Francis Wayland, *Report to the Corporation of Brown University on Changes in the System of Collegiate Education, Read March 28, 1850* (Providence, R.I., 1850), quoted in Frederick Rudolph, *The American College and University* (New York, 1962; reprint, Athens, Ga., 1990), 238.

15. The following survey of army organizational development relies primarily on White, 233–50; O'Connell, "The United States Army," 21–86, and "The Corps of Engineers"; Skelton, 119–30; and Koistinen, 81–86 (all n. 3 above).

16. Skelton, 120; White, 246; Koistinen, 82; O'Connell, "The United States Army," 40–43.

17. Skelton, 120–21; O'Connell, "The Corps of Engineers," 94–95, and "The United States Army," 49–50.

army life, reached the army in the field via Brigadier General Winfield Scott's *General Regulations for the Army*, first issued in 1821 and revised in 1825. By the time Calhoun left the War Department to become vice president in 1825, the army was, in the words of one historian, "well on its way to becoming a modern, reasonably effective corporate bureaucracy, more advanced and better organized than any contemporary social, political, or business organization in the United States."[18]

The rise of complex management bureaucracies within the army magnified the importance of system and uniformity. The same quest for order that motivated the creation of administrative hierarchies governed by strict regulations also manifested itself in the military approach to technology, most notably in ordnance production. French military engineers of the Enlightenment first introduced science, precision, and planning to the production of cannons and small arms. French engineers and American admirers brought the French system to the United States, where the U.S. Army Ordnance Department adopted it. As heads of the Ordnance Department, Decius Wadsworth and his successor George Bomford worked tirelessly to implement the uniformity system. They commissioned pattern arms to guide production, introduced sophisticated bookkeeping methods to evaluate operations, and instituted regular inspections. Uniformity became, in the words of Merritt Roe Smith, "the great desideratum" of nineteenth-century American military engineers and ordnance officers. Its popularity was apparent not only in military circles but also in civilian forums, such as Southern agricultural journals and educational reform movements.[19]

The army engineers who surveyed railroads demonstrated a remarkable independence, which sometimes contradicted both the emphasis on the roads' military value and the engineers' membership in a complex, hierarchical bureaucracy that often stressed uniformity. Although they did occasionally acknowledge the military utility of rail transport, they demonstrated more interest in the commercial possibilities of the routes they surveyed.

18. O'Connell, "The Corps of Engineers," 96. See also Skelton, 120–22; O'Connell, "The United States Army," 44; and Erna Risch, *Quartermaster Support of the Army: A History of the Corps, 1775–1939* (Washington, D.C., 1962; reprint, 1989), 181–88.

19. Skelton argues (p. 129) that uniformity, order, and system were the principal themes of military reform after 1815. On French military engineers and the development of ordnance production, see Alder (n. 4 above). On the adoption of the French system in the Ordnance Department, see Smith, "Army Ordnance and the 'American System'" (n. 2 above); for the quote identifying uniformity as the great desideratum of nineteenth-century military engineers, see Smith, introduction to *Military Enterprise and Technological Change* (n. 2 above), 21. On the influence of uniformity and system on Southern society and ultimately on the Confederate Ordnance Department during the Civil War, see Steven G. Collins, "System in the South: John W. Mallet, Josiah Gorgas, and Uniform Production at the Confederate Ordnance Department," *Technology and Culture* 40 (1999): 517–44.

When locating a railroad, they focused on grade and expense. They often detoured from the most direct route in order to avoid steep grades or expensive cuttings and embankments. When advising on the construction of a railroad, they concentrated on lowering construction and operating costs rather than maximizing performance or ensuring uniformity. They followed no consistent procedure when making recommendations regarding construction, instead tailoring their suggestions to companies' individual needs. The result was a diversity of railroad construction styles, many of which sacrificed performance in order to keep expenses low.[20]

The tasks that army officers performed during their surveys reveal the extent of their independence. Army surveyors first scanned the area through which the line would run to identify possible routes and determine the feasibility of construction. This initial reconnaissance consisted of a cursory inspection to ensure that no significant obstacles, such as ravines, rivers, hills, or mountains, blocked construction. They then made a preliminary instrument survey to measure key elevations, assemble information on the nature of the soils, determine the availability of building materials, and prepare cross sections of land at appropriate intervals along the route. They made no attempt to lay out the route with any exactitude. As the Board of Commissioners of Internal Improvements for Massachusetts observed, "a first examination can only give a general view of the distances, and the facilities and obstacles to the road, sufficient to form an opinion of the expediency or inexpediency of commencing a work of the kind, but by no means so accurate that it ought to be implicitly followed in the execution."[21]

If the route proved feasible, the engineers next prepared maps and profiles and located the road definitively. Locating the roadbed was the army

20. Most of the historical work examining the military's impact on American railroad development has focused on the army's influence on the railroads' organizational culture. See, in particular, O'Connell, both "The Corps of Engineers" and "The United States Army," and Frederick C. Gamst's editor's notes in Gerstner (n. 7 above), 822–24 n. 46, 825 n. 5. The few historians who have addressed the army's effect on railroad technology have tentatively suggested that military need also influenced railroad routes and construction styles. Hill asserts that "military considerations were a criterion which the army engineers kept constantly in mind" when making their surveys; see Hill (n. 1 above), 9. Dunlavy indicates that the military influence on the location of rail lines is a subject worthy of further attention; see Dunlavy, *Politics and Industrialization* (n. 1 above), 48 n. 6. Barton C. Hacker notes that "although military needs and wants hardly dictated railroad development in the United States, they nonetheless emerged as a significant factor"; see "Science and Technology in the Nineteenth Century," in *A Guide to the Sources of United States Military History*, suppl. 4, ed. Robin Higham and Donald J. Mrozek (Hamden, Conn., 1998), 88.

21. *Report of the Board of Commissioners of Internal Improvement in relation to the examination of sundry routes for a railway from Boston to Providence* (Boston, 1828), 12–13. See also *American Railroad Journal* 1 (28 January 1832): 67, and the comments of Stephen H. Long in U.S. House, *Railroads—Atlantic to the Mississippi*, 23rd Cong., 2nd sess., 27 February 1835, H. Doc. 177, Serial 274, 2–3.

engineers' primary contribution to surveying a railroad route. The process involved balancing conflicting requirements. Railroads worked most efficiently when they were as straight and level as possible. Curves not only lengthened the line but also reduced the speed at which trains could travel. Steep grades or numerous ascents and descents also slowed traffic considerably. But straight, level routes were hard to find. Creating them where they did not exist increased construction costs substantially. Locating the roadbed therefore required, as army civilian engineer George W. Hughes noted in 1832, comparing expense, distance, curvature, and grade.[22]

The engineers did not ignore the principle of directness; where practical, they preferred to lay out railroads with as few curves as possible. Captain William Gibbs McNeill, the best known of the army railroad engineers, boasted in an 1832 letter to the editor of the *American Railroad Journal* that the railroad he was surveying from Boston to Providence would be virtually straight, with no curve less than six thousand feet in radius. In later years he reported to the president of the Boston and Providence that the company's line from Providence to Stonington would avoid "a single abrupt curvation" and praised the Louisville, Cincinnati, and Charleston's line for the directness of its route and its lack of sharp curves.[23]

