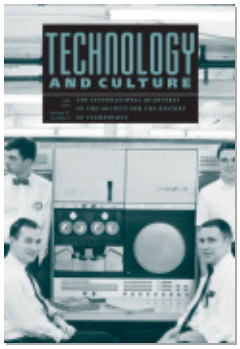
Aligning India in the Cold War Era Indian Technical Elites, the Indian Institute of Technology at Kanpur, and Computing in India and the United States

Ross Bassett



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Aligning India in the Cold War Era

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ROSS BASSETT

In July 1963, a chartered DC-7 landed at a military airbase in Kanpur, India, a large but unremarkable city on the Ganges River, in a region often considered backward by Indians. The plane held an International Business Machines (IBM) 1620 computer, commonly used in American universities, which was destined for the Indian Institute of Technology (IIT) at Kanpur, an institution supported by a nine-university American consortium. At the institute, a group of young Indian men muscled the machine into place (fig. 1). There to greet the computer was Harry Huskey, one of the foremost figures in U.S. computing. Huskey, who had consulted on the pioneer computer ENIAC, worked with Alan Turing in England, and served as president of the American computing professional society, was a professor of electrical engineering and head of the computer center at the University of California, Berkeley. Shortly after he and two computer experts from Princeton University had the computer up and running, they began an informal course for twenty-five specially selected IIT Kanpur first-year students, who, after completing their normal class work, would stay long into the night programming the computer (fig. 2).[1]

Dr. Bassett teaches the history of technology at North Carolina State University. He thanks Gary Downey and Jack Brown; the anonymous referees for *Technology and Culture*; the participants in the 2006 INES Workshop held at Virginia Tech; David Gilmartin; the staff at the MIT Institute Archives, especially Nora Murphy; the CMU University Archives; the Caltech Archives; Director Sanjay Dhande and the faculty and staff at IIT Kanpur; and Deborah Bassett. Research for this article was supported by the National Science Foundation under Grant No. SES-0450808.

0040-165X/09/5004-0003/783–810

1. Forman Acton (Huskey's colleague from Princeton University), letter to author, May 2005; Harry D. Huskey, *Harry D. Huskey: His Story* (Charleston, S.C., 2004); "Harry Douglas Huskey," box 2, folder, "Harry Huskey," Kanpur Indo-American Program records, collection AC334, Institute Archives and Special Collections, MIT Libraries, Cambridge, Massachusetts (hereafter MIT-KIAP); IIT Kanpur, *Annual Report, 1963–64*, 88–89.

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FIG. 1 Delivery of the IBM 1620 computer to IIT Kanpur, July 1963. (Source: Normal C. Dahl, "Revolution on the Ganges: A Report on the Indian Institute of Technology, Kanpur," *Tech Engineering News*, April 1967, 18, photographer unknown. Reproduced courtesy Institute Archives and Special Collections, MIT Libraries, Cambridge, Massachusetts.)

FIG. 2 Students working on the IBM 1620 computer at Kanpur, circa 1964 (note the IBM "Think" sign on the wall). (Source: Indian Institute of Technology, Kanpur, 1965 Convocation publication, p. 23. Reproduced courtesy IIT Kanpur and CMU University Archives.)

The historiography of Indo-American relations during the cold war has been focused on a pair of bipoles: the United States–Soviet Union, and Pakistan–India. Jawaharlal Nehru famously declared India nonaligned, which for the United States meant refusing to take its side in the cold war, and India's independent foreign policy was a continual irritant to the United States. America's close relations with, and arms sales to, Pakistan, which was willing to align itself with U.S. interests, was a provocation to India, driving it closer to the Soviet Union. The United States and India became "estranged democracies" that maintained a "cold peace."[2]

One can see parts of this narrative in the story of Kanpur. Kanpur was one of four IIT sites developed with programs of assistance from individual nations; the Soviet Union, Great Britain, and West Germany also provided assistance to these IITs, putatively reflecting India's nonalignment. Unlike any of the other programs, the U.S. program of assistance had an abrupt and unceremonious ending in 1972 as relations between the United States and India deteriorated due to the crisis in East Pakistan, which culminated in the creation of Bangladesh. However, from the perspective of the early twenty-first century—now that India has become an important information technology (IT) business partner with U.S. companies and Indian engineers play prominent roles in America's technical workforce—focusing solely on the twin-bipoles narrative has the effect of a magician's distractions: flashy motions drawing the eye one way, while important action takes place elsewhere.[3]

The end of the cold war, along with the U.S. interventions in Kuwait and Iraq, has led to a reconsideration of the country's role in the world—a reconsideration focused on the question of American empire. While their authors come to different conclusions as to whether the United States meets the conditions to be called, literally, an "empire," many studies analogously apply concepts from the study of well-recognized empires to the United States and its interactions with the world.[4] This article borrows

2. Dennis Kux, *India and the United States: Estranged Democracies, 1941–1991* (Washington, D.C., 1992); H. W. Brands, *India and the United States: The Cold Peace* (Boston, 1990); Robert J. McMahon, *The Cold War on the Periphery: The United States, India, and Pakistan* (New York, 1994).

3. The most prominent, if not the most rigorous, chronicler of the Indian IT business and its relations to the United States is, of course, Thomas Friedman; see his *The World Is Flat: A Brief History of the Twenty-First Century* (New York, 2005). AnnaLee Saxenian, *The New Argonauts: Regional Advantage in a Global Economy* (Cambridge, Mass., 2006), highlights the role that Indian entrepreneurs play in Silicon Valley. As of May 2008, Indians held deanships in the engineering colleges at MIT, Carnegie Mellon, UC Berkeley, Harvard, and UCLA.

4. Charles S. Maier, *Among Empires: American Ascendancy and Its Predecessors* (Cambridge, Mass., 2006); John Lewis Gaddis, *We Now Know: Rethinking Cold War History* (New York, 1997); Odd Arne Westad, *The Global Cold War: Third World Interventions and the Making of Our Times* (Cambridge, 2005); Eric W. Robinson, "American Empire? Ancient Reflections on Modern American Power," *Classical World* 99 (2005): 35–50. One

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from studies of empire the concept of a transnational elite and its role in mediating between entities. In his tour-de-force study seeking to understand the United States "among the empires," historian Charles Maier gives the following definition of empire: "Empires are a particular form of state organization in which the elites of differing ethnic or national units defer to and acquiesce in the political leadership of the dominant power."[5] A major theme of studies of the British Empire in India has been the role of Indian elites as active agents in the creation of the empire, its maintenance, and its ultimate end.[6]

A close look at the Kanpur computer center reveals an American-oriented Indian technical elite which played a central role in the establishment of computing education in India, and in the development of the Indian IT industry. This elite, aligned technically rather than politically, believed that India's best interests (and implicitly its own) were served by technological and economic ties with the United States. It crafted a network of interactions with American businesses, the American educational system, and (at times) the American government itself. This elite's alignment was strong enough to endure the most severe strains to formal Indo-American relations. These interactions, however, had unexpected and costly consequences for India: Indian students used an American-oriented system of education in India as an express path to the American educational system, and then to America's larger technological system.

Engineering Education for India: The Indian Institutes of Technology and Indians Studying Abroad

The engineering colleges established by the British in India had a circumscribed role: to prepare Indians to work in subsidiary positions under British rule. While some Indians had attended the Massachusetts Institute of Technology (MIT) on their own to obtain an engineering education not available in India, the deficiencies of the Indian engineering-education sys-

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work applying concepts of empire to the history of science that has particularly shaped my thinking has been John Krige, *American Hegemony and the Postwar Reconstruction of Science in Europe* (Cambridge, Mass., 2006). Michael W. Doyle presents a theoretical examination of empire in *Empires* (Ithaca, N.Y., 1986).

5. Maier, 33.

6. One can see this in many works on modern Indian history, such as Barbara D. Metcalf and Thomas R. Metcalf, *A Concise History of India*, 2nd ed. (New York, 2006) and Sugata Bose and Ayesha Jalal, *Modern South Asia: History, Culture and Political Economy*, 2nd ed. (New Delhi, 2004). It is a particular theme of the Cambridge School, whose leading figure in recent years has been C. A. Bayly. His works include *Indian Society and the Making of the British Empire* (Cambridge, 1988), and *Rulers, Townsmen and Bazaars: Northern Indian Society in the Age of British Expansion, 1770–1870* (Cambridge, 1983). A summary and critique of this work is given in Nicholas B. Dirks, *Castes of Mind: Colonialism and the Making of Modern India* (Princeton, N.J., 2001), 303–13.

tem came to the fore in 1944, when British Nobel laureate A. V. Hill, visiting India as an advisor to the British Indian government, noted the absence of an MIT-type institution in India and recommended the establishment of at least one or two technical institutes "of the highest possible standing."[7]

In 1945, as India stood on the brink of independence, the member of the Viceroy's Council with responsibility for education appointed a commission headed by N. R. Sarker to consider the development of institutes of higher technical education in India. The committee, which included two Indians with doctorates from MIT, reported back proposing the establishment of four institutions geographically distributed throughout India that would train students to the standard of MIT. Nehru, a leader in the movement for independence and India's first prime minister, was one of the most powerful voices arguing for the central role of science and technology in India. The government of independent India embraced the Sarker report, establishing the first Indian Institute of Technology in 1951 at Kharagpur, west of Calcutta. IIT Kharagpur received support from a variety of sources including the United States, the United Kingdom, the Soviet Union, and UNESCO. The government of India arranged for each subsequent IIT to receive support from a specific national patron. Thus the Soviets provided support to IIT Bombay, which opened in 1958; West Germany to IIT Madras (1959); the United States to IIT Kanpur (1960); and the British to IIT Delhi (1963, originally as the Delhi College of Engineering) (fig. 3).[8]

7. A. V. Hill, *Scientific Research in India* (London, 1945), 29. Further information on engineering education in colonial India is given in Arun Kumar, "Colonial Requirements and Engineering Education: The Public Works Department, 1847–1947," in *Technology and the Raj: Western Technology and Technical Transfers to India, 1700–1947*, ed. Roy MacLeod and Deepak Kumar (New Delhi, 1995), 216–32. For Indians who attended MIT during the colonial period, see Ross Bassett, "MIT-Trained Swadeshi: MIT and Indian Nationalism," *Osiris* 24 (2009): 212–30.

