Asia-Pacific Transnational and Inter-regional Contexts
of Scientific Enterprise Development

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This study explores transnational and inter-regional parallels and connections in basic science, technological innovation and commercialization, scientific and technological expertise formations, and technologically based development in the Asia-Pacific region during the early and mid 20th century, also considering late 19th century situations. Path dependence and discontinuities, institutional change and organizational development including patent and securities systems and medical, scientific, and engineering publishing are of interest, along with technological innovation and market development linkages, geographic contexts and demographic change, and individual and institutional leadership.

East-west linkages in the late 19th century occurred around developments including the Yugoslavian Nicola Tesla's wireless wave transmission and Thomas Edison's electrical generator and distribution systems, as uranium mining developed in the western United States and South Africa, as X-ray science and technology developed. Westinghouse, a competitor of GE's, gained rights to Tesla's alternating current motor technology, a technology apparently referred to, likely along with high-energy detonation, in *New York Times* stories about technology diffusion during the 1884 Philadelphia Electrical Exhibition, as the Sino-France conflict developed.[1] The Paris

[1] Michael Aaron Dennis, "Accounting for Research: New Histories of Corporate Laboratories and the Social History of American Science," *Social Studies of Science* 17.3 (August 1987), 483.

Convention for the Protection of Industrial Property was adopted in 1883. The American Institute of Electrical Engineers was founded in 1884.

Japan's imports of dynamo-electric machinery increased dramatically during 1893-97, with apparently rivalrous fluctuations of imports. German imports increased steadily in the mid-1890s, from 12,344,500 yen to 18,199,120 yen to 41,170,960 yen from 1893 to 1895 and then increased dramatically from 1895 to 1896, to 152,157,920 yen, and continued to rise, to 166,858,680 yen, in 1897. British imports increased rapidly and steadily from 1893 to 1896, from 26,956,510 yen to 49,322,220 yen to 173,707,840 yen to 247,748,340 yen, and then in 1897 declined to 185,063,020 yen. U.S. imports increased from 99,253,320 yen to 145,908,020 yen from 1893 to 1894, declined to 69,826,280 in 1895 as Great Britain advanced, and then increased from 279,515,960 yen to 605,049,820 yen from 1896 to 1897.[2] During these years, the 1894-95 Sino-Japanese War started when China and Japan independently sent troops to the Korean Court for counter-insurgency action and Japan had Korea declare war on China, leading to conflict between China and Japan, according to Joshua A. Fogel.[3]

Reactions to changing trade patterns included development of Miami in 1896 with expanded shipping infrastructure. Also in 1896, an Imperial Cable Committee was formed to plan a cable connecting Britain, Canada, Australia, and New Zealand, and a London company built the cable, which began service in 1902, governed under the UK Pacific Cable Act of 1901. By 1899, the year of U.S. annexation of the Philippines, international automobile races including the *Tour de France* attracted attention, and

[2] Board of Commerce and Industry of the Imperial Department of State for Agriculture and Commerce, Japan, *General View of Commerce and Industry in the Empire of Japan* (Paris: M. de Bruoff, 1900).
[3] Joshua A. Fogel, "To Reform China: Naitō Konan's Formative Years," *Modern Asian Studies* 16.3 (1982), 353-395, 355.

automobiles were on the streets of American cities including Miami. Guglielmo Marconi's American Marconi Corp. and the Nippon Electric joint venture with Western Electric investment were formed in 1899. During technology and trade change later, England's Cable & Wireless (Imperial & International Communications Ltd.) incorporated in England in 1929, combining Marconi Wireless, Eastern Extension, Pacific Cable Board, and smaller companies.[4]

Transnational telegraphy networks were well developed by the late 1850s. As systems proliferated, interconnectivity within technology as well as across treaty-governed geographies was an issue. A U.S. patent (21895) was granted in August 1882 for an electric telegraph "transmitting or 'translating'" from one cable or line to another, a system for cable and for aerial or subterranean land lines, invented by James Anderson and Benjamin Smyth of London. This "Electric Telegraph" patent filing described conditions of intermediate cable stations like Aden, which connected with the Suez, where cables worked independently and the operator for one cable would receive a message and give the message to the operator of the other cable for retransmission. Aden or Yemen, a trading center port from ancient times in southern Arabia at the entrance to the Red Sea, along the Silk Road trade route, became a British colonial protectorate in the 19th century. A British patent, No. 13,497, granted to Francois DuMont in 1851 for a complex telegraph switching system with loops and trunks was generally forgotten, the Bell Telephone History of Engineering and Science in the Bell System notes.[5] A U.S. patent, 11763, on a galvanic telegraph safety switching system for railroad bridges was

[4] John Braithwaite and Peter Drahos, *Global Business Regulation* (Cambridge: Cambridge University Press, 2000), 353.

[5] M. D. Fagen, ed., *A History of Engineering and Science in the Bell System: The Early Years* (1875-1925) 1 (Bell Telephone Laboratories, 1975), 475; John Thomas Scharf and Thompson Westcott, *History of Philadelphia* 1609-1884 (Philadelphia: Everts & Co., 1884).

granted to William O. McBea of Philadelphia, a city where extensive telegraph switching systems developed.

Late 19th-century United States spatial structures relate to Western Union Telegraph Co. rate practices and connectivity of eastern and western areas of the United States. Although there was interest in repeating transmission of messages to avoid errors, half-price rates were developed for night transmission of messages sent from areas east of the Mississippi if the messages were not repeated for confirmation and if the sender signed an express agreement not to hold the company liable. Morris Gray in an 1885 treatise formulates the inherent spatiality of telegraphic technology enterprise flexibly, suggesting the viability of wireless telegraphy, although also suggesting continuities of telecommunications enterprise spatiality, ". . . a telegraph company may be defined as a company that undertakes for hire to communicate intelligence with the aid of electricity, between points situated upon its route for such as choose to employ it." Drawing on *Ellis* v. *American Telephone and Telegraph* (1866), Gray suggests complexities related to reducing a message to written form.[6]

Richard B. du Boff, noting that after 1868 only the United States and Canada had private control of telegraph enterprise, analyzes technological change as a source of economic power. He describes the extreme increase in spatial range and immediacy of enterprise as telegraph systems developed along with railroads. In 1849, in early telegraphic enterprise, Philadelphia merchants were told they could access business of the far west and New Orleans business when Philadelphia and Louisville were connected. The region east of the Mississippi became a single market for most commodities, and part of the trans-Mississippi West (Minnesota, Iowa, and eastern Kansas and Nebraska) also

[6] Morris Gray, *A Treatise on Communication by Telegraph* (Boston: Little, Brown, 1884), 4, 39, 62-64, 81-93.

became part of an almost national market, du Boff adds, drawing on Davis and North's studies of institutional change and economic growth. Although evolution of telegraph systems after the Civil War decentralized cotton marketing, shifting it away from marketing by factors in a few southern port cities to many small markets, cotton buying became concentrated toward cotton at pre-manufacturing stages, and cotton sold by a few American and European enterprises moved by telegraph around the world.[7] During the Civil War, Peru and India were developed as cotton sources.

In 1838, a Chinese Museum opened in part of the new building constructed for the Philadelphia Museum. It displayed representations of history and culture including "houses, temples, bridges, boats, and war junks, etc." The collection was removed in 1848.[8] The Japanese Embassy was established at Philadelphia in 1856, the year the U.S. Congress passed legislation for reorganizing the consular service. The Japanese Embassy moved to New York on June 16, 1860.[9]

At the 1876 centennial exhibition in Philadelphia, Professor Bell, who was doing experiments at MIT, honored U.S. President Grant and the emperor of Brazil, Dom Pedro, connecting them by telephone between the Main Building and Machinery Hall, after a demonstration early in 1876 connecting two houses. In February 1877, Elisha P. Gray of Chicago received "airs of a musical instrument" "connected with the telephone and played at Milwaukee."[10]

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[7] Richard B. du Boff, "The Telegraph in Nineteenth-century America: Technology and Monopoly," *Comparative Studies in Society and History* 26.4 (Oct. 1984), 571-586.
[8] Scharf and Westcott, *History of Philadelphia*, 2, 948-49.
[9] "The Japanese Embassy. Their Departure from Philadelphia, Incidents along the Route. Splendid Reception in this City," *The New York Times* (June 18, 1860); Gaillard Hunt, "History of the Department of State," *The American Journal of International Law* 6.4 (October 1912), 910-930.
[10] Scharf and Westcott, *History of Philadelphia* 3, 2134.

"No catalogues are as yet ready for visitors to gain definite data as to what is to be seen," a *New York Times* story observed about the 1884 Philadelphia exhibition, also conveying the idea that the machines were based on "new principles." This was the fourth large exhibit of electrical appliances in three years, following Paris, Vienna, and Munich. The comment "Despite the large number of entries, . . . the exhibition from present appearances will have more the character of an American than of an international exhibition" paradoxically suggests international technology transfer. Lighting display including "a fiery fountain radiant with prismatic hues of wonderful brilliancy" was "only a portion of it." Some distance from the main building and an old railway station and space for lectures, concerts, and refreshments, another building, connected by conductors, provided tests of "more delicate apparatus" and "appliances for photometric and other measurements." Edison's company, the War Department with Capt. Michaelis, and the Navy Department with Lieut. Bradley A. Fiske presented major exhibits. A torpedo control system and a "detector to indicate the proximity of torpedoes by induction" were shown. "A vibration, which is caused by the nearness of a torpedo, is instantly communicated to an apparatus in the searching boat, and causes a distinct murmur or humming there," the *New York Times* reported.[11]

On September 8, 1884, the day after the Philadelphia Electrical Exhibition opened, the Chinese emperor issued a manifesto declaring war on the French. The German Consul at Canton announced closing of the harbor at Canton to steamers, the German government was buying three Chinese warships at Kiel, and a command that "German artificers and engineers" transfer their services to the Chinese arsenals, leave

[11] "A Dazzling Exhibition: A Splendid Display of Electrical Inventions, A Scene of Bustle and Brillancy," *The New York Times,* September 3, 1884, 1; "A Declaration of War," *The New York Times,* September 9, 1884, 5.

Kiel, and go to Shanghai was issued.[12] Zhang Heng (78-139 AD) invented the first seismograph.[13]

The institution of *kuan-tu shang-pan* "official supervision merchant management" enterprises in industries including telegraphy, shipping, mining, and metalwork developed in China in the 1870s, as officials were skeptical about Western influences including baseball, Shannon R. Brown finds. Small programs for graduate training in France and Germany for "suitably Chinese" adults were developed. Western technical workers worked alongside Chinese workers with imported machinery as Chinese in Hong Kong and Shanghai were building "simple" machines during the late 19th century. By the 1860s, Chinese military projects including shipyards were under way, and by 1872, there were spin-offs of some military technology enterprise. After some conflict, by the end of the century, the enterprises were "mostly private Chinese-owned private firms."[14] Chang Chi-tung's leadership in developing "modern ordnance production during the decade prior to the [Sino-Japanese] war" was in the context of threats affecting China and its military approach during the 1860s as well as part of a forward-looking reform and modernization through an "integral" "self-strengthening," Thomas L. Kennedy observes.[15] Chang (1834-1909), a statesman who synthesized Confucianism with Western technology, later planned ways to continue production at Foochow, across the Formosa Strait from Taipei and Taiwan, and add production including mine laying and work with coal and other raw materials at Kwangtung, north of Canton, applying merchant capital. As constraints developed, the economic development was more limited

[12] *Ibid.,* “A Declaration of War,” September 9, 1884, 5.
[13] *Beijing Review,* “Science Town to Open,” Weekly Watch (March 1, 2001), 5.
[14] Shannon R. Brown, “The Transfer of Technology to China in the Nineteenth Century: The Role of Direct Foreign Investment, *Journal of Economic History* 39.1 The Tasks of Economic History (1979), 181-197.
[15] Thomas L. Kennedy, "Chang Chi-Tung and the Struggle for Strategic Industrialization: The Establishment of the Hanyang Arsenal, 1884-1895," *Harvard Journal of Asiatic Studies* 33 (1973), 154-182.

and was formed with local or provincial and governmental capital. The Franco-Sino war in 1884 was "transformational" for Chang. One strategy developed was inland waterway arsenal sites. The first full year of production at Hanyang, on the Han River where it joins the Yangtze River, was in 1896, after Chang, transferred to the Hukwang provinces Hupeh and Hunan, north of Canton in central China, developed the Lu-Han railroad. In July 1888, Chang had contacted German ordinance machinery companies via the Chinese ministry in Berlin. Chang developed cotton mills as well as iron and steel mills.

Naitõ saw Japan influencing reform in China, developing Japanese influence and culture, according to Fogel. Japan rejected structures with Japanese annexation of China or Japan as a middleman in East-West interactions. China developed shipyards, arsenals, telegraph, rail, and foreign office functions. However, European-style troops with Mauser and Remington weapons and battleships on the Chinese coast were defeated in the Sino-Japanese War.[16]

Potential innovation diffusion paths going back to the 19th century include links between Roentgen and Western Electric, between Philadelphia, Chicago, and Japan. Northern California was a science and technology center by the mid-19th century, with a Jesuit college founded in a Franciscan seminary at Santa Clara in 1849. After the 1865-67 Western Union expedition resulted in U.S. purchase of Alaska rather than construction of a San Francisco to Moscow telegraph across Alaska, telegraph connections between Shanghai, Vladivostok, and Nagasaki began in 1871-72, as a telegraph code dictionary for representing Chinese characters as numerals into Morse Code was prepared. Patent conflicts with Western Union led Edison to organize the Edison Speaking Phonography

[16] Fogel, "To Reform China," 355-60, 374.