The shortest distance between two points, however, was not always level. Army civilian engineer Charles Anderson discovered during his survey of a section of the Hudson and Berkshire Railroad that "too close and rigid adherence to an apparently straight line led us frequently over ground which was thought sufficiently bad to warrant a change in course." William Howard, another army civilian engineer, was even more convinced that the benefits of directness were illusory. He argued that maintaining a straight line should be the last consideration. And John M. Fessenden, a former

22. Capt. George W. Hughes, "Report on the Survey of the Fredericksburg and Potomac Creek Railroad," 1 May 1832, Entry 250, Reports on Internal Improvements, RG 77, Records of the Office of the Chief of Engineers [hereafter E-250, RG 77], NA, 4:622. Despite the military title, Hughes was a civilian engineer when he conducted the survey. He attended West Point, but was expelled days before graduation for brawling. When the Corps of Topographical Engineers was formed in 1838, he received a commission. The report was probably transcribed some time after 1838 and the transcriber simply used Hughes' rank at the time. Another civilian engineer who worked for the army, William B. Guion, also attended West Point but failed to graduate. See Thomas J. Fleming, *West Point: The Men and Times of the United States Military Academy* (New York, 1969), 58, 70. Stephen Long noted the desirability and the scarcity of straight, level routes; see U.S. House, *Railroads—Atlantic to the Mississippi*, 6. On balancing conflicting requirements in the design of a technology, see, for example, Walter G. Vincenti, "The Retractable Airplane Landing Gear and the Northrop 'Anomaly': Variation Selection and the Shaping of Technology," *Technology and Culture* 35 (1994): 1–33.

23. On McNeill's work in New England, see *American Railroad Journal* 1 (1 September 1832): 562, and *American Railroad Journal* 2 (27 April 1833): 258. His comments regarding the Louisville, Cincinnati, and Charleston are quoted in Hayne (n. 9 above), 8.

army engineer working for the Boston and Worcester Railroad, noted that "the inclination of the road" qualified the need for directness.[24]

Army engineers thus focused more on elevation than linearity, and often deviated from a straight line in order to avoid steep grades. Lieutenant Isaac Trimble asserted that "not only the practicability but the beneficial operation of Rail Roads, depends upon their general levelness or slight inclination and avoiding a frequent repetition of summits and abrupt ascents and descents." Lieutenant Colonel Stephen H. Long argued that "it is obvious that wherever a hill can be avoided, even at the expense of horizontal distances, . . . this measure is to be preferred." Long advised curves in order to avoid ascents or descents and included several with radii of less than 800 feet in his surveys, while other army engineers proposed curves of 400 feet or less. French engineers, in contrast, had established a minimum radius of 2,700 feet. Lieutenant Joshua Barney, in his survey of a section of the Baltimore and Ohio, proposed a route nearly twice as long as the direct distance in order to avoid steep grades.[25]

The engineers' preoccupation with the grade of the railroads they surveyed reflected their focus on the commercial benefits of railroads and their desire to keep operating costs low. Long explained that he avoided summits because they "constitute such serious impediments to the cheap and expeditious interchange of commodities." Indeed, commercial considerations, particularly the volume of trade flowing in each direction along the route, frequently determined the elevation of a railway; wherever possible army engineers followed a formula that based the grade of a railroad on trade volume between its endpoints. As Lieutenant John Pickell explained, "when the amounts of tonnage in both directions are equal, it [the railway] ought to be level; when as one to two, the inclination should be such that the same power would be attended with equal resistance both ways." Thus, if a road carried traffic primarily in one direction, it should slope so that the power

24. Charles E. Anderson, "Report on Survey of Section of Hudson and Berkshire Railroad," 18 November 1828, E-250, RG 77, NA, 3:142; William Howard, "Report to the President and Directors of the South Carolina Canal and Railroad Company," 27 August 1829, E-250, RG 77, NA, 3:64. For Fessenden's comments, see *American Railroad Journal* 1 (14 April 1832): 242.

25. Lt. Isaac Trimble, "Descriptive Memoir," in *Report of the Engineers on the Reconnaissance and Surveys, made in reference to the Baltimore and Ohio Railroad*, by the Baltimore and Ohio Railroad Company (Baltimore, 1828), 129–30; Lt. Col. Stephen H. Long to P. E. Thomas, printed in *American Railroad Journal* 1 (4 February 1832): 82–83; U.S. House, *Railroads—Atlantic to the Mississippi*, 8; Lt. Col. Stephen H. Long, "Report on the New Hampshire and Vermont Divisions of the Boston and Ogdensburg Railroad," 1 May 1832, E-250, RG 77, NA, 5:33; Lt. Joshua Barney, "Descriptive Memoir," in *Report of the Engineers on the Reconnaissance and Surveys*, 94. Among those recommending very abrupt curves was Lt. Col. P. H. Perrault: see "Report on the Survey of the Hudson and Berkshire Railroad," 14 January 1829, E-250, RG 77, NA, 3:135. For French standards, see Colleen Dunlavy, "Politics and Industrialization" (n. 1 above), 254–55.

required to haul the loaded trains equaled that required to return the empties. Since the difference in elevation between two points is fixed, it remains unclear what Pickell and his fellow engineers thought they might do when the grade and traffic flows did not fit their formula. Pickell himself admitted that the ground over which a railroad passed rarely permitted an inclination throughout the line corresponding exactly to the ratio of tonnage. Still, he argued, a standard of reference was essential. Lieutenant William H. Swift summarized the army engineers' approach to railroad location best when he advocated "subserving the public interest in the best possible manner, viz. by locating the road in a manner that will conform nearest to the present state of the trade, with a due regard to the cost of construction."[26]

Army engineers also emphasized grade in order to keep construction costs to a minimum. Railroads, argued Long, should facilitate and speed transportation at the least expense. Since lines over uneven ground usually required deep cuts, heavy embankments, and long viaducts, which could raise the construction costs of the railway substantially, engineers often deviated from the most direct route in order to avoid expensive digging and filling. Lieutenant Jefferson Vail's recommendations embodied this attitude toward railroad construction. Vail proposed a longer alternate route during his survey of a section of the Hudson and Berkshire Railroad because it offered a more even grade and lower construction costs.[27]

In cases where army engineers could not avoid a steep grade with curves and had to choose between minimizing construction costs by laying out a steep line or minimizing operating costs by expensive cutting and filling, they usually picked the latter. Long frequently recommended routes that cost more to construct in order to lower operating expenses. He supported equalizing the grade and eliminating abrupt curves on a section of the

26. Baltimore and Ohio Railroad Company, *Report of the Engineers on the Reconnaissance and Surveys*, 9; Lt. John Pickell, "Report on the Canajoharie and Catskill Railroad," 3 November 1830, E-250, RG 77, NA, 3:288–89; Lt. William H. Swift, "Report on the Catskill and Ithaca Railroad," 31 March 1830, E-250, RG 77, NA, 3:257. For other examples of army engineers relying on trade flows to determine railroad grade, see Capt. William Turnbull, "Further Report on the Survey of Routes for the West Feliciana Railroad," 3 May 1832, E-250, RG 77, NA, 4:633; Perrault, 3:131; Lt. William H. Swift, "Report in Relation to a Communication between Cayuga Lake and the Susquehanna River," 31 July 1828, E-250, RG 77, NA, 3:238–39; Hughes, 4:621; and Howard, 3:69. Civilian engineers followed the same formula. The Philadelphia and Reading Railroad, surveyed by Moncure Robinson and intended to carry coal from the Schuylkill region to Philadelphia, sloped downhill for almost its entire length; Gerstner (n. 7 above), 607–8.

