WORKING WITH COMPUTERS, CONSTRUCTING A DEVELOPING COUNTRY: INTRODUCING, USING, BUILDING, AND TINKERING WITH COMPUTERS IN COLD WAR TAIWAN, 1959-1984

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This dissertation uses a developing country's appropriation of mainframe computers, minicomputers, and microcomputers as a lens for understanding the historical relationships between the digital electronic computing technology, the development discourse underlying the Cold War, and the international exchanges of scientific and technological expertise in the context of the Cold War. It asks why and how, during the Cold War, Taiwanese scientists, engineers, technocrats, and ordinary users—all in a so-called developing country—introduced digital electronic computing to Taiwan and later built computers there. To answer the why question, I argue that these social groups' perceptions of Taiwan's developmental status shaped their perceptions of the importance of possessing, using, and manufacturing computers. As for the how question, I propose that Taiwanese computer users modeled their practices after the existing successful practices of using mainframe computers and later started to build and tinker with minicomputers and microcomputers.

The beginning chapter of this dissertation discusses that a group of Taiwanese engineers, technocrats, and scientists advocated the introduction of 'electronics science' and digital electronic computing from the United States to Taiwan for expanding the industrial sector of Taiwan's economy in the late 1950s. Their efforts

resulted in a UN technical-aid program, in which National Chiao-Tung University's (NCTU) professors, students, and technicians worked with two US visiting professors to set up a computing center, equipped with an IBM 650 and an IBM 1620 computer, at the NCTU campus from 1962 to 1964 (chapter 3). Chapter 4 analyzes how, in 1964, a Cornell econometrician relied on NCTU's 1620 computer to form an economic-planning project for a Taiwanese government agency. Chapter 5 discusses a project in which a NCTU graduate program planned to build a minicomputer from scratch from 1968 to 1971, despite being able to buy a minicomputer from various US suppliers. Chapter 6 explores two intriguing phenomena that surfaced between 1980 and 1984: why many of Taiwan's computer users preferred to build their own microcomputers and how this preference initiated a series of debates about whether legal institutions allowed Taiwanese companies to make Apple compatibles.

BIOGRAPHICAL SKETCH

Honghong Tinn was born in Taipei, Taiwan in 1978. She received a B.A. in sociology and a M.A. in journalism from National Taiwan University, in 2000 and 2002, respectively. While studying and working at National Taiwan University, her research focused on resource mobilization in Taiwanese social movements, Taiwanese online news websites at the moment of the Dot-com bust, the social image of Internet cafes in Taiwan, and Taiwanese teenagers' clan culture in online role-playing games. In 2005, she enrolled at Cornell University in Ithaca, NY, where she studied under Ron Kline. While at Cornell, she turned her college hobby—putting together computer parts to build and fix personal computers—into a dissertation about the history of Cold War digital electronic computing in Taiwan. During the academic year 2008-2009, she was a visiting student at the Institute of Modern History, Academia Sinica, Taiwan. She is a member of two Special Interest Groups in the Society for the History of Technology (SHOT): Computers, Information, and Society and the SHOT Asia Network. In 2012, she will take a postdoctoral fellowship at National University of Singapore.

For My Parents

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LIST OF ABBREVIATIONS

CIECD	Council for International Economic Cooperation and Development
CUSA	Council for United States Aid
ICA	(US) International Cooperation Administration
ITU	International Telecommunication Union
KMT	Kuomintang, or the Nationalist Party
NCTU	National Chiao-Tung University
NTHU	National Tsing-Hua University
NTU	National Taiwan University
USAID	United States Agency for International Development

CHAPTER 1

INTRODUCTION

In this dissertation, I propose that two specific dimensions are central to understanding the history of digital electronic computing in Taiwan: (1) Taiwanese scientists, engineers, technocrats, and ordinary users' practice of introducing and building digital electronic computers; (2) their perceptions of Taiwan's status of development. I propose that, by paying careful attention to the two dimensions, we can gain a more complete picture of the history of digital electronic computing during the Cold War.

This dissertation asks why and how, during the Cold War, Taiwanese scientists, engineers, technocrats, and ordinary users—all in a so-called developing country—introduced digital electronic computing to Taiwan and later contributed to the building of computers there? The answer to the why question is that these social groups' perceptions of Taiwan's developmental status shaped their perceptions of the importance of possessing, using, and manufacturing computers. To these individuals and their respective social groups, owning and using computers and eventually being able to manufacture this cutting-edge technology could help Taiwan's electronics industry advance to a substantial degree. Through these efforts, these social groups expected and planned to help transform Taiwan from a developing country into a developed country. The answer to the how question is that, although the aforementioned social groups' knowledge of digital electronic computing partially rested on their interactions with US experts or US-based companies, the Taiwanese social groups did not simply engage in wholesale copying of US sources. Instead, they modeled their practices after the existing successful practices of using mainframe computers and later started to build and tinker with minicomputers

and microcomputers. I define ‘tinkering’ as the practices of adapting, modifying, assembling in an innovative manner, and otherwise working creatively with technologies. To answer the how question, I trace how Taiwanese scientists, engineers, technocrats, and ordinary users’ engagement in introduced, used, built, and tinkered with computers.