8. *Development of Higher Technical Institutions in India*, Interim Report of the Sarker Committee (New Delhi, 1946). Today there are seven IITs, with plans in place to greatly increase that number. Scholarly literature on the history of the IITs includes Kim Patrick Sebaly, "The Assistance of Four Nations in the Establishment of the Indian Institutes of Technology, 1945–1970" (Ph.D. diss., University of Michigan, 1972), and Stuart W. Leslie and Robert Kargon, "Exporting MIT: Science, Technology and Nation-Building in India and Iran," *Osiris* 21 (2006): 110–30. Several popular histories have been published recently: Suvarna Rajguru and Ranjan Pant, *IIT: India's Intellectual Treasures, Passage through the Indian Institutes of Technology* (Silver Spring, Md., 2003); Sandipan Deb, *The IITians: The Story of a Remarkable Indian Institution and How Its Alumni Are Reshaping the World* (New Delhi, 2004). British support to IIT Delhi contained a certain irony, given Britain's reduced position in the post–World War II technological world. In a 1949 speech at MIT, Winston Churchill lamented that Britain had nothing of a "comparable stature" to MIT and was himself involved in efforts to remedy the situation. And "brain drain," which would become an issue with the IITs, was a term that had its origins in the movement of British scientists to the United States. See "Text of Winston Churchill's Address before the MIT Convocation at Boston Garden," *New York Times*, 1 April 1949; Peter Carpenter, "Churchill and His Technological College," *Journal of Educational Ad-*

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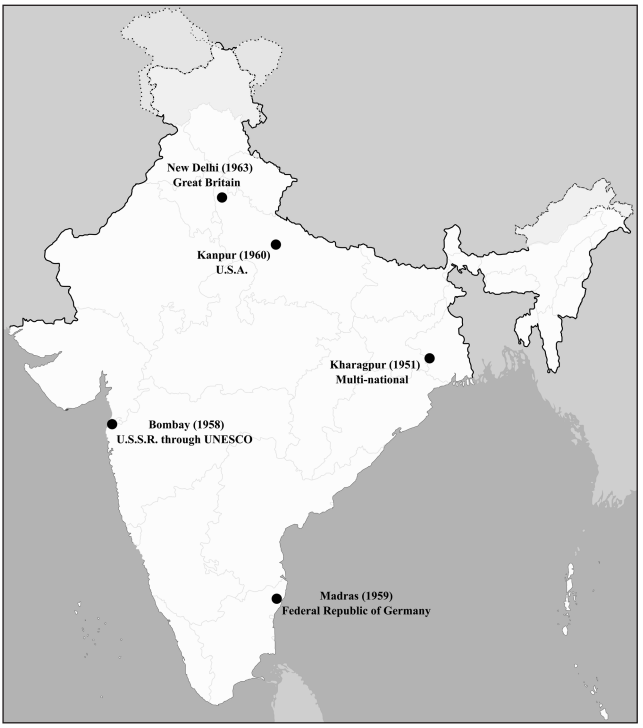

FIG. 3 Early Indian Institutes of Technology, their dates of establishment, and their foreign patrons. (Source: Blank public-domain map from Wikimedia Commons, http://incubator.wikimedia.org/wiki/File:India-locator-map-blank.svg, accessed 17 August 2009. Dates and locations added by the author.)

Even before the establishment of the first IIT, there was a significant change in the Indian educational environment: the United States became the most important destination for Indian students studying abroad. Annual surveys prior to World War II showed one to two thousand Indian students studying in Britain, while the maximum in the United States was 208. In 1944, the British Indian government, recognizing the need for greater scientific and technological talent in India, began paying for Indian students to attend universities in the United States. The government of a sovereign India continued this policy. For the academic year 1949–1950, the U.S. Bureau of Education reported 1,680 Indian students studying in the country's universities, while a similar survey counted just less than 700 Indian students studying in universities in the United Kingdom, indicating an Indian preference for the United States that would grow over time (fig. 4).

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ministration and History 17 (1985): 69–75; *Oxford English Dictionary Online*, s.v. "brain drain," http://dictionary.oed.com (accessed 5 May 2008).

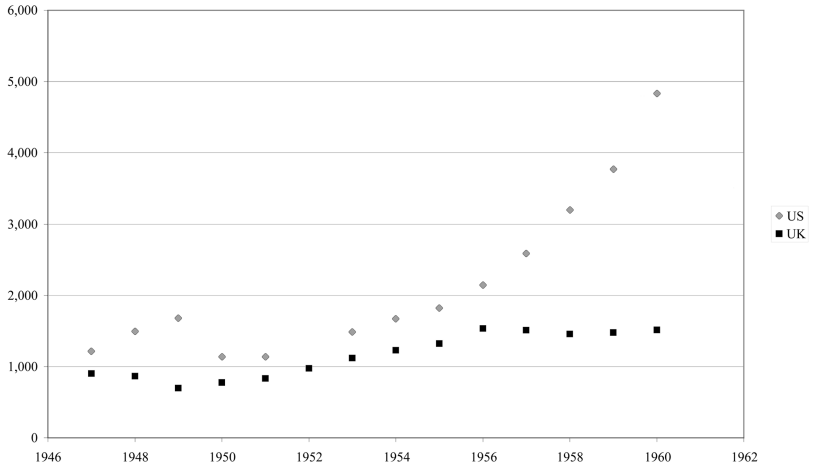

FIG. 4 Indian Students in colleges and universities in the United States and the United Kingdom, 1947–1960. (Sources: Data for Indian students studying in the United Kingdom is from the 1948–1961 volumes of the *Yearbook of Commonwealth Universities* [London, 1948–1961]. Data for Indian students studying in the United States is from Federal Security Agency, Office of Education, *Annual Report 1948*, 524, and from Robert C. Story, *Residence and Migration of College Students, 1949–50*, Office of Education, Misc. No. 14, 9; data from 1950 onward comes from the annual reports of the Institute for International Education, *Open Doors*.)

A survey published by the Indian government in 1949 indicated that most of the students it sponsored in the United States were studying in the engineering or agricultural fields. Indians educated in the United States would provide the strongest and most enduring technological link between the two countries.[9]

P. K. Kelkar, Computing, and U.S. Assistance to Kanpur

By 1958 India and the United States had an informal agreement that the United States would provide aid to IIT Kanpur, but delays in negotiating specifics led India to start the institute in 1960 without American assistance. The first director of IIT Kanpur was P. K. Kelkar, an electrical engineer with a doctorate (1936) from the University of Liverpool who then taught at the Victoria Jubilee Technical Institute in Bombay. Just prior to coming to Kanpur, Kelkar served as the chief planning officer in the development of IIT Bombay, working closely with its Soviet sponsors.[10]

9. Education Department, Embassy of India in the U.S.A., *List of Indian Students in the U.S.A. and Canada as on May 1st, 1949* (Washington, D.C., 1949).

10. For specific information on Kelkar, I have relied on S. Ranganathan, "Uncanny

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As he set about planning IIT Kanpur, Kelkar drew on his deep knowledge of foreign engineering-educational systems. But in his memoir, written after he retired, he described an epiphany when, before any program of American assistance was in place, he had read the proceedings of the 1957 conference of American engineering deans describing curricular reforms made to reorient their programs around engineering science. Kelkar was impressed by the idea that a scientific foundation could provide the basis by which teams of diverse experts could collaborate to solve complex problems. He was also struck by how the American reforms were based on anticipating a "complex and challenging future" and the need to prepare for it, just as he was anticipating a changed India. Historians have shown that the proximate cause for the triumph of the engineering-science model in the United States was the desire of engineering schools to share in the military's largesse in funding scientific work. However, the rhetoric of engineering science was broad enough to attract someone like Kelkar, who tended toward idealism and had himself come to engineering through physics.[11]

Kelkar sought a program of assistance that would advance his desire to base the institute on the American reforms in engineering science. In January 1961, MIT sent a team of three professors to India to explore the possibilities of supporting technical education there. In Kelkar they found a kindred spirit. Based almost exclusively on the possibilities of partnership with him, the professors recommended that MIT provide support to the Kanpur institute as a way of introducing American engineering-education models into India. The MIT team conceived of a consortium of American universities, informally anchored by MIT, which would provide visiting faculty to Kanpur. In 1961, the Indian and U.S. governments and nine American universities reached an agreement to establish the Kanpur Indo-American Program.[12]

Confidence: An Obituary of P. K. Kelkar," *Current Science*, 10 February 1991, 185–86; "The Passing of a Legend," *Indian Institute of Technology Kanpur Alumni Association Newsletter*, January 1991, 1–2; and Arawind Parasnis, "IITK, Kelkar and I: Reminiscences of a Bygone Era" (undated document in the author's possession), as well as lengthy discussions with Parasnis, who was one of the first professors at IIT Kanpur.