27. Stephen H. Long, *Rail Road Manual, or a Brief Exposition of Principles and Deductions Applicable in Tracing the Route of a Rail Road* (Baltimore, 1829), 5; Lt. Jefferson Vail, "Report on Survey of Section of Hudson & Berkshire Railroad," 12 December 1828, E-250, RG 77, NA, 3:151. See also Turnbull, 4:634, and Hughes, 4:620. For an example of a leading army engineer's attempts to avoid expenses, see William G. McNeill's report to the president of the Providence and Boston Railroad in *American Railroad Journal* 2 (27 April 1833): 258.

Boston and Ogdensburg Railroad even though it required much excavation and embankment. And in his survey for a rail line between Augusta and Portland, Maine, Long chose a route that required expensive bridging over another that included steeper grades and tighter curves, arguing that lower operating costs would compensate for its greater initial expense. Avoiding a grade of thirty feet per mile justified, in his view, spending twenty-five thousand dollars.[28]

In addition to surveying the route and laying out the roadbed, army engineers also outlined plans for constructing the track. One of the most important technical recommendations they made as part of a construction plan concerned track gauge. The gauges of antebellum American railroads varied widely. Intercity or commercial railroads employed at least seven different gauges prior to 1848. The differences were rarely large, but often enough to prevent the rolling stock of one railroad from passing on to another. The problem had little impact when railroads were in their infancy and remained on the whole isolated from each other. As the number of railroad projects multiplied, however, the variety of gauges also increased.[29]

Army officers recommended several different track gauges in their surveys. Howard, surveying the South Carolina Railroad, proposed a gauge of 4 feet, 6 inches, a common track gauge in Scotland and the one recommended by engineering textbook author Thomas Tredgold. The line eventually adopted a gauge of 5 feet, following the recommendation of its chief engineer, Horatio Allen. The engineers surveying the Baltimore and Ohio initially planned to follow Tredgold's recommendation as well, but later switched to a gauge of 4 feet, 8 1/2 inches after visiting the Liverpool and Manchester Railway in England. In his survey of the Canajoharie and Catskill Railroad, Pickell recommended another gauge popular in Scotland, 4 feet, 6 1/2 inches, while Hughes recommended a gauge of 4 feet, 9 1/4 inches for the Fredericksburg and Potomac Creek Railroad.[30]

28. Long, "New Hampshire and Vermont Divisions of the Boston and Ogdensburg Railroad," 5:34; Lt. Col. S. H. Long, "Report on a Reconnaissance for a Railroad from Portland to Bangor," 8 December 1836, E-250, RG 77, NA, 5:44–46.

29. Although significant, gauge variation during the years of army involvement was less than many historians have suggested. When the army ended its engineering assistance to railroads in 1839, nearly 80 percent of the total route length in North America used standard gauge (4 feet, 8 1/2 inches). Of course, there were only 2,277 miles of track. The early dominance of standard gauge nevertheless makes the army engineers' willingness to recommend alternatives even more striking. The most comprehensive discussion of gauge variation on American railroads is Douglas J. Puffert, "The Economics of Spatial Network Externalities and the Dynamics of Railway Gauge Standardization" (Ph.D. diss., Stanford University, 1991), esp. 59, 138, 194, 197–200, 210, 212, 256–302. For the effects of gauge diversity on military operations during the Civil War, see George Edgar Turner, *Victory Rode the Rails: The Strategic Place of Railroads in the Civil War* (Indianapolis, 1953), 44.

30. Howard (n. 24 above), 3:67–68; Pickell, 3:291–92; Hughes (n. 22 above), 4:625–66. Puffert notes that minor variations of the standard gauge, such as those rec-

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Army engineers also suggested the materials the railroads should use to build their rights-of-way. Here their biggest challenge was balancing durability with expense. Stone and iron lasted longer, but were often scarce and therefore more expensive. Wood was less sturdy, but plentiful and thus much cheaper. The wooden superstructure of a bridge cost between eight and fourteen thousand dollars, whereas a similar structure of stone cost between two and three hundred thousand dollars.[31] Just as they did when locating the roadbed, army engineers showed a keen awareness of commercial considerations when recommending construction materials. If the projected traffic on the line did not justify the use of stone and iron, the engineers recommended less expensive alternatives until usage increased. Thus, Hughes acceded to the Fredericksburg and Potomac Creek's desire for "a cheap and economical mode of construction" by recommending a single track consisting of wooden sleepers and wooden rails topped with iron plates five-eighths of an inch thick. Howard posited that whatever the material ultimately used on the South Carolina Railroad, wood was the most suitable substance for its initial construction. As the wood wore out and the road became more profitable, he noted, granite sills and iron rails could replace wooden ones.[32]

On the other hand, if the railroad's backers expressed greater confidence in their project's success, the engineers favored construction with stone and iron. Since the supporters of the Catskill and Ithaca Railroad, according to Swift, "had it in contemplation to construct it, in all its parts, of the most substantial and durable materials, that is to say, as far as would be considered judicious and consistent with a proper economy," he recommended continuous stone supports beneath iron rails. Lieutenant Colonel Paul H. Perrault also recommended granite runners topped with iron for the Hudson and Berkshire Railroad. Similarly, former army engineer John Fessenden reported to the directors of the Boston and Worcester Railroad: "The question of a cheap or temporary construction, with a view to a more durable one, if successful (a mode certainly to be advised in cases of uncertainty) I think need not be raised upon this route. The merits of it in every

ommended by some of the army engineers, were often the result of variations in engineering practice—for example, allowing different lateral clearance between wheel gauge and track gauge. Interestingly, gauge variance increased after army engineering assistance ended. By the eve of the Civil War only about 55 percent of North American rail mileage was standard gauge. The increased diversity was the result of the revival of broad gauge construction in international engineering practice, not the withdrawal of army engineering aid; see Puffert, 197–98, 256–302. For other discussions of gauge variation, see George Rogers Taylor and Irene Neu, *The American Railroad Network, 1861–1890* (Cambridge, Mass., 1956), 77–81, and Dunlavy, *Politics and Industrialization* (n. 1 above), 198–99.