Co. in 1878 in New York and Connecticut, after he and Charles Cros, a Frenchman, both described sound recording process inventions in 1877.

Western nations' laying of cables in China in 1871 for "electrical communications" ended isolation related to long distances from foreign sites and to long distances within China, Alec T. Rixon explains in a 1938 analysis of blockings of Chinese telecommunications at the time. Shanghai was the center of a system that branched internationally to Nagasaki, Hong Kong, and Manila. Within the system developed in the early 1870s, British interests owned and controlled the Great Northern Telegraph Co. Ltd., a Danish enterprise formed in 1868 and initially connecting Denmark, Norway, England, and Russia, and the Eastern Extension, Australasia, and China Telegraph Co. was British; foreign cable interests owned three-quarters of the stock of the Commercial Pacific Cable Co. Radio communications began in China in 1905, and radio-phone service from China began February 15, 1936, between Shanghai and Tokyo. RCA in 1930 and Mackay in 1933 developed radio circuits from China to San Francisco to points in North and South America.[17] Sheng Xuanhuai, economic deputy for Li Hongzhang, a statesman and general, established the Imperial Telegraph Administration in 1881 and reorganized cotton, mining, and railway enterprise in the 1890s.[18] Tin mines at Yunnan in south China north of Burma and Vietnam are near the Mengtse, or Mongtse, treaty port opened near the Red River under China and France's *Convention additionelle* signed in June 1887, and tin, silver, iron, and lead mining

[17] Alec T. Rixon, "Telecommunications of China with Foreign Countries," *The Public Opinion Quarterly* 2.3 (July 1938), 478-483; Daniel R. Headrick and Pascal Griset, "Submarine Telegraph Cables: Business and Politics, 1838-1939," *The Business History Review* 75.3 (Autumn 2001), 543-578.
[18] Zhaojin Ji, *A History of Modern Shanghai Banking* (Armonk, NY: M. E. Sharpe, 2003), 59.

developed not far to the west, at Kochiu, or Kíochíu.[19] Long-distance hydroelectric transmission began in California in the 1890s, with California's San Antonio Light & Power Co. developing the first alternating current station, which allowed long-distance energy transfer.[20] *Nature* in April 1887 noted publication of *The Australasian Directory of Commerce, Trades, and Professions* from London and Paul Bedford Elwell's English translation of Gaston Planté's "The Storage of Electrical Energy."[21]

In the last years of the 19th century, the number of post offices with telegraph offices in Japan increased dramatically, from 638 in 1895 to 648 in 1896 to 965 in 1897 to 1,086 in 1898. The number of post offices in Japan spurted up and then declined between 1895 and 1898, changing from 3,080 in 1895 to 3,976 in 1896 to 2,770 in 1897 to 2,659 in 1898, as inter-modal connectivity developed and as fast communication became more important.[22] Quing Empress Dowager Cixi in 1906 developed reforms including founding the Ministry of Finance and Ministry of Posts and Communications.

Communications advances paralleled immigration circulations including hostaging, smuggling, and bondage. Until 1869 Britain had a policy of limiting direct access to India by keeping European political establishment out of Egypt and protecting Egypt, according to Halford L. Hoskins.[23] The relationship continued toward the partition of Africa in the 1880s.

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[19] George G. Chisholm, "The Resources and Means of Communication of China," *The Geographical Journal* 12.5 (November 1898), 500-519.
[20] Jessica B. Teisch, "Great Western Power, 'White Coal,' and Industrial Capitalism in the West," *The Pacific Historical Review* 70.2 (May 2001), 221-253.
[21] *Nature* April 14, 1887.
[22] *General View,* 11.
[23] Halford L. Hoskins, "British Policy in Africa 1873-1877: A Study in Geographical Politics," *The Geographical Review* 32.1 (Jan. 1942), 140-49.

British and Dutch East Indies companies intermediated trade between continents overseas, following on Italian and North Sea trade with areas including China and Africa. These British and Dutch enterprises maintained *entrepot* connections with enterprise in the Mediterranean, Africa, and Northern and Eastern Europe. During the late 19th century, as Asian, European, and U.S. enterprises developed transportation and communication technologies, redemptionist circulations into and out of China were important. U.S. trading company legislation and export-import bank infrastructure developed in the 1980s, which have strongly influenced contemporary East-West trade, follow on earlier trading company structures.

Chinese factory in the Street of Teng-chan in Nagasaki, founded in 1688, Perry-Castañeda Library Map Collection, University of Texas at Austin. From Illustrations of Japan consisting of private memoirs and anecdotes of the reigning dynasty of the Djougouns, or sovereigns of Japan, *by Isaac Titsingh, London, J. Ackerman, 1822. Chinese and Dutch were restricted to specific districts. Note the advancing signal tower connected with railroad contact outside the wall at the upper left.*

At the turn of the 19th century, many steamship lines in Japan ran within Asia. Among them, the American Line served Canada and the United States, running between Hong Kong and Seattle, serving terminals at Kobe, Yokohama, and Victoria, connecting with the Great Northern Railway at Seattle, and working with bills of lading also connecting to Shanghai, Vladivostok, Corea, Java, and the Philippines. The European Line connected Yokohama, London, and Antwerp, also calling at ports including Hong Kong, Singapore, Penang, Colombo in Sri Lanka, and Marseilles. The Australian Line linked Yokohama and Melbourne via Kobe, Shimonoseki (travels outward only), Nagasaki, Hongkong, Manila, Thursday Island, Townsville, Brisbane, and Sydney. Other lines included the Hongkong-Vladivostock Line and the Kobe-Vladivostock Line.[24]

Yeijiro Ono's "The Industrial Transition in Japan," published in an American Economics Association journal in January 1890, notes the influence of Viceroy Ismail's borrowing from London and Paris to build telegraphs and railroads, "constructing improved methods of immigration," and the state of ethnic combination in Japan when he wrote. Telegraph and railroad systems begun a few decades earlier were expanding, and Japan was extending trade to South America, Australia, and the Pacific Islands. Ono looks back to the era of isolated feudal city and annual tribute visits, when communication between neighboring provinces was slight. Although he observed that machinery might bring industrial disturbance, citing J. S. Nicholson, Ono predicted industrial expansion based on Japanese strengths in shipping, developing from mechanization advances toward market development in newly connecting areas where manual labor would be developed. Nicholson had predicted that "a radical change made

[24] *General View,* 5-7.

in the method of invention will be gradually and continuously adopted" and will lead to incremental change. In Nicholson's view, industrial development required opening of internal communication, so that new machinery would develop railroads and steamships. At a time when foreigners could not hold real estate or develop industry in Japan, a German vessel from Korea attempting to bring coal and other provisions a few months earlier was diverted to a treaty port, Ono states. After decades without foreign investment, Ono recommends treaty change to encourage foreign investment in mines and public industry.[25]

The Japanese government imported reeling machinery from France in 1872 and developed a mechanized silk industry, and this development led to investment in more complicated machinery for producing cotton yarn. Cotton milling also developed with government sponsorship, with government funding industry in 1870 and bringing in technicians from England. Between 1892 and the turn of the century, Japan shifted from imported machinery to automatic looms invented locally and expanded exports. By 1910, Japanese cotton automatic loom process technology was exported to western nations. After Eiichi Shibusawa (1840-1931) traveled in France, he led the Ministry of Finance, Japan's First National Bank and the Chamber of Commerce, promoting infrastructure funding and developing cotton and other industries, then developing many small and medium-sized companies and developing cooperative joint stock investment.[26] Shibusawa promoted silk manufacturing modernization in 1872. In the 1880s, he promoted cotton mills with ring spinning rather than mule spinning as cotton mills in

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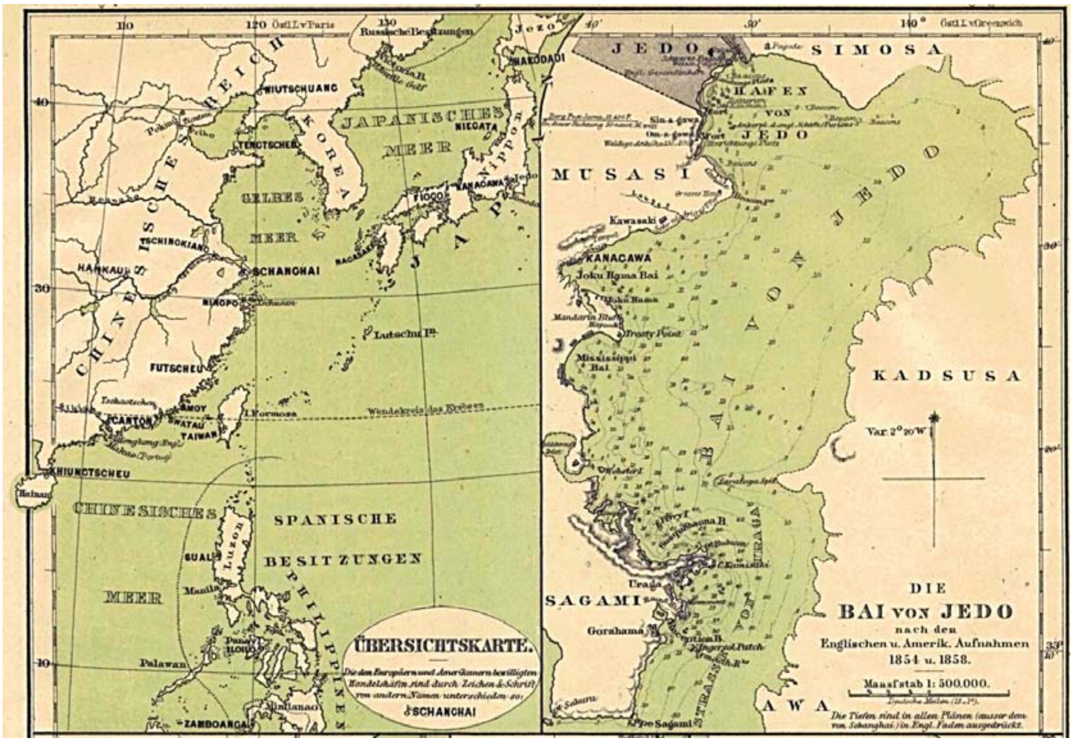
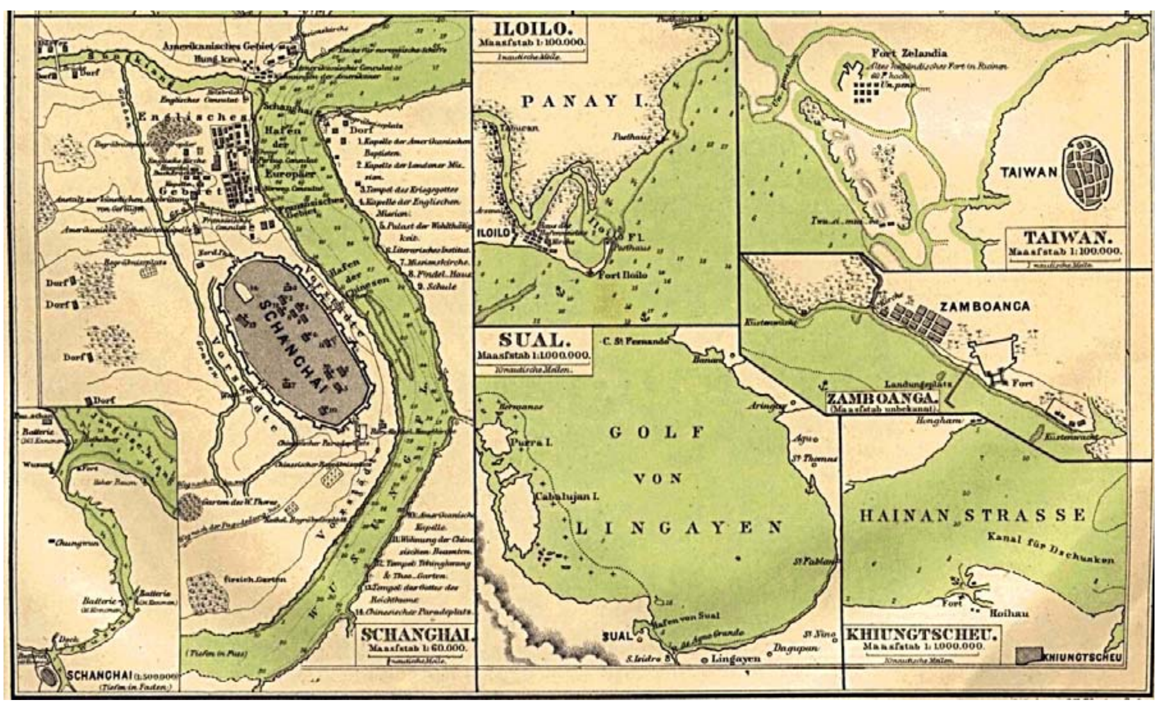
[25] Yeijiro Ono, "The Industrial Transition in Japan," *Publications of the AEA* 5.1 (Jan. 1890), 17-121, 69, 117, 17-18, 20, 101, 108-09, 112.
[26] Nancy Ettlinger, "The Roots of Competitive Advantage in California and Japan," *Annals of the Association of American Geographers* 81.3 (Sep. 1991), 391-407. 398-99; George M. Oshiro, "The Autobiography of Eiichi Shibusawa: From Peasant to Entrepreneur," *Monumenta Nipponica* 49.4 (Winter 1994), 506-08.