11. P. K. Kelkar, untitled, undated, and unpublished reminiscence in author's possession. The volume Kelkar read was *Recent Advances in the Engineering Sciences: Their Impact on Engineering Education, Proceedings of the Conference on Science and Technology for Deans of Engineering* (New York, 1958). For a discussion of the 1950s reforms in American engineering education centered around engineering science, see Bruce E. Seely, "The Other Re-Engineering of Engineering Education, 1900–1965," *Journal of Engineering Education* 88 (1999): 285–94.

12. W. W. Buechner, N. C. Dahl, and L. D. Smullin, "An Opportunity for United States Participation in Indian Technical Education," 3 March 1961, MIT-KIAP, box 5; Leslie and Kargon, 110–32. The nine U.S. universities were MIT, Caltech, Carnegie Institute of Technology, Case Institute of Technology, Princeton, UC Berkeley, University of Michigan, Ohio State University, and Purdue University. Stanford was asked to participate but declined, a profound irony given that it has been a notable U.S. beneficiary of IIT Kanpur graduates.

A computer was fundamental to Kelkar's plans for IIT Kanpur. Even before the MIT-led program had been formulated, he was making plans to purchase an IBM computer (with American funds) and have physicists from the University of Delhi train his faculty on its use. Knowing how impressed Kelkar was by American engineering-education reforms makes it possible to infer why he was so interested in computing: the conference proceedings he read had two central themes—the engineering sciences and the computer—both of which promised to unify the engineering curriculum in the midst of diversity. One author claimed that the computer was not just a new piece of equipment, but "the embodiment of a new attitude toward the utilization of ideas" and would become, like the research library, the intellectual hub of the university.[13]

Control engineering, the branch of engineering dealing with the regulation of systems, was a central field in the development of computing. In the late 1950s, Kelkar, along with F. C. Kohli—an MIT-trained control engineer working at Tata Electric—had established a master's degree program in control engineering at the Victoria Jubilee Technical Institute. The report on American engineering contained several pieces by control engineers, including one by Gordon Brown, the dean of engineering at MIT, who had been a professor of Kohli's. Brown essentially defined the modern engineer as someone who "builds mechanisms to program, to control or to compute with lightning-like speed."[14]

The Computer at Kanpur

Although the American curriculum based on engineering sciences and the computer was a product of specific forces in American society and culture that did not exist in the same way in India, under Kelkar's leadership and with the help of American faculty and funds, IIT Kanpur established such a curriculum. Undergraduate majors were offered in five branches of engineering (electrical, mechanical, metallurgical, chemical, and civil), often using American textbooks. Kanpur's first machine was an IBM 1620, a small computer introduced in 1959. The centrality of the computer to the plans for IIT Kanpur is indicated by the fact that the delivery of the 1620 was scheduled for the earliest possible date—as soon as an appropriate building to house it had been completed on the permanent campus. (While

13. D. S. Kothari to P. K. Kelkar, 27 December 1960, attachment to "Purchase of Digital Computer," Meeting of the Board of Governors, IIT Kanpur, 5 March 1961, IIT Kanpur, Registrar's Office, Kanpur; S. N. Alexander, "Computer Development and Applications: A Survey of the Field," in *Recent Advances in the Engineering Sciences*, 231.

14. F. C. Kohli, personal interview with author, 25 January 2008; Gordon S. Brown, "Automation and Automatic Control: The Impact on Engineering Education," in *Recent Advances in the Engineering Sciences*, 32. On control engineering's link to computing, see David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics* (Baltimore, 2002), 7–10.

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its permanent campus was under construction, IIT Kanpur had started classes in space borrowed from an existing technological institute.)[15]

After its computer arrived in July 1963, Harry Huskey, along with Forman Acton and Irving Rabinowitz (two colleagues from Princeton University), had the computer up and running in time for a demonstration to the Kanpur Board of Governors in late August. The computer center started with the initiative of visiting computing faculty members from the United States, who stayed for approximately a year, after which Gio Wiederhold, an associate of Huskey's at UC Berkeley, came for another year.[16]

The first years of the computer center were also the crucial years in the appointment of Kanpur's permanent faculty. To a large degree, Kelkar chose for these positions Indians who had received their doctorates from U.S. institutions; in many cases, these individuals had been working or teaching in the United States when they were hired. Kelkar hired individuals capable of running the computer center and teaching computing, as well as others in other disciplines who would use the computer in their own research. Soon these new faculty members assumed leadership of the center. H. K. Kesavan arrived in January 1964 to head the electrical-engineering department, and in May he became the first head of the computer center. Kesavan obtained a master's degree in electrical engineering from the University of Illinois and his doctorate from Michigan State University before serving as a professor at the University of Waterloo in Ontario. V. Rajaraman arrived at IIT Kanpur in 1963, after earning his master's in electrical engineering at MIT and his doctorate at the University of Wisconsin, working in the field of analog computation. Kelkar and Kesavan recruited other faculty members with training in North America, including Kesavan's former colleagues at Waterloo, H. N. Mahabala and T. R. Viswanathan, who both held doctorates in electrical engineering from the University of Saskatchewan.[17]

15. R. M. Drake to the steering committee of the Kanpur Indo-American Program (n.d.); and E. F. Ormby to Robert M. Drake, 4 April 1962, box 36, INSTEP Records, university archives, Carnegie Mellon University (hereafter CMU-INSTEP). The transistor-based IBM 1620 had a magnetic-core memory and cost roughly $320,000, before a 60 percent educational discount. The Computer History Museum notes that because of its small size and relatively inexpensive price, many colleges and universities in the United States bought 1620s, with the result that "hundreds of thousands of students had their first hands-on experience with the IBM 1620"; see "Computer History Museum—IBM 1620 Data Processing System," online at http://www.computerhistory.org/projects/ibm_1620/index.shtml (accessed 3 April 2007).

16. Acton (n. 1 above). The tenures of U.S. guest faculty at Kanpur are given in Kanpur Indo-American Program, *Kanpur Indo-American Program Final Report* (Newton, Mass., 1972 [?]).

17. H. K. Kesavan, personal interview with author, 8 March 2007; H. K. Kesavan and J. N. Kapur, "The Generalized Maximum Entropy Principle," *IEEE Transactions on Systems, Man, and Cybernetics* 19 (1989): 1052; V. Rajaraman, "Theory of a Two Parameter Adaptive Control System," *IRE Transactions on Automatic Control* 7 (1962): 20–26. Rajaraman's biography can be found in V. Rajaraman, "Undergraduate Computer Science and

Students took to the computer center wholeheartedly. The center maintained an open atmosphere, with the equipment available for student use around the clock by April 1964. Beginning in the spring of 1964, all students received training in computing. Undergraduates worked at the center as programmers. Just as in the United States, some Kanpur students' lives were transformed by their early encounters with the computer, and they sought out any possible opportunity to work on it.[18]

IIT electrical-engineering faculty members quickly integrated computer studies into the curriculum. By 1965, detailed plans were established for a master's degree program in electrical engineering that would provide a concentration in computer science. The institute's 1969 catalog indicates a full complement of undergraduate and graduate computer courses, with offerings in software engineering, information theory, hardware design, image processing, and systems engineering (graduate only). A large part of this computer-science teaching load was undertaken by Rajaraman and Mahabala.[19]

Both Rajaraman and Mahabala had obtained their computing education on the fly, without formal training. They subsequently spent time at leading centers of academic computing in the United States under the auspices of the Kanpur Indo-American Program—Rajaraman at UC Berkeley and Mahabala at MIT. Despite their extensive experience in U.S. universities, the program they conducted at Kanpur was much different than those conducted in the United States. Rajaraman and Mahabala undertook research, but their focus was teaching—teaching not only IIT students, but education more broadly. Rajaraman, who came to be recognized as the leading figure in computing education in India, wrote an introductory textbook on programming and usage in 1969 and later authored books on FORTAN and COBOL programming. While Rajaraman and Mahabala published research, they never specialized narrowly. Instead they covered a wide range of areas and acted to facilitate Indian computing in whatever ways were necessary.[20]

Engineering Curriculum in India," *IEEE Transactions on Education* 36 (1993): 176–77. H. N. Mahabala, personal interview with author, 26 May 2005; T. R. Viswanathan, personal interview with author, 14 April 2005.