31. Dunlavy, *Politics and Industrialization* (n. 1 above), 257.

32. Hughes, 4:625–26; Howard, 3:66–68. Howard uses the term "sills" to refer to what we would usually call "sleepers."

respect, are such, in my opinion, as to recommend at once a construction of the most durable materials."[33]

Army engineers' recommendations for track construction lacked uniformity. Even when different railroads served the same town or city, the engineers ignored the possibility of through traffic and recommended incompatible construction styles. The double track of stone rails Swift suggested for the Catskill and Ithaca Railroad was incompatible with the single track of oak sleepers and oak rails capped by iron plate 2 1/4 inches wide and 1 1/2 inches thick he recommended for the Ithaca and Owego Railroad. Meanwhile, Pickell proposed a single track of stone rails with still different dimensions for the Canajoharie and Catskill Railroad.[34]

The political culture of the early republic provided the essential context for both the diversity of army engineers' recommendations and their independence from constraints that might have been expected given their place in a relatively rigid hierarchy. Citizens viewed national governmental institutions as instruments to serve local political and commercial interests, yet they distrusted the vested powers of any organized body. Although the army's engineering assistance program aimed to further projects of national importance, local political and commercial influence determined which railroads received aid. The importance of local considerations encouraged engineers to tailor their recommendations to the needs of the railroads they surveyed and enabled engineers to use their political connections to pursue their own career goals. Simultaneously, the prevailing suspicion of centralized power discouraged attempts by either the federal government or the army to mandate uniform standards, even concerning questions such as track gauge, where civilian and military observers recognized the lack of uniformity as a potential obstacle to military operations.

The General Survey Act of 1824, which provided the legal authority for the army's engineering aid to railroads, empowered the president to assign officers of the Corps of Engineers to surveys of such works "as he may deem of national importance, in a commercial or military point of view, or necessary for the transportation of the public mail." Spokesmen for railroads, either congressmen or high-ranking state officials, would send formal requests to the War Department asking it to furnish engineers for surveys of proposed routes through their states. If approved, the War Department passed the request to the Topographical Bureau and asked the bureau to

33. Engineers of the period referred to iron plates fastened to a continuous stone foundation as stone rails; see the report of the Committee on Railroads, State Assembly of New York, reprinted in *American Railroad Journal* 1 (18 February 1832): 115. For engineers' recommendations of stone rails, see Swift, "Catskill and Ithaca Railroad" (n. 26 above), 3:268, and Perrault (n. 25 above), 135. For Fessenden's report, see *American Railroad Journal* 1 (14 April 1832): 242.

34. Swift, "Communication between Cayuga Lake and the Susquehanna River" (n. 26 above), 3:242–43, and "Catskill and Ithaca Railroad," 3:268; Pickell (n. 26 above), 3:291–92.

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undertake the work as soon as possible. The Topographical Bureau ostensibly followed a long-standing policy when assigning engineers: surveys ordered by acts containing specific appropriations received priority, followed first by surveys called for by resolutions of either house of Congress, and then by surveys of a "national or highly interesting commercial character" requested by states or private companies. Only officers and instruments that could be spared were allowed for the last category.[35]

The true measure of a railroad's importance in the eyes of the War Department, however, was the political clout of its supporters, not its national or military utility. The Baltimore and Ohio Railroad, the first to receive assistance from the War Department, demonstrated the value of political influence. It counted some of the wealthiest and most prestigious citizens of Maryland among its backers, including Charles Carroll, the last surviving signer of the Declaration of Independence; Senator Samuel Smith of Maryland; former Congressman Isaac McKim; Baltimore city council members John B. Morris and Solomon Etting; and merchant princes William Patterson, Alexander Brown, and Robert Oliver. When the Baltimore and Ohio sought engineering assistance from President John Quincy Adams, it sent three of its most influential directors: Philip E. Thomas, a wealthy and politically influential banker who had been elected president of the railroad, Patrick Macauley, a city council member appointed by the city of Baltimore to represent its interests, and George Hoffman, a Baltimore merchant. Adams received their petition enthusiastically. He referred them for particulars to Secretary of War James Barbour. Although Barbour had long supported federal assistance for internal improvements, he was also not above partisan politics. During the period when the Baltimore and Ohio requested engineering aid, Barbour was corresponding with political allies in Maryland regarding Adams's prospects for re-election the following year. He may have viewed the provision of federal assistance as a way to secure valuable political support. In any case, he swiftly dispatched three engineering brigades, headed by Long, McNeill, and Howard respectively, to survey the road. By the time Carroll laid the first stone for the Baltimore and Ohio on 4 July 1828, twelve army engineers worked for the company. The President's implicit endorsement of the Baltimore and Ohio's request and the wealth and political prestige of the railroad's supporters played at least as great a role as the road's national military or commercial importance in Barbour's decision to provide it with aid.[36]

35. On the General Survey Act and the Topographical Bureau's policy regarding the assignment of engineers to surveys, see Hill (n. 1 above), 44–47, 121. On how railroad companies requested a survey, see Calhoun (n. 12 above), 57–61, and Garry D. Ryan, "War Department Topographical Bureau, 1831–1863: An Administrative History" (Ph.D. diss., American University, 1968), 38, 104–5.

36. On the Baltimore and Ohio's efforts to secure federal assistance, see James D. Dilts, *The Great Road: The Building of the Baltimore and Ohio, the Nation's First Railroad,*

Soon after approving assistance for the Baltimore and Ohio, Barbour confirmed the importance of political support in determining which railroads received assistance. In response to an inquiry regarding a survey from Joseph Caldwell, president of the University of North Carolina, the secretary admitted in December 1827 that the railroad Caldwell envisioned promised great advantages. In order for the War Department to provide engineers, however, the North Carolina legislature needed to pass a resolution requesting a survey. Such guidelines effectively made political backing a prerequisite for a railroad to receive military engineering assistance.[37]

It did not take long for other railroads to understand the rules of the game. In 1828, the Ithaca and Owego Railroad and the Catskill and Ithaca Railroad both asked their congressional representatives to apply to the secretary of war on their behalf in order to win surveying assistance. Both companies soon received aid. Chief Engineer Alexander Macomb noted the influence of Representative David Woodcock of New York in his letter assigning an engineer to the surveys. Similarly, the promoters of the Erie and Ohio Railroad sent a request for engineering assistance from the War Department to Representative John Thompson of Ohio. Thompson gathered the signatures of all of the members of the Ohio congressional delegation before submitting the request. With such significant political backing, the company's petition received quick approval. Lieutenant Colonel John J. Abert, head of the Topographical Bureau, noted that the road possessed "a highly national and interesting character" and recommended the detail of an engineer for the survey. Other railroads, although they understood the importance of political connections for obtaining federal assistance, lacked sufficient influence to obtain the help they needed. The commissioners of the Clinton and Vicksburg Railroad in Mississippi appointed a committee to write to the president requesting the services of an engineer and to the senators and representatives representing the railroad's district asking them to promote their application, but failed to procure any aid from the army.[38]

1828–1853 (Stanford, Calif., 1993), 8–9, 47. On Barbour's interest in Maryland politics, see T. Matthews to James Barbour, 12 September 1827, James Barbour Papers, Special Collections Library, University of Virginia, Charlottesville. On Barbour generally, see Charles D. Lowery, *James Barbour, A Jeffersonian Republican* (University, Ala., 1984). Political interference in military spending is a constant theme in American history. See, for example, William M. McBride, "The Unstable Dynamics of a Strategic Technology: Disarmament, Unemployment, and the Interwar Battleship" *Technology and Culture* 38 (1997): 421.