Lancashire and China stayed with mule spinning. During the 1890s, Japan developed cotton cloth industry, influenced by Toyota Sakichi's move from hand loom patenting in 1891 to power loom patenting in 1896-97, according to Yshihiro Tsurumi. Sakichi visited the United States in 1907 and observed Northrop's power loom, which had led U.S. and English manufacturing by 1894. Sakichi, who received a patent for a faster automatic loom in 1916, led advances in cotton and silk weaving in Japan especially after the Russo-Japanese war in 1905. By 1901, Shibaura was innovating with a three-phase current dynamo, in work interacting with bidding by General Electric for the Yokosuka Navy Arsenal. Shibaura licensed technology from GE in 1909 and continued technological alliance with GE for electrical equipment manufacturing that continued beyond a brief break during World War II. Japanese enterprise interacted broadly with the West in technological innovation during the early 20th century, according to Tsurumi.

Exchange of persons through college and university exchange programs paralleled development of transportation and communications systems for trade and diplomacy. January 31, 1873, the *New York Times* reported that the bill to establish an American college in Japan, focused on "the education of interpreters and others," went to the Senate Committee on Foreign Relations and to the House Foreign Affairs Committee. Also, Cæsar Moreno, "an Italian gentleman, and a representative of the American, Japan and China Telegraph Company," spoke to the Foreign Affairs and Foreign Relations committees about the company's proposal to build a telegraph cable to China running through the Sandwich Islands, which would become the United States' Hawaii territory and then the U.S. state of Hawaii.



1860 maps in the Perry-Castañeda Library Map Collection, University of Texas, Austin. Ports in China, Japan, and the Philippines. *Part I includes Jedo Bay, Part II includes Plans of Schanghai. From* Mittheilungen aus Justus Perthes' Geographischer Anstalt uber Wichtige Neue Erforschunger auf dem Gesammtgebiete der Gesammtgebiete der Geographie von Dr. A. Petermann *Vol. 6, 1860. http://www.lib.utexas.edu/maps/historical/taiwan_1860.jpg. The map shows a Spanish presence at the Philippines oriented to China and Japan and southward and details a church district at Shanghai.*



Zhao Ziyang's March 1985 speech about China's Seventh Five-Year Plan for 1986-90 included an announcement of Special Economic Zones established on China's southern coast between Hong Kong and Taiwan and open coastal cities established along the rest of the coast as geographic elements in a strategy of development including technological and economic exchange.[27]

Transnational connections between the United States and Asia in the 19th century and early 20th century included contact through Scandinavia and through Brazil. British influence continued, and American direct communication linkages with Asia developed as indirect linkages continued. June 7, 1866, in "An Affray at New-Changwee," a *New York Times* story suggesting wireless or atmospheric transmission of electricity related to disturbance, reported a Chinese group's attack on a boy at the American Consul as telegraph service between Europe and Shanghai via Kiatcha (in Russian territory, near Pekin) began. A Chinese firm was hosting a banquet in San Francisco for Anson Burlingame, trade minister to China, and George R. Van Valkenburg, trade minister to Japan, with other guests including C. S. Bulkley, chief engineer from the American-Russian Telegraph Expedition, G. H. Mumford from Western Union, and Caleb Lyon, governor of Idaho.

April 25, 1899, the *New York Times* reported, along with a proposed combination of western and eastern paper mills and the incorporation of the Union Steel & Chain Company to "control the entire chain production of the company," dissolution of a

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[27] T. David McDonald, *The Technological Transformation of China* (Washington, D.C.: National Defense University Press, 1990), 6-10. Richard Butsch links spiritualist contexts of early electric telegraphy in the 1830s and 1840s with imagery from the time of wireless introduction during the late 19th century. Richard Butsch, Review of *Haunted Media: Electronic Presence from Telegraphy to Television, Journal of American History* 88.3 (December 2001), 1145. Claude Chappe built semaphore communication towers for Napoleon's armies in the 1790s. Headrick and Griset, "Submarine Telegraph Cables," 545.

merger of Pacific Coast banks and a race riot at Hammond, Louisiana, also reporting that the Portuguese Cortes had "approved a project for laying and working a cable from the Azore Islands to North America, Great Britain, and Germany," with construction of the line by the European and Azores Telegraph Company. Also, President McKinley and the Attorney General had approved the first German transatlantic cable. The German-American Telegraphy Company, sponsored by Secretary Hay and Dr. von Holleben, the German ambassador, would run from Ems in Hesse-Nassau, Prussia, near Coblenz, to New York via the Azores, a Portuguese possession. This line, along with the Franco-American cable, would be "the only line not touching on British soil."[28] Also in 1899, Japan shifted from a single non-discriminatory tariff on all imported items to tariffs raised selectively on many items.[29]

Telegraphy technology implementation and structures of financial circulations were related. *In re Broad, ex parte Neck(e),* decided in 1884, the year of the Philadelphia Electrical Exhibition and the year that Tesla, who demonstrated wireless waves, moved to the United States, as Edison drew electrical current from vacuum of his incandescent lamp and began developing electronics, concerns insolvency of a London banker, Neck, that developed in processing commercial accounts from Thomsen in Sweden. Neck, who sometimes got bills paid and sometimes discounted bills, became insolvent after accepting a draft from Westenholz Brothers to cover Thomsen's drawing on him and then giving his bankers Thomsen's draft on Westenholz Brothers. Also in 1884, *Ex parte Dever, in re Suse,* addresses a merchant, Sentence, at Shanghai trading in tea with Mussett at London (Loudon in typography), drawing on Suse and Sibeth, bankers in

[28] *The New York Times,* "A German-American Cable," April 25, 1899, 2.
[29] Yul Sohn, *Japanese Industrial Governance: Protectionism and the Licensing State* (Abingdon and New York: RoutledgeCurzon, 2005), 15-27.

London, sending bills of lading attached to the drafts and discounting with the Hong Kong and Shanghai Bank. *Dever*, settled with distribution of unsold tea only versus proceeds alleged related to a dispute, distinguishes commercial lending and commercial transactions processing.[30] Spatiality and communications and transportation infrastructure as well as treaty and other governance contexts of transactions also are contexts of a 1920 suit from a Belgian company against Neuss, Hesslein, an American trading company with its main office in New York, regarding shipment of egg yolk and albumin partly in Shanghai and partly in transit.[31]

During these years of expanding communications, transportation, and trade, Thomas Edison, working in New York and Menlo Park, New Jersey, in 1885 bought land at a site on the west coast of Florida that would become Fort Myers and developed a research and development laboratory there. After Albert Myer, a surgeon, chief Signal Corps officer, and then meteorologist in the Army, who published *Manual of Signals* (1868), used for training in the Signal Corps at Fort Whipple, Virginia, died in 1880, the Signal Corps School site established its name as Fort Myer in 1881. A fort built along the Caloosahatchee River in Florida during the Seminole Wars after a hurricane in 1841 was renamed Fort Myers in 1850 after Abraham Myers from South Carolina, whose father-in-law commanded Fort Brooke at Tampa. The fort was abandoned after the Civil War. In 1876 the Florida town in an area that shipped cattle to Cuba was named Myers to avoid confusion with Fort Myer in Virginia.[32]

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[30] Blackburn, Colin, William Norman Raeburn, and Leonard Charles Thomas, *A Treatise on the effect of the Contract of Sale on the Legal Rights of Property and Possession in Goods, Wares and Merchandise* 1845 3d ed. (London: Stevens and Sons, 1910), 314-16.
[31] Tahira V. Lee, "The United States Court for China, A Triumph of Local Law," *Buffalo Law Review* 52.92 (Fall 2004).
[32] Downtown Fort Myers, "The History of Downtown Fort Myers, http://www.downtownfortmyers.com/History/default.cfm; Joseph Thomas, *Universal Pronouncing Dictionary of*

In 1884, Maeda Masana's *"kogyo iken"* report and the Trade Association Ordinance developed protected industrial cartels following earlier guilds. Practices including information sharing were encouraged for the cartels. Okubo Toshimichi's industrial promotion policy in the 1880s included restructuring of cutthroat competition of the Postal Steamship Company and Mitsubishi Trading Co. into a monopoly. Ship building promotion including subsidy for building steel ships[33] was in the context of broader technological innovation.

International exchanges in higher education and Western influence on university founding and curriculum development in Asia emphasized science and technology and offered humanistic studies including natural philosophy and political economy that U.S. universities also continued as they developed courses for leaders in commerce. November 2, 1873, *The New York Times* reported that Japan was starting an engineering college at Yeddo (later Tokyo), with an engineer from Glasgow serving as president. London and Edinburgh universities were sending professors in natural philosophy, telegraphy, mathematics, and chemistry. The report referred to the "philosophical apparatus" of the college. The apparatus likely was an "old Chinese observatory" at Pekin set up by Jesuits, supplemented instruments from an American expedition that left Chicago after its great fire, in 1871. A March 3, 1875, *New York Times* report on Professor C. A. Young of Dartmouth's lecture to the Stevens Institute in Hoboken about the Chinese observation of the astronomical "Transit of Venus" describes the American expedition traveling to San Francisco and then to Pekin.[34]

Biography and Mythology 1870 4th ed. (Philadelphia: Lippincott, 1915); Paul A. Roales, Meteorology Schools in the U.S. Army Signal Corps, 2006-2007, home.ionet.net/~paroales/methis.htm.
[33] Sohn, *Japanese Industrial Governance* 20-24.
[34] Ruth Hayhoe, "The Forging of a Chinese University Ethos: Zhendan and Fudan," *China Quarterly* 94 (January 1983), 323-341.

Ruth Hayhoe, in "The Forging of a Chinese University Ethos: Zhendan and Fudan," shows early Jesuit and French influences in Chinese and Confucian educational institutions and in reforms toward multifaceted interactions with Western knowledge. She notes that Ma Xiangbo (1840-1939), a Chinese scholar and diplomat from Jiangsu Province, who founded Zhendan as a private college with a nationalist perspective in 1903 and funded Jesuits to run it, had studied at the Jesuits' Le Collège St. Ignace (Xuhui Gongxue) in Shanghai, beginning in 1851, a year after the college was founded. Xiangbo headed St. Ignace from 1872 to 1875, encouraging Chinese studies and religious aspects of Confucianism while writing about Chinese and Western mathematics. He was transferred to an assignment of running a newly established observatory. He left the Jesuits in 1876 and by 1878 was working with his younger brother, Ma Jianzhong, who had studied at the *Ecole Libre des Sciences Politiques* in Paris, with modernization projects and in planning a training institute that would include studies in western culture. Ma Xiangbo worked with a machine factory and at a mining factory. During 1884-85, he worked with the China Navigation Company in South China and visited Taiwan and suggested economic development approaches. He visited American and European universities in 1885.[35]

During his 1853-54 diplomatic missions to Japan developing trade harbors and commercial practices, Commander Perry of the U.S. Navy brought gifts including a telegraph and a telescope.[36]

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[35] Brown, "The Transfer of Technology to China in the Nineteenth Century, 182-83, 181-197; Hayhoe, "The Forging of a Chinese University Ethos," 323-341; "William Dall." *Dictionary of American Biography*, Base Set.

[36] U.S. Navy, Naval Historical Yard, *A Brief Summary of the Perry Expedition to Japan,* 1853 (Washington, D.C.: U.S. Navy, 1953).

The Meteorological Observatory on Shanghai's Bund, originally called the Xujiahui Observatory, built in 1872, was run by the Catholic Church (student.science.nus).

After Japan's Meiji government started its Ministry of Industry in 1870, it led founding of a college of engineering and announced a new Engineering Bureau (*Kõgakuryõ*). The ministry was operating government-owned production sites as it managed industrialization. Offices of its agent in Britain, Hugh Matheson of the Jardine and Matheson trading company, recruited Henry Dyer, a Glasgow engineer, to direct academic curriculum at the college. Yamayo Yõzõ, who had studied science and engineering in Britain, with some time at Anderson's College in Glasgow, where Dyer also had taken classes, was head of the college. Yõzõ as Vice-Minister of Industry had promoted technical education. Between graduation of its first students in 1870 and its merger into Tokyo Imperial University in 1886, a year after the Ministry of Industry was abolished, the technical college shifted to a Japanese approach from a mainly British Western approach that included a course based on a program at a college in Zurich. Johann Friedrich Horner, who developed the ophthalmological clinic at Zurich University after he returned to his native city in 1856, reported sex-linked transmission of red-green color blindness in 1876.[37] The technical college in Tokyo developed as industrial cotton fabric manufacturing technologies were transferred from Lancaster and other centers and as cotton industries restructured globally. Several large cotton mill enterprises developed in Japan, especially at Osaka, and Italian import substitution change included development of cotton textiles.[38] The father-in-law of Wilhelm Röntgen, who during the late 1880s was doing physics research related to his discovery of X-rays reported in 1895-96, ran a café in Zurich.

Ophthalmological publishing began in Japan by February 1897, when *Nippon Ganka Gakkai zasshi* starting publishing as the Japanese Ophthalmological Society formed in Tokyo. Ophthalmology was a specialty in Japan by the 15th century, and German ophthalmology influenced Japanese ophthalmology after the 1857 Meiji Revolution.[39] *Ophthalmologica,* published from Basel beginning in 1899, followed an earlier journal published from Berlin beginning in the 1850s and later in the 19th century published from Leipzig. Gabriel Gustav Valentin, a researcher in neurology, medical physiology, embryology, microscopy, and biological physics who published in Paris Academy networks with scholars at Zurich and Basel and was appointed a professor at

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[37] "Johann Friedrich Horner," Who Named It? www.whonamedit.com/doctor.cfm/1044.html.
[38] Hayashi, Takeshi, *The Japanese Experience in Technology: From Transfer to Self-Reliance* (New York: UN University Press, 1990); Eikoh Shimao, "Some Aspects of Japanese Science, 1868-1945," *Annals of Science* 46.1 (January 1989), 69-91; Tom Kemp, *Industrialization in Nineteenth-Century Europe* 1969 2d. Ed. (London and New York: Longman, 1985), 151.
[39] Akira Nakajima and Shizu Sakai, "History of the Japanese Ophthalmological Society," *Documenta Ophthalmologica* 68.1-2 (January 1988), 171-76.