18. "Annual Technical Report, Kanpur Indo-American Program," 30 June 1964, box 21, CMU-INSTEP; Ravi Sethi, personal interview with author, 25 May 2005; Hari Sahasrabuddhe, personal interview with author, 23 September 2005; Raj Kanodia, personal interview with author, 9 August 2005; Mahabala, personal interviews with author, 26 May and 21 June 2005. Those who worked at the computer center included Ravi Sethi, who later became a senior manager in the communications sciences department at Bell Labs; Jayadev Misra, who became the head of the electrical engineering department at the University of Texas at Austin; and Raj Kanodia, who was a member of the group that connected MIT to the ARPANET in the early 1970s.

19. IIT Kanpur, "Computer Centre," August 1965, box 4, MIT-KIAP; IIT Kanpur, *Courses of Study, 1969–70* (Kanpur, 1969), 116–27.

20. Mahabala interview, 26 May 2005; Kanpur Indo-American Program, Final Re-

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The IBM 1620 was an ideal introductory computer: relatively small, it was a simple machine to use and did not require a large staff to operate. Within a year of its delivery, however, IIT Kanpur had fully utilized the 1620. Furthermore, the system was not capable of processing some faculty members' sophisticated problems. Therefore the institute obtained a much larger system, an IBM 7044, whose arrival in 1966 made IIT Kanpur home to one of the most powerful computers in India.[21]

Scholars of computing in India have noted that IBM marketed computers there long after they were introduced in the United States, and the 7044 was well on its way toward obsolescence when Kanpur received the machine. IBM and other computer users were writing less software for it, and by 1969, just three years after Kanpur had acquired its 7044, IBM was phasing it out. Neither IBM India nor its parent company in the United States provided assistance to Kanpur in obtaining additional software.[22] However, the problem of producing up-to-date software for out-of-date hardware proved a spur to innovation. In 1970, IIT Kanpur undergraduates produced the first compiler written in India, which incorporated features implemented on newer versions of FORTRAN written for more recent hardware not available in Kanpur. Prior to this, IIT Kanpur students had been learning FORTRAN II, which, in the words of the student newspaper, was "almost a dead crow on the world market."[23]

In 1968, Kelkar gave a talk describing IIT Kanpur at a UC Berkeley con-

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port, C3; "Report on Activities of Professor H. N. Mahabala at Massachusetts Institute of Technology, September 14, 1968–February 10, 1969," box 2, MIT-KIAP; V. Rajaraman, *Principles of Computer Programming* (New Delhi, 1969). Mahabala described his research philosophy to me in our interview on 26 May 2005.

21. Kanpur Indo-American Program, "Monthly Report to AID, October 1965," folder 2.1, Kanpur Indo-American Program collection, California Institute of Technology archives (hereafter Caltech-KIAP), Pasadena; "Larger Computer for the Institute," *Spark*, 15 February 1965, 4, box 12, CMU-INSTEP. The 7044 was introduced by IBM in late 1961 as part of a temporizing plan to provide products while IBM developed its System/360. A version of the 7044, described in 1964, had 32,000 36-bit words of main magnetic-core memory, and a disk drive with 28 million bytes of memory. See Martin Weik, *A Fourth Survey of Domestic Electronic Digital Computing Systems* (Aberdeen Proving Ground, Md., 1964), 164–65. The system's list price was $3 million, but IBM gave IIT Kanpur its standard 60 percent educational discount and allowed it to pay in rupees—a major concession to a country for which foreign exchange was precious. See "IBM 7044 for IIT/K," *Spark*, 31 October 1965, 10, box 4, folder "Programs and Projects, Norman C. Dahl," MIT-KIAP.

22. Joseph M. Grieco, *Between Dependence and Autonomy: India's Experience with the International Computer Industry* (Berkeley, Calif., 1984); H. N. Mahabala, "Proposal for Acquiring Software for IBM-7044 System at IIT Kanpur," 14 February 1969, and H. N. Mahabala, to Professor Halfman, 24 July 1969, box 2, MIT-KIAP.

23. "New Compiler Developed at IIT/K by Undergraduates: First Indian Compiler," *Spark*, April 1970, 2, box 39, CMU-INSTEP. A compiler is computer software that translates a program from a high-level language such as FORTRAN into machine language so that it can be executed by the computer.

ference on "The Role of the Professional as an Agent of Political, Economic, and Social Change in Low-Income Countries." He related his enthusiasm for Kanpur's computer experience, saying that after its introduction in 1963, "we soon became aware of the compelling power of the computer. It exercised a unique fascination over the minds of not only post-doctorals, but also freshmen and it had an equal appeal to the faculty as well as the students." Kelkar further praised the computer's powerful pedagogic value, asserting that "there is no better instrument for generating a scientific and quantitative attitude of mind."[24]

American Technical Elites and Computing at IIT Bombay and IIT Madras

The existence of five IITs established at approximately the same time allows for an analysis of how different configurations of personnel and resources led to different choices and, ultimately, to different computing programs. It also reveals the extent of American involvement in helping establish computer centers at IITs other than Kanpur. Part of the reason the Indian government sought different sponsors was to introduce a variety of ideas into its engineering institutions. The institutes' mission was to provide technological education. Given the existing state of technology in India, a range of choices was possible regarding how a technical institute should be fashioned and what roles, if any, a computer might play in an engineering education.

Considering computing at the IITs as a whole during the 1960s, Kanpur was the aberration. A particular set of conditions allowed the computer to thrive there in a way it couldn't at the others. It was championed in Kanpur by Kelkar and electrical-engineering faculty members, who worked to integrate the computer into the curriculum. Furthermore, the extraordinary support Kanpur received as the flagship program of U.S. engineering-education assistance in India enabled it to pursue capital-intensive technologies that others could not. The United States' contribution to Kanpur was twice as large in terms of funding for equipment and guest faculty members as the Soviet Union's was in Bombay or the West Germans' in Madras, and it was three times larger than that of the impecunious British in New Delhi.[25]

While the American faculty at Kanpur kept a wary eye on IIT Bombay because of its Soviet support, the respective programs of assistance were not at all comparable. Language differences and the organizational struc-

24. P. K. Kelkar, "Establishing a Technological Institute: A Joint Indo-American Experiment in Kanpur," talk presented at the UC Berkeley conference on "The Role of the Professional as an Agent of Political, Economic, and Social Change in Low-Income Countries," 19, 24–26 May 1968, Kanpur Indo-American Program collection, box 1, Caltech-KIAP.

25. Sebaly (n. 8 above), 2.

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ture of the program at Bombay muted the Soviet presence; moreover, a substantial American influence existed at Bombay in ways not replicated by the Soviets in Kanpur. Some IIT Bombay faculty members had earned their advanced degrees from U.S. institutions, and students read American magazines ranging from *National Geographic* and the *Saturday Evening Post* to *Mad* and *Playboy*.[26]

The first director of IIT Bombay, Brigadier S. K. Bose, previously the commandant of a college of military engineering, had neither Kelkar's academic orientation nor his enthusiasm for computers, and he pursued a cautious approach to computing. In August 1961, he declared to an official at the Tata Institute for Fundamental Research (TIFR) in Bombay that he had declined the offer of a Soviet Ural-I computer due to its high costs, noting that the Bombay institute preferred to use its funds to obtain other instruments. At the same time, Bose inquired about the possibilities of training his staff in computing at TIFR, further noting that in a city such as Bombay, one computer could meet the needs of a variety of institutions.[27]

Three years later, IIT Bombay placed its first order for a computer, but now the organizational structure of the institute's assistance program hampered its efforts. Soviet support came indirectly through UNESCO, adding a complicating level of bureaucracy. A Soviet Minsk II computer was delivered in 1965, but it took two years for the Soviet Union and UNESCO to work out the funding arrangements for Soviet technicians to arrive and install the machine. The technicians finally came in July 1967 and, after much work in repairing the damage caused by its extended storage, the Minsk II commenced operation in January 1968.[28]

The IIT Bombay computer center was headed by J. R. Isaac, a professor of electrical engineering at Bombay, who had obtained his master's degree from the Carnegie Institute of Technology and had worked at IBM in Poughkeepsie, New York, before returning to India. Isaac and his team pursued computing with a great deal of energy, but the Soviet machine limited them in a variety of ways. Within India, the Minsk was essentially a one-off machine. Isaac and colleagues undertook to do all the maintenance for it and also to design hardware upgrades. The Minsk ran the Soviet-developed ACE computer language rather than FORTRAN. Any programs written in the latter therefore had to be translated into ACE, making the Minsk ineffective in training general computer users.[29]

26. Information on students' reading comes from an article in a student publication that surveyed reading preferences in one student dormitory: "A Reader's Survey," *Pragati '63–'64*, 21–23, in IIT Bombay Project files, UNESCO archives (hereafter IIT Bombay-UNESCO), Paris.

27. S. K. Bose, *The Early Years: IIT Bombay* (Pune, India, 1988 [?]), iii–iv; S. K. Bose to M. G. K. Menon, 7 August 1961, Tata Institute for Fundamental Research archives, Mumbai, India.

28. I. L. Bratchikov and I. M. Souchtchinski, *Computer Technology IIT Bombay* (Paris, 1969); D. A. Butaev to G. Friedmann, 15 June 1965, folder 4, IIT Bombay-UNESCO.