37. Barbour to Caldwell, 1 December 1827, roll 2, M-1113, NA.

38. On the efforts of the New York railroads to obtain federal aid, see Gen. Alexander Macomb to Lt. W. H. Swift, 22 April 1828, roll 2, microfilm T-1255, Letters Sent by the Chief of Engineers to Engineer Officers, NA; Macomb to Rep. D. Woodcock, John C. Clarke, and S. R. Hobbie, 6 May 1828, roll 2, M-1113, NA; Macomb to Woodcock, 22 May 1828, roll 2, M-1113, NA; Macomb to Swift, 23 May 1828, roll 2, M-1113, NA. For the Erie and Ohio's request, see *American Railroad Journal* 1 (23 June 1832): 405. For the

The most egregious example of political influence trumping national interest was the successful campaign of the West Feliciana Railroad to obtain an army surveyor. The twenty-six miles of the West Feliciana Railroad connected Woodville, Mississippi, to Bayou Sara, Louisiana, on the Mississippi River. The road transported cotton from the surrounding Feliciana parishes and from Wilkinson and Amite counties in Mississippi to market. It had little national or military significance. At a meeting of the railroad's supporters on 16 March 1830, William Haile, a former congressional representative, outlined the advantages and the plan of organization of the railroad. He also suggested that he could ask his friend President Andrew Jackson to assign officers to survey the railroad. Eighteen months later, in October 1831, the former territorial printer of Louisiana, James M. Bradford, armed with a letter from Haile, left for Washington to petition Jackson for surveying assistance. Bradford was a particularly shrewd choice. He had fought under Jackson at New Orleans, and his eye-witness account of the battle in a local newspaper had greatly pleased his commanding general. To further guarantee a warm reception, Bradford carried a letter from General John J. Joor, Jackson's close personal friend, who had also fought with him at New Orleans and who had hosted Jackson at his home on several occasions. The company's strategy worked. Jackson gave Bradford a letter for the secretary of war directing that a brigade of engineers be sent to survey the railroad. Bradford took the letter to the secretary's office and then to the office of the Topographical Bureau, where he discussed the details of the railroad with Abert. Before the end of the year, five army engineers arrived to survey the railroad; they completed the survey in July 1832.[39]

Recognizing that local political and commercial interests drove the engineering assistance program, army engineers focused on the commercial nexus necessary to sustain the new lines when recommending rail routes. Howard advised the South Carolina Railroad not to limit itself to the planned termini of Charleston and Hamburg but to consider other destinations as well, such as Columbia, where the lure of "the extensive trade of the Congaree" would repay the expense required to secure it, and the Tennessee River, the trade of which "offers a reward too rich, not to demand every exertion to obtain it." Swift noted that the Catskill and Ithaca Railroad would equalize price competitiveness between farmers distant from the Erie Canal and those close to the waterway, while Pickell predicted that the Canajoharie and Catskill Railroad would establish cheap and certain

Clinton and Vicksburg's unsuccessful bid, see *American Railroad Journal* 1 (28 April 1832): 275.

39. Carlton J. Corliss, *Main Line of Mid-America: The Story of the Illinois Central* (New York, 1950), 250–53. The West Feliciana Railroad eventually became part of the Illinois Central system.

transportation to market, increasing the productive capacity of the surrounding country.[40]

The military importance of railroads remained an afterthought, if the engineers acknowledged it at all. Major James D. Graham, after noting the commercial benefits of the Winchester and Potomac Railroad in Virginia, added that the national significance of railroads derived from their ability to concentrate rapidly arms, munitions, and troops at any point. Even Long, who was perhaps the most consistent advocate of the military utility of railroads among the army engineers, emphasized the commercial value of routes he surveyed at least as often as he noted their military advantages. In his survey of the Atlantic and Mississippi Railroad he noted that the line would accommodate "the vast amount of business likely to spring from the resources of the country, most of which have hitherto remained latent and unproductive." In his discussion of a railroad from Boston to Ogdensburg, he devoted as much attention to the commercial benefits gained by connecting Boston to the St. Lawrence River and the Great Lakes as to the facilities the line would afford for the speedy concentration of troops and military stores.[41]

The centrality of politics also enabled army officers to use their own political connections to secure assignments to particularly desirable surveys. When Captain William G. Williams, Lieutenant Thomas F. Drayton, Lieutenant Edward B. White, and Lieutenant James G. Reed were assigned to survey the Louisville, Cincinnati, and Charleston Railroad, the *Columbia Telescope* noted happily that all four officers were natives of the state. In fact, Drayton was the son of William Drayton, a former member of Congress and a member of the committee representing South Carolina's interests in matters concerning the railroad. Similarly, Frederick Harris, one of the original backers of the James River and Kanawah Canal Company, wrote to his son David, a West Point cadet, assuring him that influential family friends would apply to the War Department for his services as an assistant when work on the project began.[42]

40. Howard (n. 24 above), 3:63, 70–71; Swift, "Catskill and Ithaca Railroad" (n. 26 above), 3:252–53; Pickell (n. 26 above), 3:283.

41. Maj. James D. Graham, "Report on the Winchester and Potomac Rail Road," 31 March 1832, file SEN 22A-F5, Various Reports of the Secretary of War concerning Rivers and Railroads, RG 46, NA, 49–50. Dunlavy quotes Long as evidence for the influence of military principles on railroad location in "Politics and Industrialization" (n. 1 above), 149. For the Long quotes, see U.S. House, *Railroads—Atlantic to the Mississippi* (n. 21 above), 51, and Long, "New Hampshire and Vermont Divisions of the Boston and Ogdensburg Railroad" (n. 25 above), 5:39.

42. On the Louisville, Cincinnati, and Charleston Railroad, see *American Railroad Journal* 5 (9 April 1836): 219; *Report of the South Carolina Commissioners to the Knoxville Convention, on the Subject of the Proposed Rail-Road from Charleston to Cincinnati and Louisville* (Knoxville, Tenn., 1836), 4; and Samuel M. Derrick, *Centennial History of the South Carolina Railroad* (Columbia, S.C., 1930), 129–30. On Frederick Harris's unceas-

Officers also relied on political ties to win exceptions from rules that governed the rest of the army. Lieutenant John M. Berrien, the son and namesake of a U.S. senator and attorney general in Jackson's cabinet, received permission from the Topographical Bureau to superintend construction of a railroad across the Michigan isthmus from Detroit to St. Joseph in his spare time. William McNeill, who had been Andrew Jackson's aide during the Seminole campaign in Florida in 1818, obtained repeated exceptions that allowed him to continue working for the railroads long after almost all other army officers had been recalled to their stations.[43]

Just as the instrumentalist view of government and the dominance of local over national interests within American political culture encouraged diversity, the distrust of governmental involvement in private affairs discouraged uniformity. There was a deep reluctance in nineteenth-century America to sanction federal interference in private enterprise, even in cases that threatened public safety. It was one thing for the government to mandate uniformity for military matériel such as firearms; it was quite another to regulate civilian technologies operated by private companies in a free and open marketplace. The opposition to vested power thus impeded efforts to promote uniformity in railroad construction.[44]

Observers recognized quite early that the use of different track gauges threatened to eliminate any military advantage railroads might provide in the future. A writer identifying himself only as "C" warned in the *American Railroad Journal* early in 1832: "Should our country at a future period be engaged in war, the evils of a dissimilarity in Rail-way tracks and the advantage of uniformity would be greatly magnified." A uniform gauge would allow troops to move great distances by rail without disembarking and reboarding each time they traveled over the tracks of a different company. "C" noted that "If we can produce a uniformity in the structure of our great lines of Railway, and of their various intersections by which our country will be traversed at a future day, the government may possess or command

ing efforts to secure a lucrative position for his son, see Frederick Harris III to David B. Harris, 24 March 1833, in David B. Harris, *The Education of Col. David Bullock Harris, C.S.A.: West Point Letters (1829–1835)*, ed. Charles W. Turner (Verona, Va., 1984), 52. Jameson Doig and David Billington have argued that the political activities of engineers are often at least as important as their technical skill in determining their selection for projects; "Amman's First Bridge: A Study in Engineering, Politics, and Entrepreneurial Behavior," *Technology and Culture* 35 (1994): 537–70.