Bern in 1835 and later appointed a professor at Tübingen, was studying effects of polarized light on tissues in 1861. Valentin, who died in 1883, was, like Johann Evangelista Purkinje, a Bohemian he researched with, a Freemason.[40] Jessica Harland-Jacobs, drawing on Karen Wigen's "'world networks'" perspective and on globalization factors perspectives like Bruce Mazlich's, finds freemasonry networks extending to colonialists in India, China, and Indonesia.[41]

The *Journal of the Japan Society of Mechanical Engineers* and the *Journal of the College of Engineering at Tokyo Imperial University* also began publishing in 1897. Shinobu Ishihara of Teikyo University of Tokyo studied with Professor Stock at Jena University in 1913 and introduced Zeiss contact lenses to Japan when he returned.[42] A brief item in *Nature* December 1896 reports H. Muraoka's findings from work with 300 glow-worms at Kyoto in June. Muraoka reported that although natural glow-worm light behaves like ordinary light, it shows properties of X-rays or Becquerel's rays when it is filtered through cardboard or through copper plates.[43]

In October 1888, the *New York Times* reported that a chair in German languages was established at Imperial College in Pekin, with Eduard Wolf from Stuttgart, who had worked several years for the Chinese government, teaching.[44] A Foreign Language College, Tung-Wên, was at Pekin by April 14, 1887, when the Chinese government funded printing of a study of anatomy, with a title page written by a Chinese minister

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[40] Bruno Kisch, "Forgotten Leaders in Modern Medicine," *Transactions of the American Philosophical Society,* New Ser. 44.2 (1954), 139-317.

[41] Jessica Harland-Jacobs, "'Hands across the Sea': The Masonic Network, British Imperialism, and the North Atlantic World," *Geographical Review* 89.2 Oceans Connect (April 1999), 237-253, 243-47.

[42] Contact Lenses – The Great Zeiss Secret? The College of Optometrists web page, http://www.college-optometrists.org/index.aspx/pcms/site.college.What_We_Do.museyeum.online_exhibitions.contact_lenses.zeiss.

[43] "University and Educational Intelligence," *Nature* 1418.55 (December 31, 1896), 214.

[44] "German to be Studied in Pekin," from the *Paris-American Register, The New York Times* (Oct. 20, 1988), 6.

known for his “beautiful calligraphy,” published by the college.[45] An April 1904 *Nature* item notes a report from Robertson, a secretary to the British Embassy in Berlin, about allocation for “furtherance of scientific, especially ethnological studies in China” and recruitment of a German scholar with knowledge in Chinese languages. Other items in this issue’s “Notes” include funding from the Goldsmiths’ Co. for a Royal Society study of radium and radioactive bodies, transmission with Tesla current of images traced from sensitized paper, the death of Arthur Greeley, professor of biology at Washington University in St. Louis, and M. Ducretet’s producing high-frequency current with a telephone for a demonstration at the French Physical Society.[46] The Natural Science Society of China, organized in 1927, began publishing its *Scientific World* in 1932.[47] Ophthalmological publishing began in Taipei by 1960 (*Transactio Societatis Ophthalmologicae Sinicae Taipei*), in Korea by 1960 (*Taehan Ankwa Hakhoe Chapchi*), and in the Philippines by 1960 (*Philippine Journal of Ophthalmology*). T. M. Li of Peking was a vice president of the International Congress of Ophthalmology listed for the 1922 Concilium at Washington, D.C., and Minoru Nakajima at Kanazawa, Sosuke Miyashita at Tokyo, and Yaeji Ito at Chiba were delegates for the government of Japan at the 1929 Concillium.

Susan A. Mohrman, Jay R. Galbraith, and Peter Monge analyze basic research communities as knowledge networks for knowledge production and knowledge combination, with value flowing vertically, from science to basic research to technology

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[45] *Nature* (April 14, 1887), 568.
[46] “Notes,” *Nature* 1797.69 (April 7, 1904), 539-542. Cyrus Field of the Atlantic Cable and Underseas Communications Co. corresponded with abolitionist Horace Greeley, whose son Arthur lived to 1875.
[47] “The Natural Science Society of China,” *Science,* New Ser. 99.2572 (April 14, 1944), 298.

to commercial application, and flowing laterally, across disciplines. They cite I. Tuomi's 2002 observation that "recombinatorial" innovation requires "relational change at the network level." Mohrman, Galbraith, and Monge's network and innovation studies survey notes Michael Polanyi's 1962 concept of an "'invisible college' of scientists" and D. Schon's 1963 view that appropriation of knowledge from different disciplines is an important path by which creativity is transformed into innovation and into social and professional practice.[48] The concept explanations about an "invisible college" and interdisciplinary circulations emerged following Jack Kilby's and Robert Noyce's inventions of the integrated circuit in 1958 and as "regular production" of computers began in China in 1962 and before China and Russia began regular production of semiconductors in 1968.[49]

Chinese banks organized in the 1860s include the Hong Kong and Singapore Bank, founded in 1864. The Deutsche-Asiatische Bank building in Shanghai would house the Bank of Communications after World War I. Shanghai was an important center of foreign trade and foreign residence, and the French Concession and its environs as an urban place within Shanghai had additional importance. In "The Rendition of the International Mixed Court at Shanghai" (1927), Manley O. Hudson describes development of governance related to extraterritorial activities at Shanghai and linked to Peking and other areas. Following formal opening to foreign traders in 1843, "commingled" business relations and residence districts developed. "[S]hanghai now

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[48] Susan A. Mohrman, Jay R. Galbraith, and Peter Monge, "Network Attributes Impacting the Generation and Flow of Knowledge within and from the Basic Science Community," Jerald Hage and Marius Meeus, *Innovation, Science, and Institutional Change* (Oxford and New York: Oxford University Press, 2006), 196-216, 196-99.
[49] John H. Maier, "Information Technology in China," *Asian Survey* 20.8 (Aug. 1980), 860-875.

stands out as a storm center in China" linked to foreign offices in "remote parts of the world," Hudson observes.[50] R. D. McKenzie's July 1927 "The Concept of Dominance and World Organization" describes Tokyo, Osaka, Shanghai, Calcutta, and Bombay as new centers of dominance.[51] In a 1934 article, William W. Lockwood Jr. describes development of shipping, trading, banking, and industry in Shanghai including growth of a Japanese presence beginning in 1914.[52]

Leaders of technologically based economic development often were influenced by previous work or study abroad. Stephen R. Mackinnon notes the influence of Liang Shi-í (1869-1933), a scholar and official in Canton who had early diplomatic experience in India, Japan, and Manchuria, in developing infrastructure and organizing the Bank of Communications.[53] Liang worked with the Ministry of Posts and Communications, started in 1906 at the direction of Dowager Empress Cixi to run all modern communications, "including railways, shipping, postal services, telegraph and telephone," and created a bureaucratic and financial network called the Communications Clique. He was part of a continuous nonmilitary influence through several eras, including 1921-22, when a Manchurian warlord held power over Peking. Liang led railroad development, including reworking of the Peking-Hankow Railroad, and buying back and consolidating foreign concessions. The Imperial Bank of China resisted control approaches from French and Austrian interests, according to Linsun Cheng. Russian and Japanese interests invested in railroads in China, including the Shandong-Jinan Railway,

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[50] Manley O. Hudson, "The Rendition of the International Mixed Court at Shanghai," *The American Journal of International Law* 21.3 (July 1927), 1-47.
[51] R. D. McKenzie, "The Concept of Dominance and World Organization," *American Journal of Sociology* 33.1 (July 1927), 28-42.
[52] William W. Lockwood Jr., "The International Settlement at Shanghai 1924-34," *American Political Science Review* 28.6 (Dec. 1934), 1030-1046.
[53] Stephen R. Mackinnon, "Liang Shih-í and the Communications Clique," *Asian Studies* 29.3 (May1970), 581-602.

in Shandong Province across from Korea and near Manchuria, with leaders of the Shanghai Bankers Association among those who proposed to buy back the rights of the railroad from the Japanese in 1922, Ji observes.[54]

Foreign banks declined in Shanghai after World War I, and modern Chinese banks advanced over the earlier native banks. The Central Bank of China was organized in 1928. The central banking move -- as the invention of television was reported -- was not, as some had planned, by merging the Bank of China and the Bank of Communications. The Central Bank of China and the Bank of Communications, which had a close relationship with the Beiyang government, were put into a coordinated relationship. Beiyang province along the northern coast across from Korea included areas that are now Liaonîng, Hebei, and Shandong. The Beiyang Army, developed by the Qing dynasty in the late 19th century, was influential in the 1911 Xĩnhăĩ Gĕming or Hsinhai revolution, which overthrew the Qîng dynasty and created the Chinese Republic and continued until the 1949 Communist gain. The army used warlord factions, *bĕiyãng jūnłá*, that worked toward a time of regional division. Beiyang was a center of military influence by the early 20th century.

There was a system of "fairly continuous" observation of solar radiation beginning by 1918 at Winnipeg in Canada and at Salt Lake City, New York, and Jacksonville, Florida, in the United States, according to Charles Greeley Abbot's 1934 Smithsonian report. Abbot describes work to redevelop an observatory among Hottentots in South Africa. Barracks left by German heliographers near Mount Brukkaros many years before "had fallen into ruin." Abbot describes "transverse cars" on South African trains. "As the

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[54] Linsun Cheng, *Banking in Modern China: Entrepreneurs, Professional Managers, and the Development of Chinese Banks, 1897-1937* (Cambridge and New York: Cambridge UP, 2003); Ji, *History of Modern Shanghai Banking.*

railway lay towards the east and as it was thought likely that heliographic signals would, for a time at least, be the only means of communication our first ascent was to the eastern rim," Abbot reports, suggesting persistence of telegraphy from the United States to Asia running eastward rather than westward and paradoxically suggesting that there were parallel explorations westward. The Transvaal and its uranium deposits reported found in 1886 were to the east; the coast, Rio de Janeiro, and the tri-border area of Argentina, Brazil, and Paraguay were to the west; Nigeria was to the north, toward Libya and the Mediterranean. In "Harnessing the Sun" Abbot narrates solar energy developments including projects in the United States, Chile, and Bombay from the late 19th century into the early 20th century and describes use of brickwork of diatomaceous earth formed from fossilized plants. The Smithsonian established its observatory on the western rim of the lava mountain at Brukkaros in 1930. A mission was set up in 1850 at Berseba near Brukkaros.[55]

Innovations from inventions before World War II brought into commercial development during the post-World War II era include grammetry and television. Advances in grammetry research in the mid-20th century were related to solar energy development continuing from industry with products sold in the 1920s. Important developments in biophysics, optics, ophthalmology, neurology, and telesensory studies occurred in the 1920s, influenced by Albert Einstein's work in photoelectric and high-energy physics. Lee DeForest, who earlier worked at Western Electric in Chicago, invented his Audion electric amplifier at Palo Alto, California, in 1907 and began working for Federal Telegraph in 1910. After Edison developed electrical current in an

[55]Charles Greeley Abbot, *The Sun and the Welfare of Man,* Smithsonian Scientific Series 2 (1934). Namibia Holiday and Travel, Brukkaros Mountain, www.holidaytravel.com.na/index.php?fArticleId=105.

incandescent lamp in 1883 and Sir John Fleming in 1904 developed a valve that increased radio power and range by adding a control plate to the Edison tube effect, DeForest added a platinum wire grid. Fleming's advance led to magnetic earphones.[56]

Innovations reported at the British Royal Society's 1921 *converszione* included the Paterson-Walsh electrical height-finder, designed during World War I to measure height of enemy aircraft, photomicrographic transparencies for display of change in microstructures of metals, and photography of protection in X-ray examination of materials.[57] *Experimental Television,* published in 1932 by A. Frederick Collins, who invented a wireless telephone in 1899, traces "the new art of television" back to Paul Nipkow's invention in Germany of the scanning disk in 1884.[58]

Films shown at the January 12, 1922, meeting of the Institution of Electrical Engineers included Dr. Garrard's high-tension switchgear tests of very large currents on transformers. The films were shown at regular speeds and in slow motion. Switching on the power sometimes had effects "similar to those produced by a high-explosive bomb." A film called "The Audion" "explained very clearly the operations which are believed to take place between the transmitter and the receiver in radio-telegraphy." The film, produced by Western Electric Co. of America for employees, showed electrons moving around the filament of a thermionic tube influenced by the valve and showed the grid influencing the electrons' motions. The film also showed currents in the antenna and waves leaving it. Another film "showed the building up of a telephone, all the various parts of it slowly and deliberately getting into their proper places apparently by their own

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[56] Lee DeForest. chem.ch.huji.ac.il/history/deforest.htm, Lee DeForest; "Electron Tube Display," Electronics, *Science News Letter,* March 23, 1957; Frederick Seitz, "The Tangled Prelude to the Age of Silicon Electronics," *Proceedings of the American Philosophical Society* 140.3 (Sep. 1996), 289-337.
[57] "The Second Royal Society Conversazione," *Nature* 107 (June 23, 1921), 536-37.
[58] A. Frederick Collins, *Experimental Television* (Boston: Lothrop, Lee & Shepard, 1932), 41.

agency." The January 19, 1922, *Nature* magazine meeting review does not mention DeForest. The issue also reports the Newton and Wright catalog's description of the Snook transformer apparatus used for radiographic work and for purposes including deep therapy.[59]

Western Electric's joint venture forming Nippon Electric Corp. in 1899, the year of Marconi's transatlantic transmission and receiving of signals,[60] as rivalrous trade fluctuations in important industries occurred, after development of a U.S. market for industrial securities in the 1880s, investing for a 54 percent share in Nippon Electric, embeds international technology migration linkages from the 19th century era of advances in wireless wave and dynamo technologies including remote sensing.