29. J. R. Isaac, personal interview with author, 7 March 2007; J. R. Isaac, "A Chair

Befitting its West German sponsorship, IIT Madras had a curriculum that was in some ways the antithesis of IIT Kanpur's, with a program heavily focused on practical training in manual skills such as blacksmithing and woodworking.[30] IIT Madras acquired its first computer in 1963, a surplus analog machine built by Bell Labs that had belonged to an American university. Later, students and faculty seeking a digital computer could use the IBM 1620 provided to the neighboring Guindy Institute of Technology through a program of U.S. assistance.[31]

Later events at IIT Madras and IIT Bombay showed how the American-aligned technical elite at least partially decoupled computing and IIT-level technical education from formal Indo–American political relations. The years 1971 and 1972 marked the worst years ever in relations between the two countries. Compounding the fact that Richard Nixon and Indira Gandhi did not like each other, a series of events revealed fault lines between the two countries. One of Nixon's signature issues, establishing relations with China, was based on using Pakistan as an intermediary, but the crisis in East Pakistan that eventually led to the creation of Bangladesh heightened tensions between Pakistan and India. In 1971 India signed a friendship treaty with the Soviet Union. Events in East Pakistan led Nixon to order the aircraft carrier *Enterprise* to the Bay of Bengal, a gesture Indians viewed as threatening. There seemed to be no doubt that India had tilted toward the Soviet Union and away from the United States. At IIT Kanpur, the Americans and Indians considered a new computer an integral part of a planned second-stage program, which would continue past the original 1972 termination date. However, the deterioration in formal relations between the countries made a second stage impossible.[32]

But events at IIT Madras and IIT Bombay showed that important American-aligned technical elites had not tilted away from the United States. In 1971, the West German government signed an agreement to provide a computer to IIT Madras. H. N. Mahabala and two of his associates from Kanpur were recruited to run the Madras computer center. The West

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Proposed in My Name," http://www.alumni.iitb.ac.in/profiles/profIsaac.htm (accessed 2 May 2008); Bratchikov and Souchtchinski, 4–6.

30. A 1961 visit by MIT professors noted that the West Germans insisted that six months of the first year and three months of the second year of undergraduate training be devoted to workshop practice; see Buechner, Dahl, and Smullin (n. 12 above), 17. A picture in the IIT Madras Heritage Center in Chennai, India, depicts a visiting West German dignitary happily showing his woodworking technique to the director of IIT Madras.

31. IIT Madras Heritage Center; R. Kalyana Krishnan, personal interview with author, 12 July 2007.

32. Kux (n. 2 above), 299–312; Brands (n. 2 above), 122–38; George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley, Calif., 1999), 161–66. Strained Indo–U.S. relations meant that no U.S. money was available for a new computer. And in the absence of funds, IIT Kanpur was forced to keep its 7044 until 1979, even though it had been obsolete for a decade. The 7044's replacement was a U.S.-made Digital Equipment Corporation DEC-10. See IIT Kanpur, *Annual Report, 1978–79*, 62–64.

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Germans had originally planned to provide a German machine and its own team of experts, but Mahabala convinced them that the experts were not necessary and that all the funds should instead be put into an IBM computer. In November 1973, the Madras institute inaugurated its computer center, featuring an IBM System 370 Model 155—the most powerful computer in India at the time. In some ways, IIT Madras consequently supplanted Kanpur as the leading computer center in India.[33]

In 1970, P. K. Kelkar was named director of IIT Bombay, returning to his hometown. As the officials who appointed him must have known he would, he sought to restructure the Bombay institute's curriculum by introducing aspects of American engineering-education practice. In March 1972, near the peak of anti-American sentiment in India, the faculty committee that Kelkar appointed made its final report, proposing a series of reforms whose overall effect was to bring the curriculum more in line with American engineering-education standards, including the requirement that all undergraduates take a computing course. And to make completely clear what these reforms signaled, Suhas Sukhatme, an MIT-trained faculty member and member of the curriculum committee, inserted at the beginning of the report quotations by MIT founder William Barton Rogers and former MIT president Karl Compton on the goals and methods of engineering education. The faculty at IIT Bombay had made its own tilt.[34]

IIT Kanpur and Indian Computing

In truth, the original computer programs of the Bombay and Madras institutes were more in line with the uncertain state of computing in India during the 1960s than Kanpur's was. Indian national enthusiasm toward technology was most strongly directed toward technologies such as atomic power, steel, and dams, which India's political leaders viewed as improving living standards more broadly. The labor-saving computer, imported from the West, was a problematic technology in a country that had a surplus of labor, prized self-sufficiency, and put little stock in international trade.[35]

33. IIT Madras, *Annual Report, 1971–72*, xxix; Mahabala interview, 21 June 2005 (n. 18 above). The date for the inauguration of the computer center is given in a picture in a display at the IIT Madras Heritage Center. The 1975 volume, *Computers in India*, stated that "[the] IBM 370/155 at IIT Madras is considered to be the largest and most modern computer system in the country"; see P. Gopalkrishnan and K. S. Narayan, *Computers in India* (Bombay, 1975), 25.

34. IIT Bombay, *Final Report of the Curriculum Committee, Part I: General* (Bombay, 1972), 5, 8. Suhas Sukhatme, personal interview with author, 28 January 2008. Sukhatme later became the director of IIT Bombay and wrote the "brain drain" studies cited below. Of course, IIT Bombay would not receive any funding from the United States for the purchase of computers and therefore was still saddled with Soviet computing equipment.

35. For broad attitudes toward technology in India after 1947, see Sunil Khilnani, *The Idea of India* (New York, 1998), 61–106, and Shashi Tharoor, *Nehru: The Invention of India* (New York, 2003), 239–47.

At the time the Kanpur program started, computers in India were a specialized scientific instrument, much as they had been in the United States during the late 1940s. They were the provenance of the Indian Statistical Institute and the Tata Institute for Fundamental Research, each an elite institute headed by personal friends of Nehru and closely tied to two of his initiatives, economic planning and atomic energy, respectively.[36] In the early 1960s, IBM began installing computers at a few scientific laboratories and large, vertically integrated companies, where they were used primarily for recordkeeping. At this time, Indian labor unions opposed the use of computers, calling them "job eaters." The government of India only began seriously looking into questions of computers and the labor issues surrounding them in the late 1960s and early 1970s.[37]

While the overall status of computing in India was uncertain and a matter of ambivalence, this was not the case at IIT Kanpur. During the 1960s and early 1970s, the institute played a central role in promoting the computer throughout India. In Kelkar's 1968 talk at the UC Berkeley conference, he claimed that in India, "there is hardly a computer installation where there is nobody who had been to Kanpur at least once."[38]

Acton, Huskey, and Rabinowitz, the three Americans charged with setting up the IBM 1620 in Kanpur, took their charter to be to serve as evangelists for computing in India. They lectured throughout India at such institutions as the Tata Institute for Fundamental Research, IIT Madras, the Indian Statistical Institute, the University of Roorkee, the University of Bombay, and the Physical Research Lab. They also conducted a special session on computing for fifteen members of the Indian Planning Commission. But the main part of IIT Kanpur's missionary work, even after Acton, Huskey, and Rabinowitz departed, was a series of ten-day courses they had established, which were held for members of institutions in India that might be potential computer users. These courses provided an introduction to computers and computer programming as well as to numerical methods, and they included laboratories where participants could get hands-on introductions to programming.[39]

Indian faculty members continued and extended these courses after the Americans left, and by August 1965, 600 individuals representing fifty insti-

36. C. R. Subramanian, *India and the Computer: A Study of Planned Development* (Oxford, 1992), 1–3; R. N. Narasimhan, "Men, Machines, and Ideas: An Autobiographical Essay," *Current Science* 76 (10 February 1999): 447–54.

37. Subramanian, 1–37; *Report of the Committee on Automation* (New Delhi, 1972); R. Narasimhan, "Meaningful National Goals in Computer Development, Production and Use," in *Electronics: Proceedings of the National Conference on Electronics* (Bombay, 1971), 371–82.

38. Kelkar (n. 24 above), 19.

39. Information on lectures and courses on computing are from Kanpur Indo-American Program, "Monthly Report to U.S. AID," from July 1963 to June 1964, box 36, CMU-INSTEP. Further details on the activities of the U.S. visiting faculty are given in Acton (n. 1 above).

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tutions had taken the ten-day course. The institutions represented included other IITs, other engineering colleges, scientific institutions, national laboratories, other government agencies, and private enterprises.[40] IIT Kanpur computer faculty members offered the courses with an almost religious sense of mission, in many cases driving to the railway station ten miles from campus themselves to pick up participants while their wives prepared meals. Mahabala recalled that later in his career he met many computer professionals who told him that they had their introduction to computing in these courses.[41]

All of the effort the Kanpur institute put into educating others in computing would have been irrelevant without IBM and its sales efforts in India. A 1974 survey indicated that India had a total of 217 computers installed, of which 65 percent were by IBM, 13 percent by the British firm ICL, and 11 percent by the Indian firm ECIL.[42] Simultaneity is not causality, but an American-oriented program of engineering education in India and an American computing firm did reinforce each other.