43. During the 1830s, War Department policy increasingly restricted officers from working for private companies as part of their official duties. On Berrien, see Corliss, 255, and Hill (n. 1 above), 119–20. On McNeill's service with Jackson, see Dilts (n. 36 above), 69.

44. A much-cited source on the reluctance of Congress to interfere with private enterprise in this era is John G. Burke, "Bursting Boilers and the Federal Power," *Technology and Culture* 7 (1966): 1–23. On the role of the marketplace in the historiography of technology and the military, see Roland (n. 5 above), S91–S93.

trains of carriages sufficient to transport a large force, with the necessary *materiel* in any direction, and to almost any distance, with the greatest facility and dispatch, but on the disjointed and ill-adapted structures, which we are now in a fair way to obtain, no such concert and despatch of movement could be effected."[45]

Despite such concerns, "C" saw no role for the federal government or the army in the establishment of a uniform gauge. Instead, he recommended that two or three of the larger states establish a specific gauge by statute or that a few of the principal railroad companies agree on a standard. The editors of the *American Railroad Journal* endorsed this call for a uniform gauge and reiterated their support in 1834. Although they believed that the country's rail network "should be one great whole," they confessed that it was easier to advocate uniformity than it was to implement it. They suggested following the example of the Baltimore and Ohio, since it was the largest and most advanced road. The reluctance of even the most vocal proponents of a uniform gauge to consider a federal solution meant that Long's 1835 recommendation that all railroads adopt a gauge of 4 feet, 8 $^{1}/_{2}$ inches went unheeded. Political culture thus undermined uniformity; American railroads did not adopt a nearly uniform national gauge until most southern lines switched to standard gauge in 1886.[46]

The relationship between engineers as individuals and the army as an organization also fostered the officers' independence and promoted variations in their recommendations. Army officers had numerous reasons to want to remain on surveying duty as long as possible. After 1828, however,

45. *American Railroad Journal* 1 (21 January 1832): 51.

46. *American Railroad Journal* 1 (28 January 1832): 66; *American Railroad Journal* 3 (7 June 1834): 337; and U.S. House, *Railroads—Atlantic to the Mississippi*, 11–14. Manufacturers of rolling stock had little influence over track gauge during the period because most rolling stock was special-ordered and produced by small firms engaged in several lines of work. Small foundries and machine shops built most early American locomotives. Similarly, carriage builders and railroad machine shops built most of the early passenger and freight cars. Large, specialized firms did not dominate production until the 1870s. William H. Brown, *The History of the First Locomotives in America, from Original Documents, and the Testimony of Living Witnesses*, rev. ed. (New York, 1874), 223–36; John H. White Jr., *American Locomotives: An Engineering History, 1830–1880*, rev. ed. (Baltimore, 1997), 13; John H. White Jr., *The American Railroad Freight Car: From the Wood-Car Era to the Coming of Steel* (Baltimore, 1993), 140; John H. White Jr., *The American Railroad Passenger Car* (Baltimore, 1978), 3, 8–18. Rolling stock nevertheless occasionally affected the choice of gauge: the Mad River and Lake Erie reportedly chose its gauge of 4 feet, 10 inches because the road's first locomotive was built in New Jersey, where that gauge was dominant. The company's engineer apparently liked the locomotive's whistle, a novel feature at the time. Such instances were rare, however; lines with nonstandard gauges had few problems ordering rolling stock. More commonly, the engineering practice (including track gauge) that the railroad adopted determined where it obtained its rolling stock. Douglas Puffert notes that the production of locomotives in standard models and large batches may have contributed to the diffusion of standard gauge, but the effect is not demonstrable; Puffert (n. 29 above), 60, 205-6, 226.

the duration of officers' surveying duty depended on the willingness of the railroads to pay the survey expenses. Army engineers therefore had strong inducements to shape their recommendations to the railroad companies' needs. The perceived disparity between payscales and promotion opportunities within the army and outside it only reinforced those incentives.

When the army first provided surveying assistance to the Baltimore and Ohio in 1827, it paid all of the costs. The following year, however, the Engineer Department established a rule requiring companies to pay all of the costs of surveys for private improvements except the salaries of the officers conducting the surveys.[47] The new policy, reflecting a belief that total government funding for private improvement projects was inappropriate, shifted the incentive structure for the officers conducting surveys. To remain on surveying duty, officers now had to please the railroads, who were paying all of the survey expenses.[48]

Among the reasons that army engineers were eager to remain on surveying duty was the location of the work. Line officers spent most of their careers stationed at small outposts on the frontier. Almost half of the officers in the army in 1835 served at garrisons of fewer than two hundred men. Loneliness and boredom characterized life at these small forts. Married officers often left their families behind, while single officers found their social contacts frustratingly limited. Only the frequent physical labor ordered by the War Department punctuated the monotony of military routine. The opportunity for duty in a more developed area of the country, possibly even close to home, appealed to many.[49]

Surveying duty also offered financial rewards. Several officers received compensation from private companies or states in addition to their regular army pay. Moreover, the War Department allowed engineers surveying for railroads to claim allowances they would have received if they had been working on exclusively federal projects. These allowances included double rations for the commandant of a party and funds for the hire and support of horses. John Abert, eager to retain talented engineers in the Topographical Bureau, defended the private compensation and additional

47. Gen. Alexander Macomb to P. E. Thomas, 20 May 1828, roll 2, M-1113, NA; Macomb to Thomas, 13 June 1828, roll 2, M-1113, NA.

48. The new policy was not always followed. In 1832, Secretary of War Lewis Cass, at the direction of President Jackson, strengthened the policy by suspending all surveys unless the interested parties paid all of the expenses except the engineer's salary and the purchase and repair of his instruments; *American Railroad Journal* 1 (11 August 1832): 513. McNeill, perhaps fearing that stricter enforcement would deter companies from using army engineers for surveys and thus threaten his sinecure, defended the practice as impartial and effective in a railroad industry journal; *American Railroad Journal* 1 (1 September 1832): 562.