Alexander Graham Bell, who began phonology studies in 1871, followed Helmholz's electromagnetism work and in 1872, after hearing about the Stearns duplex system, planned a system for sending multiple messages at the same time by using tone codes that would give each message a different tone. During patent conflict in 1876-77, Alexander Graham Bell and his backer Gardiner G. Hubbard offered to sell telephone patents to the Telephone Company, which evolved into Western Union. However, Western Union did not accept the offer, instead planning to work with Edison, Elisha Gray, and George Phelps, who supervised Western Union electrical shops. American Bell Telephone Co., incorporated in 1880 to buy equipment of rival companies owned by Western Union Telegraph, after an 1879 incorporation as National Bell Telephone Co. consolidating Bell Telephone Co. and New England Telephone Co., bought a controlling interest in its supplier Western Electric from Western Union in 1882.

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[59] "Notes," *Nature* 109.2725 (January 19, 1922), 85-8

[60] Seitz, "The Tangled Prelude to the Age of Silicon Electronics," 291-92.

American Bell evolved from an enterprise that Bell, a native of Edinburgh who researched speech technologies including ways to translate undulatory currents to sound, formed. Boston and Canada investors worked with Bell during the 1870s. Thomas A. Watson, then with a Boston machine shop, while Bell taught elocution at Boston University, worked with Bell using a transmitter and undulatory current in 1875, creating variations of air density using magnetism, and Bell linked back to put his 1874 idea for a membrane speaking telephone into practice, developing an induction telephone. Watson was part of Bell Telephone Co. when it organized in 1877. Watson built the first telephone switchboards and managed manufacturing for Bell Telephone. American Bell's subsidiary American Telephone and Telegraph started long-distance telephone service between Philadelphia and New York in 1895 and started long lines service between New York and Chicago, an endpoint for many Western telegraph communications from the West, in 1891. After Bell and Watson divided royalties in 1881, Watson traveled and then in 1883 started the Fore Ship & Engine Co., which built small engines and then built torpedo ships for the U.S. Navy and then was acquired by Bethlehem Steel in 1913. In 1915, Watson at Grant Avenue in San Francisco received the first transcontinental telephone call.[61]

Western Electric combined the shop of Elisha Gray and Enos Barton with Western Union in 1872. Western Electric manufacturing plants were at sites including Kearny, N.J., Cincinnati, an abolitionist center, and Chicago. H. Clyde Snook, an electrophysicist from Antwerp, Ohio, a Mason and former schoolteacher who invented the X-ray transformer and received patents in optics, radio, metallurgy, and

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[61] "The Evolution of Bell Labs." http://history.sandiego.edu/GEN/recording/bell-evolution.html; Michael E. Gorman and W. Bernard Carlson, "Interpreting Invention as a Creative Process: The Case of Alexander Graham Bell, Edison, and the Telephone," *Science, Technology, and Human Values* 15.2 (Spring 1990), 131-164.

communications, served as president of the Roentgen Manufacturing Co. in Philadelphia from 1903 to 1913, headed Snook-Roentgen Manufacturing from 1913 to 1916, served as vice president of Victor Electric in Chicago from 1916 to 1918, and then was with Western Electric until 1923. Wilhelm Conrad Röntgen reported his discovery of X-rays in 1895, his report translated in *Nature* magazine followed in January 23, 1896, and Robert Röntgen started the Röntgen Metallsägen Co. in Remscheid in the center of Germany's machine tool manufacturing region in 1899.[62] "The X-Ray in the Orient," a January 4, 1903, *New York Times* article, describes an X-ray apparatus ordered for the financial department in China for examinations of employees to prevent smuggling gold.[63]

Mohrman, Galbraith, and Monge's analysis of transferring knowledge across organizations and across locations includes Morton's account of work at AT&T's Bell Laboratories related to Western Electric. Morton described barriers and bonds in innovation, with tendencies for barriers between organizations. When two activities occurred in the same location in the same organization, although knowledge could be transferred easily, little new innovation would be transferred. When two activities occurred in different organizations in different sites, innovation happened and was difficult to transfer across two barriers. It was difficult to transfer knowledge in switching technology developed at Bell Labs at Murray Hill, New Jersey, to Western

[62] Loving, R. E. "The Arc in High Vacuua." *The Astrophysical Journal* 22.5 (December 1905) 285-304; Pancoast Era. epository.upenn.edu/cgi/viewcontent.cgi?filename=1&article=1006&context; Canon web page; Canon web page. www.canon.com. 1940: Japan's first indirect X-ray camera is developed. Röntgen Metallsägen Co. About Us. www.roentgen-usa.com/English/About_Us/body_about_us.html; http://www.canon.com/about/history/episode02b.html; William R Denslow, *10,000 Famous Freemasons Part Two.* Vol. III, K-P, reprinted from the transactions of the Missouri Lodge of Research for the Educational Bureau of the Royal Arch Mason Magazine, Trenton, MO, 2004, 165. Japanese Industries Association of Radiological Systems. *Radiology Japan* 42 (February 2001) with reference to "A History of Canon Inc." (December 1987).

[63] "The X-Ray in the Orient," *The New York Times,* January 4, 1903, 8.

Electric's switching division at Columbus, Ohio. Mohrman, Galbraith, and Monge note Morton's reflection that he created a Bell Labs satellite unit at each AT&T Western Electric manufacturing subsidiary site. Bell Labs at Murray Hill transferred switching technology to Bell Labs in Columbus, and then Bell Labs in Columbus transferred knowledge to Western Electric in Columbus.[64] In 1936, Mervin Kelly, head of vacuum tubes research at Bell Labs, who wanted to develop switching technology, had recruited Jack A. Morton to Bell Labs from graduate school at University of Michigan. While Kelly headed radar research and development for Bell Labs and Western Electric during World War II, Morton continued his prewar microwave circuit design research and worked on a microwave amplifier circuit used to expand the range of radar in the Pacific. Morton headed device development for Bell Labs during the 1950s and 1960s.[65] Bell Systems electronic switching systems development in the late 1950s and early 1960s included private branch exchanges and stored program control. In 1961, an electronic switching development group worked at Murray Hill, and a military applications group doing integrated voice and data, analog and digital, work for the Signal Corps was at Whippany in New Jersey. The "out of band . . . 'common channel interoffice signaling'" method following from early "'call wire'" signaling was studied by the late 1950s, and in the late 1960s the *Comité Consultatif International Téléphonique* considered the method for an international signaling standard that it adopted in 1968. The Bell system from 1970 to 1972 was part of international trials of the new signaling method from Bell Laboratories at Columbus.[66] During antitrust action against AT&T, Bell Labs, with the

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[64] Mohrman, Galbraith, and Monge, "Network Attributes," 209.
[65] Michael Riordan, "How Bell Labs Missed the Microchip,"www.signallake.com/innovation/HowBellLabsMissedtheMicrochip1206.pdf.
[66] G. E. Schindler, Jr., ed., *A History of Engineering and Science in the Bell System*: *Switching Technology* (1925-1975) 3 (Bell Telephone Laboratories, 1982), 253-59, 319-321.

view that cooperative information exchange would benefit AT&T as well as others, held a Transistor Technology Symposium including licensing in 1952, to increase technology access for small businesses. Sony as well as GE, RCA, and Texas Instruments, then a smaller enterprise, participated in the symposium.[67]

In 1896, Ikegai Shotaro, a mechanical engineer who trained at government arsenals, started building gasoline engines in Japan, as internal combustion engines were imported for factories and farmers. Government arsenals had not allowed Japanese machine tool makers to bid. However, in 1907, Navy arsenals let Japanese machine tool enterprises have minute blueprints of imported machine tools that they were using, according to Tsurumi. As the Ministry of Industry and Commerce organized in 1918 and 1919, research organizations were reorganized, forming the Nitrogen Research Institute, the Osaka Industrial Application Research Institute, the Textile and Synthetic Fiber Research Institute, and the Ceramic Research Institute. The Electric and Telecommunication Research Institute separated from the Ministry of Telecommunication and Postal Affairs as a government sponsored independent research institute. In 1925, Professor Yagi Hidetsugu at Osaka Imperial University invented a directional antenna for transmitting ultra-microwaves.[68]

Gullstrand in Uppsala, Sweden, introduced his slit lamp apparatus in 1911.[69] Federal Telegraph worked with continuous wave radio transmission and provided wireless telephone service for the Navy during World War I, developing the arc converter

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[67] 1952 – Bell Labs Licenses Transistor Technology, A Timeline of Semiconductors in Computers, The Computer Museum, www.computerhistory.org/semiconductor/timeline/1952-transistor-technology-education-and-licensing-begins.html.
[68] Yoshihiro Tsurumi, *Technology Transfer and Foreign Trade: The Case of Japan 1950-1966* (New York: Arno Press, 1980), 96-122.
[69] Electrical Engineering at Stanford Timeline, www.ee.stanford.edu/timeline.php.

for generating continuous wave radio signals that Poulsen in Denmark introduced in 1902. Researchers in Switzerland, the Netherlands, Germany, France, and Italy worked on advances in slit lamp and bright light technologies from 1918 into the 1920s,[70] with Alfred Vogt of the ophthalmological hospital in Basel's slit-lamp research influential among presentations at the 1921 international ophthalmological congress in Washington, D.C.

In 1914, AT&T bought U.S. patent rights for DeForest's Audion, as DeForest was working on combined sound and image transmission using the Audion. A son of a Congregational minister who was president of Talladega College for Negroes in Alabama, DeForest, whose 1899 Yale dissertation was Hertzian Waves from the Ends of Parallel Wires, applied radiotelegraphy at an early stage. He worked pushing chairs at the 1893 Chicago Exposition and began working at Western Electric's dynamo department in 1899. DeForest, working with Abraham White, a stock broker and promoter, built a transmitter in Jersey City and incorporated his American DeForest Wireless Telegraph Co. in January 1902. The Army contracted with DeForest, buying a receiving apparatus for a tugboat and having him build two land stations for the Signal Corps. DeForest was then asked to build two land stations for the Navy, which had used wireless equipment from the German Slaby-Arco Corp., which evolved into Telefunken. In January 1904, sailing back from England, DeForest met Lionel James of the London *Times,* who was traveling to the Orient, and convinced him to install a transmitter on a dispatch boat in the Pacific. In 1907, DeForest broadcast reports of yacht races at Put-In

[70] Murat V. Kalayoglu, "The Evolution of Split Lamp Biomicroscopy." Medcompare. http://www.medcompare.com/spotlight.asp?spotlightid=186; Alfred Vogt, *Textbook and Atlas of Slit Lamp Microscopy of the Living Eye, Three Volumes.* 1920. Vol. 1, Principles and Methods, Cornea and Anterior Chamber. Verlag Editions. Bonn-Bad Godesberg Wayenborgh. 2d ed. Berlin: Julius Springer, 1930; IEEE Radio History Center, Poulsen Arc Radio Transmitter, 1902 www.ieee.org/web/aboutus/history_center/poulsen.html..