The Road from Kanpur to Bangalore: The Indian IT Industry

Even today, traveling from Kanpur to Bangalore is difficult, and the path leading from the Kanpur computer center in the 1960s to today's IT industry centered in Bangalore was by no means short or direct. While both MIT and Stanford each spawned a local IT industry, the fact that no IT industry exists in Kanpur today suggests the limitations of Kanpur resources. IIT Kanpur made a major contribution in terms of the early personnel of two of today's three biggest IT firms in India, Tata Consultancy Services (TCS) and Infosys. But one discovers the forces behind the creation of the Indian IT industry not so much by looking directly at IIT Kanpur, but instead by looking at India's American-oriented computing elites.

The House of Tata, India's largest business group, established a computing enterprise in 1967, and in 1969, F. C. Kohli moved from his position at Tata Electric to head the new business, by this time called Tata Consultancy Services. Kohli led TCS for decades, and under his leadership it became India's premier IT firm. Kohli, mentioned above, had worked with Kelkar in Bombay, and when Kelkar came to Kanpur, he convinced Kohli to serve on the electrical-engineering faculty-selection committee and to make regular visits to the institute. Kohli received his practical introduction

40. IIT Kanpur, "Computer Centre" (n. 19 above).

41. H. N. Mahabala recalled that participants in the ten-day course would also arrive at IIT Kanpur by cycle rickshaw from the train station; see Mahabala, "Early Computer Education in India—a Reminiscence," in *Computer Education in India: Past, Present and Future*, ed. Utpal K. Banerjee (New Delhi, 1996), 41–46, and Mahabala interview, 26 May 2005 (n. 17 above).

42. Gopalkrishnan and Narayanan (n. 33 above), 24–26.

to computing on Kanpur's IBM 1620, and he introduced computing to Bombay-based Tata Electric. In the early years of TCS, H. N. Mahabala spent his summers there working as a consultant; in addition, Kohli often hired Kanpur's master's graduates in computing.[43]

IIT Kanpur also proved to be an important source of talent for Infosys, but in this case that talent consisted of one person: Naryana Murthy, its principal founder. Murthy, a south Indian, had attended the University of Mysore and studied electrical engineering, intending to become a hydropower engineer. He then enrolled in the Kanpur institute to earn a master's in electrical engineering and while there got "hooked" on computing. What was important about Kanpur for Murthy's later work was not simply its role in getting him interested in computing, but also that it introduced him to a network of U.S.-educated Indian elites working with computers. After leaving Kanpur, Murthy took a position working with MIT-trained professor Jashwant Krishnayya at the Indian Institute of Management in Ahmedabad (IIM), where Krishnayya was introducing a Hewlett-Packard computer purchased with Ford Foundation money (Krishnayya had made a special trip to Kanpur to recruit engineers with computing skills). Murthy, after leaving IIM and working a brief stint in France, then returned to India to work again for Krishnayya at a think tank he had established, which was modeled after RAND. From there, Murthy took a job working for MIT-educated Narendra Patni, whose Patni Data Systems was one of the first Indian firms to get computing work from U.S. companies. In 1981, Murthy and six other Patni employees left to establish Infosys.[44]

India had many computing businesses in the 1960s, 1970s, and 1980s. The critical factor in TCS's and Infosys's success was their ability to do busi-

43. Kohli is considered by many to be "the father of Indian IT." Kohli, whose career has been spent in and around Bombay, was also heavily involved with IIT Bombay, where an auditorium is named in his honor. In 1973, he became the first Indian to sit on the board of directors of the IEEE, the international (but U.S.-oriented) electrical-engineering professional society. See F. C. Kohli, *The IT Revolution in India: Selected Speeches and Writings* (New Delhi, 2005), and Kohli interview, 25 January 2008 (n. 14 above). H. Kalyanasundaram, "Status Report of IEEE in India on 31 December 2006," http://www.ewh.ieee.org/r10/india_council/Status%20Report%20on%20IEEE%20in%20India.pdf (accessed 16 April 2008).

44. Naryana Murthy, personal interview with author, 20 January 2006; Jashwant Krishnayya, personal interview with author, 31 January 2008; Narendra Patni, personal interview with author, 24 January 2008. On Patni's role in early outsourcing, see Robert Weisman, "At the Center of a Culture Shift," *Boston Globe*, 25 May 2004, online at http://www.boston.com/business/articles/2004/05/25/at_the_center_of_a_culture_shift/ (accessed 11 August 2009). The three largest IT companies in India are TCS, Infosys, and Wipro. Wipro, without any IIT Kanpur connection, was started by Azim Premji, a Stanford-educated electrical engineer who transformed his family's cooking-oil business into computers; see Joel McCormick, "The World According to Azim Premji," *Stanford Magazine*, May/June 2006, http://www.stanfordalumni.org/news/magazine/2006/mayjun/features/premji.html (accessed 29 April 2008).

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ness with the United States. Murthy and others like him had computing ability based on their work at the Kanpur institute, but what Murthy lacked were the connections necessary to obtain business from the United States. Patni had those connections, and by working with him, Murthy developed connections he could later use in starting Infosys. American-oriented elites already on the ground in India, like Patni and Kohli, gave a special potency to the computing work of IIT Kanpur graduates.[45]

IIT Kanpur and Computing in the United States

Kelkar and the Americans who had designed the program of assistance to Kanpur had conceived of IIT Kanpur as an Indian institute that would train Indian engineers to provide technical solutions to India's problems. The institute's students at least partially frustrated this effort by remaking Kanpur, actualizing its place in a hierarchy that its very name implied—the Indian MIT.[46] Kanpur students quickly became part of the American educational system, and then part of the larger American computing community.

While during the 1960s baby boomers swelled American colleges and universities, the number of foreign students in the United States, Indians among them, increased substantially as well. In 1948, 26,759 foreign students were enrolled in American colleges and universities; by 1966 that number had increased to 100,262. By the 1965–1966 academic year, almost 7,000 Indians studied in the United States. In 1966 at MIT, the only foreign country represented by more than India's eighty-two students was Canada.[47]

Kelkar, his faculty, and the visiting American faculty had expended great energy introducing the American system of engineering education to Kanpur, though the purest form of the system existed, of course, in the United States. Even if Kanpur had the best computer-education program in India, it never could match the American programs with their superior funding. It can hardly be considered surprising, therefore, that many of IIT Kanpur's best students decided to continue their education in the United States.

ITT Kanpur operated within two different educational systems. For its top undergraduate students, the institute was often only a step toward enrolling in the best American graduate programs. Kanpur's own graduate programs (and the programs of the other IITs) drew students primarily

45. After completing his formal education at MIT, Patni worked with computer pioneer and academic entrepreneur extraordinaire Jay Forrester, doing consulting work and participating in his business ventures.

46. These nested hierarchies of educational systems display what Charles Maier has called "the fractal nature of imperial power"; see Maier (n. 4 above), 10, 146.

47. The numbers on foreign- and Indian-student enrollments are from the Institute for International Education's annual publication, *Open Doors*; see *Open Doors, 1948–49*, 7, and *Open Doors, 1967*, 1. The numbers on Indian students at MIT are from MIT, *Report of the President, 1967*, 513.

from further down in the Indian educational hierarchy, students who were advancing themselves by attending an IIT. For the IITs, recruiting doctoral students in competition with well-funded American universities was to be a persistent issue.[48]

Prior to 1965, many opportunities existed for Indians to study in the United States, but a discriminatory quota system severely restricted the numbers of Indians who could permanently emigrate to the United States. Had that system continued, whereby engineers from India could access the American educational system but were generally denied the right to work in the country, it might have been possible for the IITs to present themselves as viable alternatives to going abroad for one's graduate education. Over time, the IITs' graduate programs could have demonstrated that they prepared students for a career in India better than American programs ever could. But in 1965—ironically, the year of IIT Kanpur's first graduating class—President Lyndon Johnson signed immigration reform legislation into law that made it much easier for Indians to take up permanent residence in the United States.[49]

After 1965, a substantial number of IIT graduates who came to the United States would stay, though they constituted a small part of the greatly increased overall numbers of Indians emigrating to the country (fig. 5). This situation would become one of the biggest factors hindering the effectiveness of the IITs as Indian institutions. The most thorough study of the migration of IIT graduates to the United States was done for IIT Bombay, and it shows that of all its electrical-engineering graduates between 1973 and 1977, slightly over 40 percent ended up abroad, the vast majority in the United States. While comparative data doesn't exist for IIT Kanpur, one would expect its percentage to be similar.[50]

48. However, the computer-science research done in an IIT that has been most widely recognized by the international computer-science community was that by Manindra Agrawal, an IIT Kanpur faculty member who received both his B.Tech. degree and Ph.D. from the institute; see Sara Robinson, "New Method Said to Solve Key Problem in Math," *New York Times*, 8 August 2002, online at http://www.nytimes.com/2002/08/08/us/new-method-said-to-solve-key-problem-in-math.html?scp=2&sq=manindra%20agarwal&st=cse&pagewanted=print (accessed 11 August 2009), and Lee Gomes, "One Beautiful Mind in India is Putting the Internet on Alert," *Wall Street Journal*, 4 November 2002, online at http://proquest.umi.com/pdqweb?did=230447981&sid=1&Fmt=3&clientId=15092@RQT=309&VName=PQD (accessed 11 August 2009).