49. Edward M. Coffman, *The Old Army: A Portrait of the American Army in Peacetime, 1784–1898* (New York, 1986), 42–103; Skelton (n. 3 above), 182–90; Prucha, *Sword of the Republic* (n. 2 above), 152, 335.

allowances. He argued that an officer was devoted to his commission; as long as "a glint of sunshine is permitted to brighten . . . his path" he would rarely abandon it. He warned, however, that "if the sunshine is withheld, if he is prohibited an occasional opportunity of bettering his condition . . ., despair . . . may drive him from the service."[50]

The prospect of obtaining a lucrative position as a civil engineer after leaving the service provided a further incentive for army engineers to cater to the desires of the railroads. Although economic hardship was the most common career motivation for army officers, military service did not pay particularly well. Base pay during the 1830s was $300 per year for second lieutenants and $360 for first lieutenants. Allowances for subsistence and the hire of a servant often more than doubled an officer's base pay, so a second lieutenant in the infantry or artillery earned approximately $800 annually. Pay increased with rank, and a colonel could earn $900 to $1,100 in base pay and over $2,000 when allowances were included. Engineers also received higher pay.[51]

Promotion, meanwhile, was very slow. In 1836 the army's adjutant general estimated that a cadet graduating from the military academy could expect to spend at least eight years in every grade, achieving the rank of colonel at the youthful age of seventy-nine. There were eight captains in the army who had served some twenty years at that rank and seven majors who had served more than twenty-five years in their grade.[52]

The salaries for civil engineers working on improvement projects therefore must have seemed quite attractive to young army officers. From 1830 to 1834, the chief engineers of large projects earned between $3,500 and $5,000, depending on the size of the undertaking and its location. The chief engineers of smaller projects usually earned between $2,000 and $3,000. The most prominent engineers were also able to hold more than one position simultaneously. Resident or principal assistant engineers' salaries ranged between $1,000 and $1,700, and assistant engineers earned between

50. Abert to B. F. Butler, 24 January 1837, roll 2, M-66, NA. Retention of the army's brightest engineers, always problematic due to the oversupply produced by West Point, became even more difficult with the outbreak of the Seminole War in 1835. In 1836, 117 officers, more than 17 percent of the army's total commissioned strength, resigned. Skelton, 216.

51. U.S. House, *Equalize Pay—Officers Army and Navy*, 23rd Cong., 1st sess., 28 February 1834, H. Rept. 295, Serial 261, 5, 10; U.S. House, *Pay of Officers of the Army—1833 and 1834*, 24th Cong., 1st sess., 4 April 1836, H. Doc. 198, Serial 290; U.S. Senate, *Document Showing the Pay and Allowances to Officers in the Army during the years 1812, 1824, 1838, and at the Present Time*, 29th Cong., 1st sess., 24 March 1846, S. Doc 246, Serial 474, 11–13. See also Skelton, 165, 190; Coffman, 50; John K. Mahon, *History of the Second Seminole War, 1835–1842*, rev. ed. (Gainesville, Fla., 1985), 118; Calhoun (n. 12 above), 173; James L. Morrison Jr., *"The Best School in the World": West Point, the Pre–Civil War Years, 1833–1866* (Kent, Ohio, 1986), 20.

52. Adj. Gen. R. Jones to Lewis Cass, 15 February 1836, roll 116, microfilm M-221, Letters Received by the Secretary of War, Registered Series, 1801–1860, NA.

$360 and $800. From 1835 to 1837, salaries rose even higher; several railroads paid engineers $5,000 or more per year.[53]

Many of the officers conducting surveys for railroads aspired to long careers in the most exciting, innovative, and lucrative field of their day. Consequently, they tried to demonstrate to railroad companies that they possessed the knowledge and skill necessary to succeed in the commercial world. They tailored their recommendations to the needs and desires of the private enterprises that were paying their survey expenses, providing them with extra compensation, and potentially employing them once they left the army.

The inchoate nature of early railroad technology provoked a corresponding variety of approaches to the problem of building railroads. In this incipient period of the railway age, engineers vigorously debated all aspects of railroad design, including the most suitable source of motive power, the relative advantages of railroads versus canals, and the most appropriate construction materials. Moreover, each line faced different financial, commercial, and topographical conditions. In their attempts to deal with the attendant uncertainty, army engineers relied to varying degrees on official guidance, foreign (usually British) examples, and textbooks, as well as on the experience they gained from previous surveys. The result was a medley of technological styles drawn from diverse sources.[54]

During the earliest years of the railway era the question of whether horses or steam locomotives could pull cars most effectively remained unresolved. Army engineers therefore surveyed routes suitable for use with either form of locomotion. Before surveying a route between the James and Kanawha rivers in 1826, McNeill received instructions from Brigadier General Simon Bernard reminding him to keep both sources of power in mind. Howard noted in 1829 that with little data to determine the superiority of locomotive or horse power it was unwise to construct railroads so as to exclude either one.[55]

The uncertainty over the most effective form of motive power for railroads also forced engineers to address questions regarding the relative advantages of railroads and canals in their early surveys. The first railroad surveys in which army engineers participated compared the cost and practicability of railroads to canals. After receiving a petition on 15 April 1826,

53. Calhoun, 167–69, 172.

54. For a brief discussion of the undefined nature of railroad technology in the late 1820s and early 1830s, see James A. Ward, *J. Edgar Thomson: Master of the Pennsylvania* (Westport, Conn., 1980), 20–23.

55. Hill (n. 1 above), 100; Howard (n. 24 above), 3:66–67; Dilts (n. 36 above), 81–99. Commenting on the railroad movement in Massachusetts in 1826, George Bliss noted that "Little was known of the construction, or usefulness of that mode of inter-communication, all the inquiries and calculations were directed to the use of horse power only." George Bliss, *Historical Memoir of the Western Railroad* (Springfield, Mass., 1863), 7.

the War Department assigned McNeill to survey the land between the Roanoke, James, and Kanawha Rivers with the objective of uniting them by canal or railroad. Two years later, Bernard and Captain Guillaume Tell Poussin performed a similar survey on the land between the Hiwassee and the Conasauga Rivers near the Tennessee-Georgia border. In both cases the engineers favored canals, supporting railroads only as secondary options if construction of canals proved impossible or too expensive. Claudius Crozet, a former West Point engineering professor, recalled that as of 1826 "I could not advocate railroads;—neither the power nor the vehicles used then were advantageous, the velocities obtained being small and the loads carried light."[56]

This preference for canals over railroads faded by 1830, largely as a result of British demonstrations of the practicality of the steam locomotive. In March 1830, Swift acknowledged recent comparisons that had demonstrated the advantages of canals over railroads but placed his faith in "the monied men of England" who supported railroads. Later that year Pickell boldly proclaimed that the advantages of railroads in speed and certainty gave them a clear advantage wherever they competed with canals. By 1832, the railroad was clearly ascendant over the canal in the minds of army engineers and their compatriots. Crozet, who corresponded with several officers after leaving West Point, likely summarized their views when he declared: "The Rail-road system is the triumph of the age—the ultimate effects of its introduction are incalculable, and with the certainty that it will produce important changes in the commercial and even political world, its early adoption is safer than its rejection in favor of another system, from which no farther developments are to be expected."[57]

56. Capt. William G. McNeill, "Report on James River and Kenhawa [*sic*] Canal Route," 24 March 1828, E-250, RG 77, NA, 2:403–4; Brig. Gen. S. Bernard and Capt. William Tell Poussin, "Report on Hiwassee and Conasauga Rivers," 11 December 1828, E-250, RG 77, NA, 4:384; Hill, 99–100; *American Railroad Journal* 1 (14 January 1832): 35–36. After leaving West Point, Crozet became principal engineer of Virginia's Board of Public Works.