Bay, Lake Erie. He promoted his equipment to the Navy, which used his radiotelegraphs for a round-the-world trip of its "'Great White Fleet'" in 1908. During 1908-09, the U.S. Army Signal Corps evaluated equipment from the German Telefunken Co. at the New York harbor. The Atlantic Communications Co., a Telefunken subsidiary, provided almost exclusive service for German ships crossing the Atlantic.[71]

Marconi had reported on yacht races for the *New York Herald* in 1899, the year he started Marconi Wireless Telegraph Co. of America in New Jersey. Marconi Wireless Telegraph Co. (British Marconi) was founded in 1897 in England. In 1904, Theodore Roosevelt set up a board to mediate Commerce, Navy, and War departments' control claims on wireless technology, and the Navy gained control of coastal stations, the Army received control of other military stations, and Commerce was assigned to license nonmilitary marine stations and oversee private, interior stations, almost all of these amateur stations. In 1904, the Navy had 22 wireless stations from New Hampshire and Puerto Rico and near San Francisco and in the Philippines. In 1905, Lee DeForest and assistants built five long-distance stations from Panama to Florida, extending the system. Congress, interested in connecting U.S. Naval bases, funded the Navy to build a high-powered station at Arlington, Virginia, in 1911, and funding was provided in 1912 to build high-power stations on the West Coast, the Canal Zone, Hawaii, Guam, American Samoa, and the Philippines. As the system expanded by 1912, the American Marconi Company put some rivals out of business, and the Marconi companies went into patent

[71] "Lee DeForest," United States Early Radio History, http://wearlyradiohistory.us/sec009.htm; "Lee DeForest," People and discoveries, www.pbs.org/wgbh/aso/dabank/entries/btfore.html; "Lee DeForest," *Encyclopedia Britannica;* DeForest, Lee, www.Answers.com; James A. Hijiya, *Lee DeForest and the Fatherhood of Radio* (Bethlehem: Lehigh University Press, 1992). 58-67; Georgette Carneal, *A Conqueror of Space: An Authorized Biography of the Life and Work of Lee DeForest* (New York: Horace Liveright, 1930), 56; Elizabeth Kruse, "From Free Privilege to Regulation: Wireless firms and the Competition for Spectrum Rights before World War I," *Business History Review* 76.4 (Winter 2002), 659-703; W. Rupert Maclaurin with R. Joyce Harman, Invention and Innovation in the Radio Industry (New York: The Macmillan Co., 1949), 80-81.

litigation and gained a near monopoly of commercial wireless in the United States. DeForest's companies evolved into United Wireless, which was acquired by American Marconi as the Wireless Ship Act and the Radio Act of 1912 regulation decreased amateur radio interference, restricting amateurs to lower wavelength and lower power broadcasting, and increased demand for wireless on ships. Federal Telegraph began working on communication across the Pacific in 1911 and reached Hawaii by 1912. American Marconi became the only commercial wireless service provider in most areas of the United States except near major seaports, notably New York and San Francisco, where there was much spectrum competition. American Marconi became Radio Corporation of America after World War I as the U.S. Navy encouraged GE to buy American Marconi.[72]

In 1909, Cyril F. Elwell, an Australian graduate of Stanford, working with a syndicate, bought patent rights for the Poulsen arc and organized Federal Telegraph, which operated in Palo Alto before moving to New Jersey in 1931. DeForest and Elwell were both at the 1904 St. Louis International Electrical Congress. The U.S. Navy bought all Federal Telegraph's stations during World War I, and after the war Congress directed the Navy to return the radiotelegraph stations to their owners.[73]

Unregulated development of wireless in the United States before World War I influenced the structure and practice of communications between the world wars, although the U.S. Navy took over all wireless stations in the United States during World War I after attempting to develop commercial radio industry as primarily research and development enterprise. The Navy might have continued control over the spectrum

[72] Kruse, "From Free Privilege to Regulation," 559, 666-68, 672-73, 682, 692-93, 697-98.
[73] Thomas H. White, "Arc-Transmitter Development (1904-1921), United States Early Radio History, http://earlyradiohistory.us/sec009.htm.

without the libertarian influence of early radio days, Elizabeth Kruse finds.[74] This public-private telecommunications transition in some ways resembles the early 1990s privatization of the Internet shift.

The Covenant of the League of Nations, focused on Europe and the Americas, called for the League of Nations to organize and oversee international organizations addressing communications, scientific data, financial interaction, trade standards, intellectual property, and suppression of African slave trade and white slave trade, C. C. Eckhardt observes in a 1919 *Scientific Monthly* article.[75] Lawson M. McKenzie in a 1953 *Science* article, analyzing scientific property beyond patents and copyright in the post-World War II years, includes science administrators interpreting credit for inventions in reporting to agencies. Corporate and government sponsorship of research and bank financing applications often were in contexts of economic pressures related to intellectual property.[76]

Several stories about televison that appeared in the *New York Times* beginning in January 1927 include information or comment about China or Japan. A January 9, 1927, *New York Times* story about transatlantic telephone service starting January 7 between New York and London predicts that "ultimately all countries which are enterprising enough to construct high-power radio transmission stations and wire-telephone systems are to be interlaced in a communication system of almost planetary

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[74] Kruse, "From Free Privilege to Regulation."
[75] C. C. Eckhardt, "The Old Internationalism and the New League of Nations," *The Scientific Monthly* 8.5 (May 1919), 437-441.
[76] Lawson M. McKenzie, "Scientific Property," *Science*, New Series, 118.3078 (Dec. 25, 1953), 764-67.

scope," suggesting, paradoxically, that wireless communication was already a possible system trajectory and that the wide-ranging communication system related to astronomical observation and heliography. The report highlights geographic scope beyond national boundaries for nations and emerging communication networks possibly competing with telecommunications from shipping line connections at Seattle and with shipping line telecommunications and New York-London telephone service across the Atlantic, networks possibly including subterranean wireless, "Who knows but the nation unwilling for political or economic reasons to provide its people with facilities for conversing with Los Angeles, Rome or Buenos Aires may be regarded in the same light as the business man who, at this late day, refuses to install a telephone in his office." "Indeed, the day of television may be nearer than many suppose," the report states. "Most of the principles that must be applied are well known. Even the sensitive devices that must convert light into electric waves and electric waves into light are in existence." The report suggests that organized industrial research and development laboratories were working on television technology networked with physical chemistry, materials sciences, and lithography likely including uranium and photoelectric work, although several fields of science worked separately in studies related to radiation materials and the photoelectric effect. "Research of the type that give us ten thousand synthetic dyes and drugs, the modern electric lamp, and now the transatlantic telephone, will solve this problem. . . . Give the modern researcher physical money enough and he will transport you electrically to China, disembodying your personality and present it to the amazed gaze of the antipodes as a perfect counterfeit of yourself and your voice."[77] Many advances in dyes

[77] *"Baird Expects Sight Across Ocean Soon: British Inventor of Television Holds There Are No Scientific Reasons to Prevent It. Chief Idea from Sun. Watchting Sunset also Supplied Plan of Using Infra Red," The New York Times* (Jan.

were from German laboratories. Uranium was used in pottery glazes and as reinforcing in photographic plates in the 19th century. German-Czech mountain areas near Schneeberg mined for silver as early as the 12th century later yielded cobalt and uranium along with silver and cobalt.[78] AT&T demonstrated television on April 7, 1927, after starting transatlantic telephone service using radio transmission from New York to London at the beginning of the year, on January 7. Earlier transatlantic voice transmission by Bell engineers included Virginia to Paris, in 1915. The S.S. Leviathan began offering radiotelephone service as a service for passengers and crew in 1929. AT&T began telephone service to Hawaii in 1931 and began telephone service to Tokyo in 1934.[79]

Early in January 1927, the *New York Times* reported that John Logie Baird, a Scottish engineer, had "exhibited on a screen the crude but identifiable living image of a man transmitted a short distance." Baird also described plans for infrared telecommunications.[80] During World War I, Baird left Glasgow University and worked as superintendent engineer for the Clyde Valley Electrical Power Co., which supplied shipbuilding yards and engineering and armaments works. He also developed several inventions and was an entrepreneur in the West Indies at Port of Spain, with jam trading one enterprise. His first television transmission demonstration included an observer's statement, after changing places with Baird for imagings, of seeing Baird's head swaying and his mouth opening and closing on the receiving screen,[81] apparently linking to Bell's

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2, 1927), 7.

[78] W. I. Finch, "Uranium, its impact on the national and global energy mix – and its history, distribution, production, nuclear fuel-cycle, future, and relation to the environment," *U.S. Geological Survey Circular* 1141 (1998), 24.

[79] AT&T, Corporate History, Technology Timeline, 1927: Transoceanic Telephone Service, www.corp.att.com/attlabs/reputation/timeline/27atlan.html.

[80] "After Radio Telephoning – What?" *The New York Times* (January 9, 1927), E12.

[81] Ronald F. Tiltman, *Baird of Television: The Life Story of John Logie Baird* (London: Seeley Service, 1933).

work on phonology and use of air density variation for an induction telephone and suggesting questions of image identity.

"Radio Corp. has now the most varied interest of any wireless company in the world," entering the amusement field in an alliance with Keith-Able, emphasizing "talking movies, television and radio receiving set business," A November 13, 1928, *Wall Street Journal* story reported. Radio Corp. was also expanding messaging business and contracting to build radio transmitters and receivers near Shanghai, working with the Nanking nationalist government. Two subsidiaries, RCA of Argentina and RCA of Brazil, were formed to develop service within territories.[82]

Sponsored advertising in England "'bootlegged'" in from the Netherlands, radio broadcasting between Manila and Buenos Aires, and China working with an American company, the Mackay Co., to build a powerful station and broadcasting to Europe were reported March 3, 1929, in the *New York Times,* along with technological developments. At the time, 95 percent of listeners were using tube sets, several manufacturers were using a shield-grid valve to change from one tuning station to another, and remote control, tuning from another room, was demonstrated. Western broadcasters were sending some programming, mostly orchestra concerts, eastward. The Federal Radio Commission had refused permits for wireless companies doing broadcasting between the United States and Alaska that would compete with government stations at Seattle and Everett, Washington. However, the "new art of picture transmission" was to be given every possible help.[83]

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[82] *Wall Street Journal,* "Radio Corp. Adds to Its Interest . . . Position in Amusement Field," November 13, 1928.
[83] *New York Times,* "Radio Moved Fast During February: Screen Grid Tube Reveals Its Possibilities." March 3, 1929.

In a November 1930 *New York Times* commentary, wireless pioneer Dr. Alfred N. Goldsmith, vice president and general engineer for RCA, forecast “electrical entertainment” in 1940, “A simultaneous broadcast of an event in both Australia and in the United States, or in both South America and Europe, or in both Japan and the Argentine involves no particular technical difficulties . . . .” Goldsmith also described facsimile broadcasting.[84] In his October 29, 1937, review of *Marconi: The Man and His Wireless,* Goldsmith commented on “the nascent arts of radio facsimile and television transmissions” “in which we abode” leading to change related to technologies of short waves and meteorology with ultra short waves.[85]

David Packard and William Hewlett graduated from Stanford in 1934, working with electronics physicist Frederick Terman, who received degrees from Stanford and then MIT and would run the Radio Research Lab during World War II. The first product of Hewlett and Packard’s test equipment company founded in 1939 was an audio oscillator sold to Walt Disney.[86] Terman, who developed electronics enterprise around Stanford beginning in the 1930s, also influenced development of vacuum tube electronics devices in China. Zhang Chen, who taught at Central University (later called Southeast University and Nanjing University), translated and published Terman’s *Radio Engineering* text in the 1930s after Tingyu Zang at Jiaotong University in Shanghai taught courses on wireless telegraphy in the 1920s. Norbert Wiener visited as a professor in Tsinghua University’s Department of Electrical Engineering. Zhaoying Meng received a Ph.D. from Caltech and demonstrated very short radio waves at a Los

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[84] Alfred N. Goldsmith, “Radio’s Second Decade Begins,” *New York Times,* November 2, 1930, XX9.
[85] *Ibid,* review, *Marconi: The Man and His Wireless* (New York: Orrin & Dulap Jr., Macmillan (October 29, 1937), 401-02.
[86] *Electrical Engineering at Stanford Timeline.*

Angeles Institute of Radio Engineers meeting in 1936. The pharmacy department at Zhejiang University's School of Medicine, which developed as an Anglican medical school during the late 19th century from the Hangzhou Opium Hospital, founded in 1871, had polariscope and vacuum pump equipment for research by 1919.[87]

Alexander M. Pontiatoff, a Hungarian from a family in the lumber business, produced the first magnetic audio tape recorder built in the United States in 1948 at his Ampex Electronic and Manufacturing Corp. in San Carlos, California, and then produced a data instrumentation recorder for storing large amounts of data in laboratories and on aircraft. Pontiatoff worked for the Shanghai Power Co. after escaping civil war in Russia before immigrating to the United States in 1927. Pontiatoff worked for General Electric, Pacific Gas and Electric, and Dalmo-Victor during World War II. McMicking and Co., a venture capital firm founded by Henry A. McMicking, a stockbroker with Dean Witter after flying on B17s in Europe as an Army Air Force combat intelligence officer during the war, with his brother Joseph McMicking, who was with General MacArthur in the Philippines, funded Ampex.[88]

Yoshihiko Koga of Tohuku University's faculty would develop the X-ray camera in 1936 with compression photography techniques, producing images on a fluorescent screen. Japan's army and navy approached Shibuya Röntgen Manufacturing Works and Morikawa Manufacturing Works in about 1940, and these companies approached Precision Optical to produce these cameras. A naval photofluorographic device also was developed at this time. A fluorographic unit was used to examine

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[87] Zang, Gangian, and Fuijang Liao. "A Brief History of the Development of Vacuum Electronics Devices in China." Vacuum Electron Sources Conferences. September 6-10, 2004. *IEEE Explore.*Zhejiang University School of Medicine. Brief History. www.cmm.zju.edu.cn/english/ABOUTUS/Briefhistory.htm.

[88] "Alexander M. Pontiatoff," Consumer Electronics Association web page, www.ce.org/Events/Awards/468.htm.

conscripts during the war. An engineer named Ando at Seiki was a distant relative of Junjiro Okanishi's at the Institute of Research. Okanishi studied Infectious Diseases and produced a prototype X-ray camera in about 1939. In 1947, Shibuya Röntgen and Morikawa ordered X-ray cameras from Seiki Optical, which became Canon.[89]

Michael Porter describes Sanborn of the United States producing cardiographs within the United States and increasing portability in the late 1920s as research hospitals developed. Porter also notes that Sanborn acquired rights to a monitor using amplifier and vacuum tube concepts and acquiring an early design-stage machine with amplifier and vacuum tube technologies from an American inventor in 1935 and working with an MIT electrical engineering student developing patient monitoring technology. By the late 1930s, cathode-ray tubes for visual display of electrocardiographs in real time were developed, although this equipment was not used commonly until the 1950s, Porter finds. Sanborn introduced machines that combined monitors with a recording system that exposed a black line as a heated stylus melted coating from white paper. Cambridge Instruments in the United Kingdom, which marketed a string galvanometer cardiograph recording electrical currents from the heart on film soon after Einthoven of Holland developed the apparatus in 1905, continued work with galvanometers and traditional recording. In 1895-96, as Röntgen reported his discovery of X-ray radiation, Willem Einthoven worked with George J. Burch in signal processing analysis on calibrating and

[89] University of Pennsylvania, Canon web page, Denslow, Japanese Industries Association of Radiological Systems; Martha Louise Reiner, The Transformation of Venture Capital: A History of Venture Capital Organizations in the United States, dissertation, University of California at Berkeley, 1989, University Microfilms.

correcting capillary electrometer recordings.[90] The Japanese war with Russia ended in 1905.