49. Prior to 1965, a system of nation-based quotas, privileging immigration from countries already heavily represented in the United States, controlled the immigration process. These national quotas were abolished in 1965 in favor of a system that had an overall cap and preferences for family members and skilled immigrants. See Ronald Takaki, *Strangers from a Different Shore: A History of Asian-Americans* (Boston, 1989), 418–20; and Judith M. Brown, *Global South Asians: Introducing the Modern Diaspora* (Cambridge, 2006), 54–56.

50. S. P. Sukhatme, *The Real Brain Drain* (Bombay, 1994), 17–18. An email list in the author's possession of the first batch of IIT Kanpur students, who graduated in 1965,

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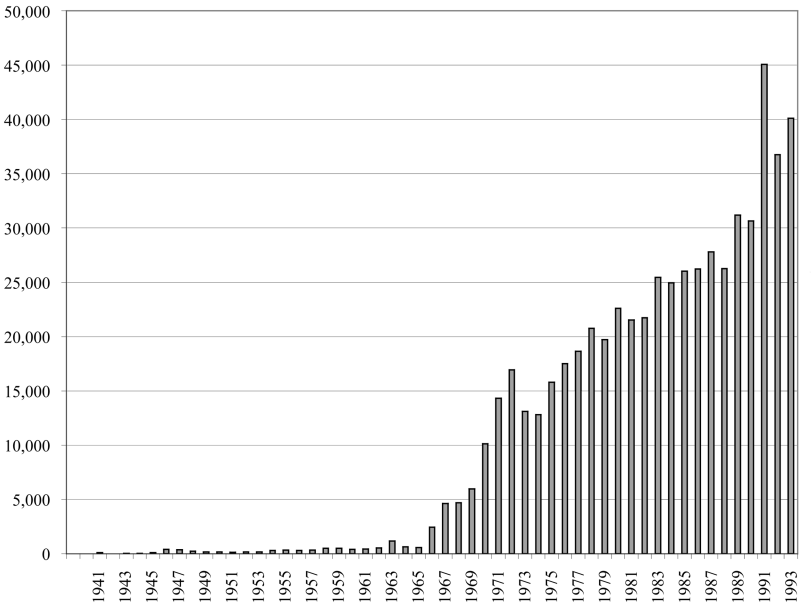

FIG. 5 Immigrants to the United States from India, 1941–1993. (Source: Robert Barde, Susan B. Carter, and Richard Sutch, "Immigrants, by country of birth—Asia: 1941–1997," table Ad149-161 in *Historical Statistics of the United States, Earliest Times to the Present*, Millennial Edition, ed. Susan B. Carter et al. [New York, 2006], 1-569–1-570.)

Since the graduation of its first class in 1965, IIT Kanpur graduates in computing who emigrated to the United States have been thoroughly integrated into the technical community. Some idea of the role IIT graduates have played in computing in the United States is suggested by the following: the connection between early IIT Kanpur graduates and the ARPANET (the forerunner of the internet); the number of IIT Kanpur graduates in faculty positions in the top ten computer-science programs in U.S. universities; and the careers of the first batch to graduate with undergraduate degrees in computer science from Kanpur (in 1983).

As might be expected from IIT Kanpur's close ties to American engineering education, Kanpur's graduates working in computing were in a position to quickly make substantial contributions to the field in the United States. Consider the following, from the header to a 1971 document published by the Network Working Group, which was comprised mainly of

indicates that roughly one-third were resident in the United States in 2005. A recent examination of the issues behind the migration of highly skilled individuals is Devesh Kapur and John McHale, *Give Me Your Best and Brightest: The Global Hunt for Talent and Its Impact on the Developing World* (Washington, D.C., 2005).

computer-science graduate students who developed a system of protocols for the ARPANET:

Network Working Group	A. Bhushan, MIT
Request for Comments #176	R. Kanodia, MIT
NIC #7100	R. Metcalfe, MIT
Categories: C and D	J. Postel, UCLA
	14 June 1971

The name R(obert) Metcalfe is familiar in the history of computing as the inventor of the Ethernet, one of the primary means of connecting computers locally, but the names R(aj) Kanodia and A(bhay) Bhushan are not. Both were early graduates of IIT Kanpur (Bhushan in the first graduating class in 1965 and Kanodia in 1968) who were able to move into positions at the leading edge of the development of computing in the United States. Kanodia went from IIT Kanpur to a position at Dartmouth, then to a staff position on MIT's pioneering program in machine-aided cognition, Project MAC. Bhushan attended graduate school in electrical engineering at MIT and while there became part of Project MAC, where he worked on connecting the university to the ARPANET. As a graduate student he served as chair of the working group that defined the FTP protocol—a standard protocol still used for transferring files among computers.[51]

In 1993, the National Research Council ranked U.S. programs in computer science. An examination in 2008 of the faculty in the top ten departments in the 1993 rankings showed that thirty-eight faculty members had obtained their undergraduate education in India—enough to fill a good-sized department. Table 1 shows the distribution of the faculty by their Indian undergraduate affiliations. IIT Kanpur was surpassed in its faculty representation only by the computing program at IIT Madras, which it essentially spawned. The other IITs were represented at significantly lower levels, with IIT Kharagpur absent altogether.[52]

Prior to 1978, IIT Kanpur had no computer-science undergraduate

51. Kanodia interview, 9 August 2005 (n. 18 above); Abhay Bhushan, personal interview with author, 23 June 2005. MIT's Project MAC is described in M. Mitchell Waldrop, *The Dream Machine: J. C. R. Licklider and the Revolution That Made Computing Personal* (New York, 2001), 217–36. Bhushan's work on the ARPANET and FTP is described in Katie Hafner and Matthew Lyon, *Where Wizards Stay Up Late: The Origins of the Internet* (New York, 1996), 174–75, 191–92. The referenced Network Working Group document is available at http://rfc.dotsrc.org/rfc/rfc176.html (accessed 13 September 2009).

52. The National Research Council's rankings of computer-science graduate programs are available at http://nt.cra.org/scripts/rankcs.pl?TOP=108&DIRECTION=DESC&ORDER=QUALITY&FIELDS=QUALITY (accessed 10 July 2009). I obtained the undergraduate institutions from the departments' websites and by emailing those whose undergraduate institution was not listed. At the time of this writing, the NRC had not updated its computer science rankings in sixteen years.

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TABLE 1

REPRESENTATION OF INDIAN UNDERGRADUATE INSTITUTIONS IN FACULTY AMONG TOP 10 U.S. COMPUTER SCIENCE DEPARTMENTS (BASED ON A 1993 NRC EVALUATION)

Undergraduate institution	*Number of faculty*
IIT Madras	11
IIT Kanpur	10
IIT Delhi	5
IIT Bombay	4
Guindy	2
Jadavpur	1
Indian Institute of Science	1
Loyola	1
Birla Institute of Technology	1
Mysore University	1
BMS College for Women	1

Note: Determination of the faculty who had attended Indian undergraduate institutions is based on an examination of computer science programs made by the author in March 2008. The most recent NRC rating of computer science programs was in 1993, at which time the top ten were Stanford, MIT, UC Berkeley, CMU, Cornell, Princeton, and the universities of Texas–Austin, Illinois, Washington, and Wisconsin.

majors; computer-science work was done within the electrical-engineering department. In 1978, the institute established a program leading to a bachelor's degree in computer science—the first such degree offered at any IIT. This Kanpur degree program was extraordinarily attractive to IIT entrants. Admission to the IITs and to specific majors was (and is) based on applicants' rank on the nationwide Joint Entrance Examination (JEE). The student ranking first on the exam can choose any seat in any major at any of the IITs. The next highest-ranking student has the choice of any seat except that one already occupied, and so on until all seats are filled. The last of twenty positions allotted to the computer-science major at IIT Kanpur was filled by JEE rank number 44, meaning that close to half of the top forty students throughout India chose to enter the program.[53]

Upon graduation, a large percentage of the first computer-science majors at Kanpur, and subsequent batches thereafter, applied for graduate training in the United States. Eventually some Kanpur faculty members,

53. V. Rajaraman, personal interview with author, 7 March 2007. The continuing dominance of IIT Kanpur's computer-science program in the hierarchy of the disciplines and the IITs can be seen again in the statistics from the group of students entering the IITs in 1988. The fourteen available computer-science seats at Kanpur were filled by JEE rank number 38, meaning that roughly one-third of the forty highest-scoring students on the JEE chose to study computer science at Kanpur. See IIT Kanpur, *29th Annual Report, 1988–89*, IV.7.