57. Swift, "Catskill and Ithaca Railroad" (n. 26 above), 3:270; Pickell (n. 26 above), 3:283; *American Railroad Journal* 1 (14 January 1832): 35–36. Among those impressed by the capabilities of steam locomotives was Swift, who extracted in his report on the Catskill and Ithaca Railroad a letter from the engineer of the Baltimore and Ohio to the president of the company noting that in England "locomotive engines are generally preferred on all inclinations adapted to their use"; Swift, "Catskill and Ithaca Railroad," 3:269. The victory of steam power was by no means complete. In 1832, George W. Hughes acknowledged the continuing disagreement over the preferred motive power for railroads, noting that "the species of power to be employed depends upon the nature of the country traversed by the road, the state of the trade, the traveling, and other circumstances." On the Fredericksburg and Potomac Creek Railroad, which Hughes was surveying, the distance was "short, ground slightly undulating, quantity of goods to be conveyed small, and fuel dear," and he therefore recommended horse-drawn cars; Hughes (n. 22 above), 4:625. Even Swift noted that "notwithstanding the introduction of the engine in England upon roads so much

Even after steam locomotives had won the favor of army engineers, the most effective design remained a matter of debate for another two decades. Long, one of the more prominent railroad surveyors for the army, also cofounded the Norris Locomotive Works, the largest locomotive manufacturer in the country in the 1850s. Long advocated a dramatic departure in locomotive design. He championed lightweight, coal-burning engines and received several patents for boiler, wheel, and valve designs. Patents failed to produce practical success, however, and Long withdrew from the locomotive business in 1835. The Norris Works based its later success on reliable adaptations of others' designs rather than radical innovations.[58]

The most appropriate construction material was another area of uncertainty. The central question was whether to follow the British example and rely on stone to support the rails or to substitute less expensive wood. The Baltimore and Ohio Railroad in 1832 stated its determination "in all cases where stone rails could be procured to use them." In contrast, Walter Gwynn, a former army officer who became chief engineer of the Portsmouth and Roanoke Railroad, advocated "the almost universal substitution of wood for stone." Among the reasons Gwynn cited for this preference of wood were its elasticity, its sufficient stability, and its diminution of the wear and tear on engines and cars.[59]

Besides official guidance and British examples, Army officers turned to an already significant literature on railroad engineering when making their surveys. The most important components of this literature were textbooks and reports on previous railroad surveys. Two of the earliest textbooks on railroad engineering, Thomas Tredgold's *Practical Treatise on Rail-Roads and Carriages* and Nicholas Wood's *Practical Treatise on Railroads, and Interior Communications in General* entered West Point's library by 1830.[60] These textbooks by British authors served as standard references for army officers on survey duty. Some engineers, however, sought help closer to home; Hughes, during his survey of the Fredericksburg and Potomac Creek

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inclined, it is very easy to show that there must be a very great portion of the power of the engine consumed in effecting its own locomotion"; Swift, "Catskill and Ithaca Railroad," 3:269.

58. On locomotive design generally, see White, *American Locomotives* (n. 46 above). On Long's locomotive designs for the Norris Works, see John H. White Jr., "Once the Greatest of Builders: The Norris Locomotive Works," *Railroad History* 150 (1984): 17–56.

59. For the Baltimore and Ohio's determination to use stone, see *American Railroad Journal* 1 (11 February 1832): 98. For Gwynn's recommendations, see *American Railroad Journal* 3 (18 January 1834): 24.

60. Thomas Tredgold, *A Practical Treatise on Rail-Roads and Carriages* (New York, 1825); Nicholas Wood, *A Practical Treatise on Railroads, and Interior Communications in General* (London, 1825). Tredgold's work inspired several army engineers to recommend a track gauge of 4 feet, 6 inches. It also provided them with the formula for determining elevation based on trade flows described above.

Railroad, referred to works by American railroad pioneers Jonathan Knight and Ross Winans. Others relied more on the experience embodied in previous survey reports than the theoretical knowledge in textbooks. Captain William Turnbull followed the example of the Baltimore and Susquehanna when surveying the West Feliciana Railroad, as did Graham during his work on the Winchester and Potomac. Long based his estimates for the construction costs of the New Hampshire division of the Boston and Ogdensburg Railroad on the experience of other American railroads then in operation. The variety of references army engineers consulted during their surveys is thus reflected in the variety of approaches they adopted.[61]

At first glance, the army appears to have played a disproportionate role in the development of antebellum American railroads. Closer study, however, reveals that its influence paled in comparison to that of French artillerists in the eighteenth century or the American military in the cold war. Political, social, and economic forces overwhelmed military factors in the shaping of this nascent technology. The influence of local and political considerations on the allocation of survey assistance prompted army engineers to adapt their recommendations to meet the railroads' desires rather than the government's or the army's, and also gave officers the freedom to pursue their own career goals. The geographic and financial benefits of survey duty and the perceived disparity between pay and promotion opportunities within the army and those outside the service further encouraged the engineers to cater to the needs of the railroads. Finally, the embryonic nature of railroad technology and the multiplicity of information sources allowed for numerous solutions to technical problems. As a result, the officers surveying railroads retained their independence and recommended a variety of technological approaches rather than a single uniform military style.

61. There is a voluminous and sometimes acrimonious literature on the influence of British examples on American railroad technology. While remaining noncommittal on the ultimate effects of the British example, this article demonstrates that that example did influence an important group of early American railroad engineers. For some competing viewpoints on the question of British influence, see Robert E. Carlson, "British Railroads and Engineers and the Beginnings of American Railroad Development," *Business History Review* 34 (summer 1960): 137–49, and James E. Vance Jr., *The North American Railroad: Its Origin, Evolution, and Geography* (Baltimore, 1995). The existence of a substantial international flow of information regarding railroad technology in the 1820s and 1830s is indisputable; see Dunlavy, *Politics and Industrialization* (n. 1 above), 203, 205–6. For the holdings of the West Point library in 1830, see *Catalogue of the Library of the U.S. Military Academy at West Point, May 1830* (New York, 1830). Perrault acknowledged that his survey recommendations were guided by several publications that had established "in a satisfactory manner many of the most essential principles" concerning railroads; Perrault (n. 25 above), 130–31. For Hughes' citation of Knight and Winans, see Hughes, 4:621. For army engineers' use of other survey reports to guide their own surveys, see Turnbull (n. 26 above), 4:635; Graham (n. 41 above), 37–40; Long, "New Hampshire and Vermont Divisions of the Boston and Ogdensburg Railroad" (n. 25 above), 5:40.

This study thus suggests that no inherently military approach to technology exists. Military bureaucracies sometimes advance systematic and uniform solutions to technical problems, while at other times they produce creative spirits who propose diverse answers. Moreover, military involvement need not dominate or distort civilian undertakings. The military can act within society as just another patron and collaborator. Armies, like technologies, reflect the full variety of their surrounding contexts. The consistency and impact of a military establishment's attitude toward a given technology depends on the society's political culture, the organization's structural relationship with its members, and the technology itself.