Medical imaging equipment development in the 1930s considered variability of imaging applications. Monitoring of ambient phenomena including metabolically interactive imaging is related to surveillance. Franklin Offner and R. W. Gerard in an August 28, 1936, *Science* article compare a high-speed crystograph, a crystal ink writer, with cathode ray oscillograph machines for following transient electrical potentials in applications like electrical studies of the brain. The crystograph used a piezo-electric crystal, measuring electricity or electric polarity related to pressure, instead of using an electro magnet. The machines could work with the output of any amplifier of sufficient voltage.[91] Seitz notes related microwave, silicon and pyrite, and instrumentation with crystal diodes work at the Institute of Science at the University of Tokyo during World War II.[92] In an August 5, 1938, *Science* article about X-rays, linking X-ray technology and radio, Arthur H. Compton describes congestion of air by X-rays.

In 1930, as antitrust concerns developed, and as Edison began work toward the photoelectric relay and cathode ray tube, developed in the early 1930s, Edison withdrew from its Radio Corporation of America partnership with AT&T and Westinghouse formed in 1919 to develop radio technologies after diversified acquisitions and mergers. RCA in 1903 acquired Stanley Electric Manufacturing Co. of Pittsfield, Massachusetts, a transformer manufacturer, and in 1918 merged with Pacific Electric Heating Co., manufacturer of the Hotpoint Iron. GE and RCA established industrial laboratories in

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[90] Porter, Michael E. *The Comparative Advantage of Nations*. New York: Free P. 1990, 196-97. Chr. Zywiets, "A Brief History of Electro Cardiography—Progress through Technology." Biosigna Institute for Biosignal Processing and Systems Research, Hanover, Germany.
[91] Franklin Offner and R. W. Gerard, "A High Speed Crystal Ink Writer," *Science,* New Ser. 84.217 (Aug. 28, 1936), 209-210.
[92] Seitz, "Tangled History," 319.

1900 after Arthur D. Little, organized in 1886, addressed a market for industrial research and development consulting.[93] J. P. Morgan took majority control of AT&T in 1907.

World War I was an important context of innovation and innovation geographies. U.S. Marconi began wireless communication in Japan in 1916. In licensing Great Northern Telegraph Co. of Denmark to connect Japan with Korea in 1882, after a riot in Korea, Japan agreed to lay no lines between Japan and the Asian continent or between Japan and islands in the region for 20 years and agreed not to license any other company for telecommunications. The Japan Wireless Communications Co. was founded for international service in 1925.[94] The U.S. government directed a shift of radiotelephony from general experimental work to specific applications as the United States entered the war in May 1917. Western Electric developed telecommunications systems for submarine chasers and then for aircraft, and the Signal Corps worked with short wavelengths and smaller antennas. Applications after the war included a 1922 demonstration telephone system between Peking and Tientsin. Western Electric withdrew almost totally from military work until the 1930s, partly influenced by patent agreements developed as Radio Corporation of America was formed.[95] United Fruit, which beginning early on bought much radio equipment, with its need for rapid communication between ports and ships carrying perishable commodities, held crystal wireless tuning patents. United Fruit along with General Electric, Westinghouse, and

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[93] www.answers.com, General Electric Company History; Dennis, "Accounting for Research."
[94] Itoh Elichi, "The Danish Monopoly on Telegraph in Japan." *Keio Communication Review* 29 (2007). www.mediacom.keio.ac.jp/publication/ pdf2007/pdf/Eiichi%20ITOH.pdf.
[95] Fagen, *History of Engineering and Science in the Bell System: The Early Years,* 370-75.

AT&T was part of the patent pooling agreement.[96] Patent agreements from 1926 linked RCA and Westinghouse, each linked with several European nations [97]

Before and during the World War I era, U.S. investment developed infrastructure including railroads, electrical utilities, electric streetcar, telephone and telegraph, and shipping as well as mining, cattle, tobacco, and sugar industry in Cuba. The United States government encouraged U.S. investment in China and the Caribbean from 1899 into the years before World War I, and U.S. foreign investment in these regions after the war often focused on oil production.[98] Bascom Palmer, who would develop ophthalmological practice and research at the University of Miami as it started in 1925, moved to Miami in 1916 after serving as a flight surgeon in the war. Palmer was a friend of Leo Baekeland's and Harvey Matheson's. Palmer invented Bakelite, an early plastic used for products including airplane propeller coating. Matheson was from an old Scottish merchant family trading in India, China, and Japan, with a base in South Florida by the late 19th century.

Farnsworth built a working all-electronic television system in 1927. He had moved to Salt Lake City and opened a radio repair shop there, and he moved to California by 1927 to be near Cal Tech after meeting California investors in Salt Lake City.[99] Farnsworth's family moved to Provo, Utah, in 1923, from Idaho. Farnsworth's grandfather was a Mormon leader, an early settler reaching Utah in 1848. He served in

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[96] Christopher H. Sterling, Phyllis Bernt, Martin B. H. Weiss, *Shaping American Telecommunications: A History of Technology, Policy, and Economics* (London: Routledge, 2006), 70. Maclaurin, *Invention and Innovation in the Radio Industry,* 81.
[97] Fagen, *History of Engineering and Science in the Bell System: The Early Years.*
[98] James A. Hitchman, "U.S. Control over Cuban Sugar Production 1898-1902," *Journal of Interamerican Studies and World Affairs* 12.1 (Jan. 1970), 90-106; Jeffry A. Frieden, "The Economics of Intervention: American Overseas Investments and Relations with Underdeveloped Areas, 1890-1950," *Comparative Studies in Society and History* 31.1 (January 1989), 55-80.
[99] Martin Greider, "The Early History of Television and Philo Farnsworth." livingtech.net/projects/television.html; "Constantin Perskyi," Wikipedia.

the territorial legislature and interpreted in negotiations between Indians and early central Utah settlers. Farnsworth's father, who had farmed in Idaho, worked in construction enterprise, and continued construction work in Idaho after the move to Utah, soon died of pneumonia. Philo shifted from Brigham Young to Annapolis and then returned to Utah as he developed inventions before moving to California.[100]

In the 1920s, the Commerce Department was assigning definite wave lengths for class B high-power, long distance broadcasters. In April 1923, Salt Lake City was in a zone also including Seattle, Portland, San Francisco, Los Angeles, and San Diego, with inspectors based in Boston, New York, Baltimore, Atlanta, New Orleans, San Francisco, Seattle, Detroit, and Chicago (the headquarters).[101] In 1924, AT&T was working toward a national radio network. After several radio conferences on federal radio policy in the United States, Congress began debate on radio legislation in 1926. Farnsworth's public demonstration of electronic television pictures in 1929 was from San Francisco. Farnsworth became a leading television set manufacturer in the early 1930s. The 1934 Communications Act extended powers of the Federal Communications Commission, which replaced the Federal Radio Commission, created in 1927. The FCC was to regulate wire and wireless communications and foreign as well as interstate communications.[102]

Nancy Ettlinger finds that during early 20th-century development in California influenced by boosterism, A. P. Gianinni was willing to finance entrepreneurs from many nations and mobilized entrepreneurship much as some Asian development organizations financed small-scale ventures. Gianinni encouraged joint stock investment. In the late

[100] Donald G. Godfrey, *Philo T. Farnsworth: The Father of Television* (Salt Lake City: University of Utah Press, 2001).
[101] *New York Times,* "Assign New Lengths for Broadcasting," April 20, 1923, 22.
[102] Godfrey, *Philo T. Farnsworth.*

19th and early 20th century, San Francisco became the main financial center for the Pacific region, after import and export trade expanded from 1886 into the 1890s, and as an oil industry developed in California in the late 19th century.[103]

Baird, who transmitted moving images across the Atlantic over telegraph wires in 1928, also developed fiber optics. Work toward broadcasting film began at companies including Radio Corporation of America and Westinghouse by 1920, as commercial radio broadcasting developed.[104] As the 1927 Radiotelegraph Union Conference in Washington, D.C., reformulated the Radiotelegraph Convention and Regulations, the United States was active in developing international rules.[105]

Also in 1927, the California Institute of Technology was developing a department of biology and biological laboratories, bringing in Professor Thomas H. Morgan, professor of experimental Zoology from Columbia University as chairman. The institute was planning research in fields including genetics, developmental mechanics, and, possibly, experimental psychology. The research under development included work concerning "intimate relations of biology to the physical sciences." England, Germany, Russia, Scandinavia, and France also were applying mathematical, physical, and chemical methods to biological studies. The Paris Academy of Sciences was setting up an Institute of Physico-Chemical Biology, with plans for studying the physico-chemical mechanisms of the "phenomena of life."[106]

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[103] Nancy Ettlinger, "The Roots of Competitive Advantage in California and Japan," *Annals of the Association of American Geographers* 81.3 (Sep. 1991), 391-407.
[104]Martin Grider, "The Early History of Television and Philo Farnsworth." livingtech.net/projects/television.html; "Constantin Perskyi," Wikipedia.
[105] John Braithwaie and Peter Drahos, *Global Business Regulation* (Cambridge, Cambridge University Press, 2000), 344.
[106] "Biology at the California Institute of Technology," *Science,* New Ser. 66.1708 (Sep. 23, 1927), 276-77.

Soon after the Science Congress at Tokyo sponsored by the National Research Council October 30 to November 11, 1926, Herbert E. Gregory presented a paper to the Social Science Association of Honolulu about organized scientific research in Japan. According to Gregory, organized scientific research in Japan began in 1871, when Japan's Hydrographic Bureau organized. A meteorological observatory and hygienic laboratories at Tokyo and Osaka were set up in 1874-75. Scientific societies organized earlier in the United States, Mexico, Columbia, Peru, Bolivia, and Chile, and in New Zealand, Australia, and Java, than in Japan. However, Japanese science was not far behind U.S., English, and German science by 1927, in Gregory's view. During 1875 to 1910, six government bureaus related to science and 11 scientific societies organized in Japan, and growth in science institutions and scientific research organizations continued. By 1890 there were three engineering societies, and by 1927 there were 11 engineering societies.

Hydrograpische Skizze der Ebene von Yedo" from Mittheilungem aus Justus Perthes' Geographicher Anstalt uber Wichtige Neue Erforshungen auf dem Gesammtgebiete der Geographie *der Dr. A. Petermann, Volume 25, Tafei 7, 1879. Perry-Castañeda Library Map Collection, University of Texas, Austin. "Hydrographic Sketch of the Elevated Plain by Yedo," middle-elevation channels, out of Justus Perthes's Geographical Arrangements concerning Essential New Investigations, from Dr. A. Petermann's General Presentation of Geography, 1879. Tokyo is shown with a dual or shadow orientation, transversal.*

Much scientific research in Japan over the years related to horticultural knowledge. Gregory finds Portuguese and Dutch influence on Japanese science before 1868 and international influence after that time.[107]

In 1929, the Chinese Society for the Preservation of Cultural Objects stated that American and European scientific expeditions were taking treasures from China, infringing on sovereign rights, searching for oil and minerals, and spying against the government, according to Roy Chapman Andrews of the American Field Expedition, an October 5, 1929, *Science News-Letter* story reports.[108] A pro-science and anti-Hitler January 1944 letter from the Natural Science Society of China to the American Association for the Advancement of Science published in April 1944 stated that the organization had formed in 1927 "(a) to spread scientific knowledge to the masses; (b) to apply scientific and technological knowledge to national reconstruction; (c) to promote scientific research; (d) to facilitate scientific cooperation." In April 1944, the society had three offices in Europe and America as well as 13 branch societies in various districts of free China.[109] During the 1930s, one stream of the China Development Finance Corp.'s work was promoting and funding research organizations and experimental stations along with new industrial enterprise.[110] China's National Economic Council, focusing nationally, formed during 1931-32 and organized "administrative machinery" including a Cotton Commission and a Sericulture Commission (silk worm culture) for infrastructure, health, and agriculture.[111] The Academy of Science of Western China organized in 1932, funded primarily by private contributions, began working in geology and in biology

[107] Herbert E. Gregory, "Science in Japan," *Institute of Pacific Relations News Bulletin*. February 1927.
[108] "Chinese Society Stops Exploration," *The Science News-Letter* 15.443 (October 5, 1929), 211.
[109] "The Natural Science Society of China," *Science,* New Ser. 99.2572 (Apr. 14, 1944), 298.
[110] Frederick V. Field, "Chinese Reconstruction in Practice," *Science* 48.1246 (Dec. 19, 1936).
[111] *Ibid.*

including horticultural work like *Styracaceae* propagation and zoological collection. The academy was based near Chungking of Szechuan province and was working with the Arnold Arboretum at Harvard and with Szechuan-Yunnan-Tibet border regions.[112] Chinese students at Cornell organized the Science Society of China during 1914-15, moved to China in 1918, and continued influence until 1950; they were led to dissolve their society when the All-China Confederation of Special Societies in Natural Sciences organized in 1949. The Science Society promoted nationally focused science and "'scientific professionalism'" as scientific internationalism developed in Japan, Zuoyue Wang finds.[113]

In November 1912, a *New York Times* story reported increased attendance during 1910-11 of foreign students at U.S. universities and a strong presence of foreign students at German universities, especially University of Berlin, and many of its students from other European nations were from Russia. 203 Asian students were at German universities, and 662 Asian students were at U.S. universities.[114]

Edwin Bidwell Wilson of MIT in a November 1918 *Science* article considered the possibility for "insidious scientific control" to develop during uneven international interaction in science. Fewer European students were at U.S. universities after the war, and French and English universities did not see what Wilson saw as their interest in encouraging admissions of U.S. students for doctoral studies. Wilson observed that an "advent" of large numbers of Chinese and Japanese university students in the United States was developing and argued that Chinese and Japanese students attending U.S.