frustrated by this outflow of students, made an ultimately futile attempt to halt it by refusing to write recommendation letters for applicants to U.S. graduate schools. Of the nineteen original graduates in computer science from 1983, an alumni website accessible in 2007 yielded information regarding the careers of seventeen. One graduate had passed away; of the remaining sixteen, fourteen lived in the United States, one in the Czech Republic, and the last in India. Nine obtained doctorate degrees, and five of them held U.S. academic positions in computer science (at Stanford and Syracuse Universities and the Universities of Minnesota, Nebraska, and Texas at Arlington). Six lived in the San Francisco Bay area, and at least three had been involved in founding their own companies. One worked for IBM Research, another was a senior manager at Hewlett-Packard, and a third worked for Google. One member of this 1983 class, Rajeev Motwani, a professor of computer science at Stanford, served as an early academic mentor to Larry Page and Sergey Brin in the work that led to the formation of Google. This remarkable record of achievement makes clear how thoroughly these graduates of IIT Kanpur integrated themselves into the American computing community.[54]

Kanpur's graduates were exceptional in some ways, but in the United States they were also representative of the graduates of all the IITs. The various national patrons of the IITs that the Indian government cultivated would suggest a multi-polar world, but no such multi-polarity existed in where IIT graduates studying abroad went for further studies. No matter what IIT a student attended, the vast majority who chose to go abroad came to the United States.[55] And, of course, computer science could always

54. Information on the graduating class of 1983 was at "Roster Batch of 1983, IIT Kanpur," http:/www./iitk78-83.org/roster.htm (accessed April 2007; this site is no longer available). Information on those receiving B.Tech. degrees in 1983 is from "IIT Convocation Held on 17 May 1983," IIT Kanpur Academic Affairs Office, IIT Kanpur. Motwani's death in a drowning accident in June 2009 was widely mourned in Silicon Valley and was reported prominently in major newspapers in both India and the United States. See Miguel Helft, "Rajeev Motwani, Guide in the Creation of Google, Dies at 47," *New York Times*, 10 June 2009, online at http://www.nytimes.com/2009/06/11/business/11motwani.html?scp=1&sq=rajeev%20motwani&st=cse (accessed 11 August 2009), and Chidanand Rajghatta, "Google Mentor Rajeev Motwani Dies in Drowning Accident," *Times of India*, 7 June 2009, online at http://timesofimdia.indiatimes.com/NEWS/World/US/Google-mentor-Rajeev-Motwani-dies-in-drowning-accident/articleshow/4627659.cms (accessed 11 August 2009). The fact that the *Times of India* carried Motwani's obituary before the *New York Times* demonstrates how sensitive the Indian press is to the activities of the Indian diaspora, particularly those involved in business and technology. An early article describing Google is Sergey Brin, Rajeev Motwani, Lawrence Page, and Terry Winograd, "What Can You Do with a Web in Your Pocket?" *Data Engineering Bulletin* 21 (1998): 37–47, online at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.36.2806&rep=rep1&type=pdf (accessed 10 August 2009).

55. For example, a 1988 article by an IIT Bombay professor estimated that India's brain-drain loss to the United States during the 1970s was 90 percent of its total global brain-drain loss. One would obviously expect this loss to track the global distribution of

be studied in the United States whether or not one had received prior training in the field in India.[56] Graduates of all the IITs, and of the other Indian technical universities as well, are well represented in the American computing community and among computing entrepreneurs.

Conclusion

Technological relations between India and the United States have been deeper and less variable than extrapolation from the standard diplomatic history would suggest. American-oriented technical elites in India, themselves a product of the American engineering-education system, served as critical intermediaries between the two societies, able to operate apart from formal Indo–U.S. relations. Without the substrate provided for computing by American-oriented technical elites, whether Kelkar, Rajaraman, and Keshavan at Kanpur or people like Kohli, Krishnayya, and Patni, computing technology would not have been established in India in the manner or speed with which it was.

To say that a group of American-aligned elites existed in India is not to say that they marched in lockstep with technological or economic developments in the United States. While their connections to the United States, particularly to the American educational system and American businesses, provided Indian elites resources with which to work, the political ties between the two countries were weak enough and the resources available in India different enough such that these elites had a great deal of flexibility and had to use a great deal of creativity in the world they established.

Kelkar was an idealist and long-range thinker, but the future did not unfold in the way he predicted. The engineering-science model did not accomplish all that he or its American sponsors had hoped. But if Kelkar's American orientation had unforeseen costs at a time when India placed great emphasis on self-reliance and self-sufficiency, it also produced unexpected benefits. Today's Indian IT industry is of course global: two-thirds

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Indian graduate students; see S. P. Sukhatme and I. Mahadevan, "Brain Drain and the IIT Graduate," *Economic and Political Weekly*, 18 June 1988, 1285–93. A 1969 memo by a British official noted the large brain drain of IIT Delhi graduates to the United States. The memo noted some possible British responses to induce IIT Delhi graduates to attend British schools, but doubted the efficacy or practicality of any such measures; see W. G. Wormal, "Brief for Sir Geoffrey Wilson for Meeting with Professor R. N. Dogra on 28th May, 1969," OD 27/31, British National Archives: Public Record Office, Kew. A few faculty members from IIT Bombay and IIT Madras went to the Soviet Union and West Germany, respectively, for advanced training.

56. Kishore Trivedi, who holds an endowed professorship in computer science at Duke University, is one example of this. He graduated from IIT Bombay in 1968 with no exposure to computing, then took a position with IBM in India working on accounting machines. After that, he went to the University of Illinois to obtain his doctorate, afterwards remaining in the United States (Trivedi, personal interview with author, 28 March 2008).

of its business comes from the United States.[57] Computing in India began in a global environment in which the United States dominated the field, and in which American firms were the largest potential customers for Indian export-oriented businesses. In such an environment, alignment with the United States made a lot of sense, and American-oriented elites were advantageously positioned to pursue that business.[58]

The success of today's Indian IT firms has justifiably been a source of great pride, but this success is not an ex post facto justification for all of the country's policies since independence. In 1947, India had numerous options before it, and it is impossible to calculate now the potential benefits and costs of each path it could have taken. However, one can discern in its implementation of science and technology projects such as the IITs not just Nehru's enthusiasm for science and technology, but a polity dominated by the interests of an urban middle class. Although the country poured large amounts of money and energy into creating the IITs, mass education did not receive the same priority. Not building the IITs would not necessarily have insured that those resources would have been spent instead on an effective mass education system, but if India's IT industry is one legacy of Nehru's policies, so too are its generally low levels of education and persistent poverty.[59]

But India's policies, certainly with respect to the IITs, are understandable in historic terms. Thomas Hughes has shown the attraction the American technological system held for Germans and Russians during the interwar period, and given the dominant position of the United States vis-à-vis the other nations of the world, it would have been remarkable if Indians had not looked to the United States during the post–World War II period. One can see in the legacy of the computer center at IIT Kanpur support for

57. Nasscom Strategic Review, 2007, Executive Summary, http://www.nasscom.in/upload/51054/Executive%20Summary.pdf (accessed 5 May 2008).

58. A brief history of the Indian IT industry that supports my basic arguments about the importance of U.S.-oriented technical elites (without putting it in those terms) is by Rafiq Dossani, "Entrepreneurship: The True Story behind Indian IT," in *Making IT: The Rise of Asia in High Tech*, ed. Henry S. Rowen, Marguerite Gong Hancok, and William F. Miller (Stanford, Calif., 2007), 221–66.

59. Amartya Sen, "I.T. and India," Keynote Address at the NASSCOM 2007 Leadership Forum, Mumbai, 7 February 2007, at http://www.hindu.com/nic/itindia.htm (accessed 4 May 2008); Lloyd I. Rudolph and Susanne Hoeber Rudolph, *In Pursuit of Lakshmi: The Political Economy of the Indian State* (Chicago, 1987), 297–99; Myron Weiner, *The Child and the State in India: Child Labor and Education Policy in Comparative Perspective* (Princeton, N.J., 1991); Ramachandra Guha, *India after Gandhi* (New Delhi, 2007), 222–23; Edward Luce, *In Spite of the Gods: The Strange Rise of Modern India* (New York, 2007), 27–32. My impressionistic sense after speaking to dozens of IIT graduates from the 1960s and 1970s is that they came from urban middle-class backgrounds and were often sons of engineers or army officers. Today, as the lower castes and classes have made their political power more apparent, the government has sought to reserve more spaces in the IITs for them, sparking protests from the middle class.

Amartya Sen's claim that India has had a long history of fruitful exchanges with other cultures. And, as with its other exchanges, this one changed both societies.[60]

Rabindranath Tagore, the great Bengali poet (whose son Rathindranath studied agriculture at the University of Illinois), wrote to British priest Charles Andrews that "whatever we understand and enjoy in human products instantly becomes ours, wherever they might have their origin."[61] Since the 1960s, if the "whatever" was computers, the legacy of IIT Kanpur raises questions in both India and the United States about the meaning of "ours."

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60. Thomas P. Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm* (New York, 1989), 249–94; Amartya Sen, *The Argumentative Indian: Writings on Indian History, Culture, and Identity* (New York, 2005), 334–56.

61. Rabindranath Tagore, *Letters to a Friend* (New York, 1929), 136. My attention was drawn to this quote by Amartya Sen in *Development as Freedom* (New York, 1999), 242. For Rathindranath Tagore's time at the University of Illinois, see "History of the Rabindranath Tagore Festival," http://tagore.business.uiuc.edu/history.html (accessed 6 May 2008).