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[112] "Scientific Work in China," *Science* 76.1877 (Nov.18, 1932), 458-59.
[113] Zuoyue Wang, "Saving China through Science: The Science Society of China, Scientific Nationalism, and Civil Society in Republican China," *Osiris,* 2d Series, 17, Science and Civil Society (2002), 291-322, 299.
[114] *New York Times,* "Our Universities Show Increasing Foreign Attendance, but German Institutions still Far in Lead." Nov. 10, 1912, X13.

universities should be encouraged. Wilson considered increased foreign influences on science in the United States not likely to cause problems in a democracy, although he observed propagandistic control in Germany.[115]

According to the American Council Institute of Pacific Relations in New York, Chinese students at U.S. universities began in 1847, when a group attended a New England college. In 1906, the United States liberalized provisions under the 1882 Exclusion Law for students, and more students attended. During the 1920s and into 1930-32, more than a thousand Chinese students attended U.S. universities each year. After a dip in 1932-33, the number of Chinese students attending increased, and the number of Japanese students attending increased dramatically, although the statistics reported for 1932-33 and 1933-34 included Chinese and Japanese students from the United States. Chinese engineering students gained practical experience in the 1930s. An American sociologist researching in China in 1931 found that Chinese leaders who had studied in the United States included Chiang Kai-shek's cabinet members, the engineer who built the Peking-Kalgar Railway, the "'Cotton King' of the textile industry," and the inventor of the Chinese typewriter. Chinese intellectual life in contact with "vigorous activity of American research workers" "stimulated curiosity."[116]

Following developments like incorporation of the Pacific Scientific Institution in 1907 and discussion of Pacific region issues at the 1914 British Association for the Advancement of Science and the 1915 Pacific Historical Congress in the Panama-Pacific International Expedition and American Association for the Advancement of Science San Francisco meeting, the 1920 Honolulu Conference organized. Representative scientists

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[115] Edwin Bidwell Wilson, "Insidious Scientific Control," *Science,* New Series, 48.1246 (Nov. 15, 1918), 491-93.
[116] "Memorandum on Chinese Students in the United States," *American Council Institute of Pacific Relations* 3.7 (April 6, 1934).

from New Zealand, Australia, Java, China, Japan, Canada, the continental United States, Hawaii, and the Philippines were to meet in 1920 to consider sciences in relation to the Pacific Ocean region. Topics chosen for cooperative investigation included areal geologic mapping and biological institutions. Following the 1920 meeting, the Pacific Science Congress met in Australia in 1923 and in Japan in 1925. International committees formed during the Australia conference to address topics including genetic research and static at wireless stations.[117] In June 1907, Japan and France signed an agreement "to respect the independence and integrity of China, as well as the principle of equal treatment in that country for the commerce and subjects or citizens of all nations. . . ." The two nations' agreement emphasized peace in areas of the Chinese empire adjacent to areas where they had sovereignty, protection, or occupation rights. Japan and France also signed an agreement in June 1907 establishing most favored nation treatment regarding persons and property for officers and subjects of Japan in French Indo-China and for subjects and protégés of French Indo-China in Japan. These agreements were published with a 1910 agreement between the United Kingdom and Montenegro for reciprocal most favored nation treatment of subjects and produce, especially regarding establishment of nationals in each others' territories and regarding commerce, navigation, and taxes.[118]

According to Zhaojin Ji, German influence in China during the late 19th century was mostly in the Shandong (Shantung) Peninsula, south of Peking and across the Yellow Sea from Seoul, and was related to mining. However, connections were trans-Asian and linked to Hamburg, on the North Sea near the Netherlands and Denmark, and Berlin, near

[117] *Ibid,* "The Pacific Science Congress," *The Scientific Monthly* 19.3 (Sep. 1924), 271-280.
[118] "Arrangement between France and Japan concerning their Policies in China," *The American Journal of International Law* 4.4 Supplement: Official Documents (October 1910), 313-14.

the Polish border, in Prussia. Germany was developing mining and metallurgy, and German artisans and entrepreneurs were going into fields like cotton textiles.[119] From 1896 to 1906, the Deutsch-Asiatische Bank, based in Shanghai, established branches in Berlin, Calcutta, Hong Kong, Yokohama, Singapore, and Hamburg. The Deutsch-Asiatische Bank joint ventured with the Hong Kong and Shanghai Banking Corporation in 1908 and with a British, French, and Russian consortium in 1910 for railroad development projects. These two banks remained influential in China through the revolution and until the beginning of World War I.[120] Scottish and German science were linked. German industrial regionality related to Germany's *lander* state banks connects to the regionality and transnationality of Shanghai banking. Native banks among foreign banks in Shanghai were broadly important in industrial development. Influence of these banks continued through several cycles of bank failure crisis, Leonard T. K. Wu finds.[121]

As the Bank of China shifted to a bank for international exchange and away from an earlier form of central banking, China's Bank of Communications took on an industrial role with stronger nationalist state control. After the United States Silver Purchase Act of 1934, there were chaotic silver circulations including smuggling in North China protected by Japanese military interests, Ji finds. A combined industrial and transportation effort of British, French, German, and American interests in China did not occur. As Japanese military presence in China increased, Shanghai and its British influences were somewhat isolated in the late 1930s. Chinese technology enterprise and university research shifted to southern China. After Pearl Harbor, Japan blocked U.S. and

[119] Kemp, *Industrialization in Nineteenth-Century Europe,* 90.
[120] Ji, *History of Modern Shanghai Banking*.
[121] Leonard T. K. Wu, "The Crucial Role of the Chinese Native Banks," *Far Eastern Survey* 4.12 (June 19, 1935), 89-93.

British financial interactions with Shanghai and influenced French activities in Shanghai. Ji links issues in Shanghai banking in the new open financial environment of globalization, with telecommunications and Internet innovations, to challenges of the 1870s and undersea cable communication innovation. Although opium production worldwide peaked in 1906, not long before the 1909 Shanghai Conference on the Opium Trade, it was a heavy semi-contraband circulation during the 1920s, a time of much immigration from many nations to the United States, with U.S. pharmaceutical and diversified corporations engaging in opium trade, while Germany dominated cocaine manufacturing, according to Braithwaite and Drahos. Cocaine, commercially manufactured beginning in 1862, was prohibited along with opium in the United States beginning in 1915, before prohibition of alcohol began in 1918. League of Nations, Geneva, and specific drug control institution treaty provisions developed. Seizures of opium worldwide peaked in 1936, after prohibition of alcohol sale in the United States was revoked in 1933.[122]

Transnational circulations of the 1930s included Jewish settlement in South Africa as well as Jewish emigration from Germany to the United States. Large quantities of financial circulations went into Shanghai, the only international city to accept Jewish refugees from Europe without entrance

[122] Braithwaite and Drahos, *Global Business Regulation* (New York: Cambridge University Press, 2000), 362.

visas.[123]

French Map, 1934, view of Shanghai Harbor, Tahirih V. Lee, The Journal of Asian Studies, *54.1 (Feb. 1995), 3-18.* [*http://links.jstor.org/sici?sici=00219118%28199502%2954%3A1%3C3%3AI%3E2.0.CO%3B2-0*](http://links.jstor.org/sici?sici=00219118%28199502%2954%3A1%3C3%3AI%3E2.0.CO%3B2-0)*. The map labels* entrepot *port function and parallel French and American communities, also suggesting inland capillary action.*

123 Ji, *History of Modern Shanghai Banking.*

The Korean conglomerate Samsung started in 1938 in Taegu in what is now South Korea, near China and Japan. Samsung developed business in textiles, chemicals, shipbuilding, and aerospace. Japan, which by the early 20th century did much of its cotton trade with Korea, expanded cotton trade with Korea in the early 20th century.[124]

During the transitional late 19th century, exports of raw cotton rugs and carpets, cotton flannel, mompa, and other cotton goods from Japan to British America, British India, Corea, France, Great Britain, Hong Kong, Russia, and the United States were at high levels during 1893 to 1898 and at high levels for Russian Asia by 1896. Beginning in 1887, Japan's ministry of Communications regulated power company siting as change from gas power to electric power, with Western technology transfer and with development of power-storage technologies, occurred.[125] In 1900, Japan imported photographica equipment worth 207,529 yen, most of this from Britain. For dynamo-electric equipment, Japan's imports from the United States increased sharply from 1896 to 1897, as Japan's imports from Great Britain declined and as its imports from Germany increased somewhat after a large increase from 1895 to 1896.[126]

Technology diffusion and population diffusion were related, with some of the technology portable in scientific instruments. In *Science* October 23, 1942, D. H. Killeffer's "Location of New and Rare Instruments" reports that a committee based in New York had formed for exchange of instruments including Curie electrometers (Paris made), Loewe-Zeiss liquid interferometers, Siemens & Halske optical pyromoters, two-circle reflecting goniometers, Westinghouse oscilloscopes with galvanometers, Coleman

[124] *General View;* "American Trade in Korea," *The New York Times,* Jan. 16, 1904, 142-43.
[125] Yoshio Sugiura, "Spatial Diffusion of Japanese Electric Power Companies, 1887-1906: A Discrete Choice Modeling," *Annals of the Association of American Geographers* (1993), 641-655.
[126] *General View* 142-43, 253, 255.

spectrophotometers, grating spectrographs, mechanical ink writing recorders, Zeiss Pulfrich refractometers, L&N portable potentiometers, microammeters, D'Arsonoval type, and quartz microscopes[127]

A brief item in the October 23, 1942, *Science* issue reports GE's construction of a 100-million-volt electron accelerator at Schenectady, New York, for industrial radiography. In the same issue, William Duncan Strong's "The Ethnographic Board" reports that the Smithsonian War Committee, the Intensive Language Program of the American Council of Learned Societies, and the Joint Committee on Latin American Studies of the Three Councils were forming an organization to make regional and personnel information available to sponsoring institutions and outside scientific organizations.[128] Ernest O. Lawrence built the first cyclotron in Berkeley in 1930. Simultaneous transmission of sound and images television was introduced in 1930.

Arthur H. Compton in an August 1938 *Science* article observes that early evolution of communication and emerging innovations were related and emphasizes the importance of links between sound and image transmission. Adding "the innovation of printing, telegraphy, the telephonic radio and moving pictures" to language and writing, "it becomes possible for people to share thoughts widely, to become quickly aware of what is happening to all mankind and to 'remember' what has happened to men in the past," Compton states. "Thus the world becomes almost a conscious unit, and very similar to a living community." Compton suggests photoelectric and telesensory advances, possibly in relation to atmospheric transmission, in stating that "even the non-mechanical inventions have found their most effective application" through scientific development.

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[127] D. H. Killeffer, "Location of New and Rare Instruments," *Science* (October 23, 1942), 381-82.
[128] William Duncan Strong, "The Ethnographic Board," *Science,* New Series 99.2495 (October 23, 1942), 381-82.

Compton notes work applying physics to "the action of living organisms." "The Orient has joined the Occident in physics research," Compton observes. "India contributes to our knowledge of scattered light and of stellar atmospheres; China interprets atoms by scattered X-rays; Japan develops iron with new magnetic properties. British research is carried on throughout the empire. Mexico joins effectively in the study of cosmic rays," Compton related earlier and emergent science, technology, and applications, "In the radio is the child of the electron, and the electron owes its recognition to the ionization of air by X-rays. Similarly, were it not for X-rays we would not now have sound movies or long-distance telephony or radio beams to guide air mail. . . .[129]

Mohrman, Galbraith, and Monge find that individuals and formal and informal communities are important in evolution of network organizations, which are "organized around and created out of complex webs of exchange and dependency relations among multiple organizations, individuals, and communities," sometimes via what Michael Polanyi calls "tacit knowledge."[130] Evolution of technology related to electricity, electronics, and radiation from the late 19th century to the mid-20th century sometimes occurred with technology diffusion across organizations, sometimes transnationally. Leadership in developmental states sometimes influenced interregional and transnational interactions. Inter-regional and transnational influences on technology evolution sometimes were related. Transnational influences were sometimes indirect, through paths including educational exchange and military procurement.

[129] Arthur H. Compton, "Physics and the Future," *Science* 88.22.75 (Aug. 5, 1938), 115-121.
[130] Mohrman, Galbraith, and Monge, "Network Attributes," 212.

After development of empire telegraphy, industrial expansion, and increased cultural connection in the 1870s, adjacencies of enterprise advanced technology transfer, technological innovation, and scientific enterprise, as new universities and scientific organizations, many with international scope, formed. Times of conjuncture include 1884, the year of the Philadelphia Electrical Exhibition, before discovery of uranium in the Transvaal in 1886 and demonstration of X-rays in 1895-96, and then 1899, a year of east-west telecommunication structuring with organization of American Marconi Corp. and the Nippon Electric joint venture with Western Electric investment, as the U.S. government annexed the Philippines and encouraged investment in China and the Caribbean. 1927, with demonstration of television and introduction of transatlantic telephone service, similarly was a time of innovation and enterprise conjuncture, with trans-Pacific telephone service following in the 1930s, as medical radiographic equipment was developed.