Taiwan was a critical actor in the international politics related to the US containment strategy during the Cold War because of Taiwan’s geographical position as well as the Chiang Kai-Shek government’s steadfast confrontation with the Chinese communists. Owing to diplomatic interests and ideological affinities, Taiwan and the United States maintained an intimate relationship with each other in the field of science and technology. For the sake of maintaining a ‘democratic China’ during the Cold War, Taiwanese bureaucrats, technocrats, and intellectuals eagerly fostered official academic and technical exchanges between the two countries during the 1950s and 1960s.

Not having participated in early computer innovations in the United States, Europe, and Japan during initial years of the Cold War, Taiwanese users gained access to digital electronic computers through a technical-aid program created on the basis of the United Nations’ commitment to aid developing countries after the Second World War. A technical-aid program sponsored by the United Nations helped National Chiao-Tung University (NCTU) to establish the campus-based Training and Research Centre for Telecommunications and Electronics in 1962. The university then recruited professors and engineers from the United States to offer courses in such subjects as programming, microwave electronics, and communications theory.

Digital electronic computing in Taiwan, therefore, constituted a set of knowledge and artifacts that had traveled from the democratic United States to “Democratic China” or “Free China.”

This dissertation explains the complicated and interactive process in which Taiwanese technocrats, engineers, scientists, ordinary users, American experts, and UN officials introduced technological knowledge and artifacts regarding digital electronic computing to Taiwan. The focus of this project is not on the success of technology transfers but on local interpretations of and local actions regarding the introduction of digital electronic computing to Taiwan. Moreover, while asserting the autonomy and agency of Taiwanese historical actors, I do not argue that the enthusiasm exhibited by Taiwanese scientists, engineers, technocrats, and ordinary users for digital electronic computers was entirely “spontaneous.” Indeed, I acknowledge that the enthusiasm was strongly shaped by the widely accepted development discourse in Taiwan at that time.

I have chosen five research cases that allow me to discuss the interactive processes between Taiwanese social groups and US experts or US companies. Focusing on different digital electronic computers in different time periods, this dissertation investigates the relationships between the materiality of different computers, corresponding Taiwanese users, and US experts and companies over time during the Cold War. Chapters 2 and 3 discuss a technical aid program that brought the first digital electronic computers, including an IBM 650 and an IBM 1620, to Taiwan; particularly, chapter 4 explores an economic-planning project reliant on the IBM 1620 computer. While chapter 5 examines a minicomputer-building project, chapter 6 looks at the practices of building microcomputers.

Below I elaborate how my analysis stems from and contributes to several streams of scholarship, including the history of computing during the Cold War, the politics of science and technology in East Asia during the Cold War, and the social construction of technology. I organize the following sections according to the two analytical themes of this dissertation: Taiwanese scientists, engineers, technocrats, and ordinary users' perceptions of Taiwan's developmental status and their practice of introducing and building digital electronic computers in Taiwan.

Digital Electronic Computing during the Cold War

Historians have pointed out that the history of digital electronic computing has been intertwined with wider societal changes. Computing has been a product of social interactions and political discourses, instead of a pure accumulation of technological innovations.[1] The wartime demand for firing tables and anti-air defense set up the beginning stage for the development of digital electronic computing.[2] During the Cold War, political discourse, military strategic concerns, and social changes co-evolved with the science and technology of digital electronic

[1] Michael S. Mahoney, "The History of Computing in the History of Technology, " *IEEE Annals of the History of Computing* 10, no.2 (1988): 113-25; William Aspray, The History of Computing Within the History of Information Technology," *History and Technology* 11 (1994): 7-19; Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge: MIT, 1996) and "From 'Impact' to Social Process: Computers in Society and Culture," in *Handbook of Science and Technology Studies*, eds. Sheila Jasanoff, Gerald E. Markle, James Petersen, and Trevor Pinch (Thousand Oaks: Sage, 1995), 257-85; Atsushi Akera, *Calculating a Natural World: Scientists, Engineers, and Computers During the Rise of U.S. War Research* (Cambridge: MIT Press, 2007); Larry Owens, "Where Are We Going, Phil Morse? Changing Agendas and the Rhetoric of Obviousness in the Transformation of Computing at MIT, 1939-1957," *IEEE Annals of the History of Computing* 18, no. 2 (1996): 34-41; Jon Agar, *The Government Machine: A Revolutionary History of the Computer* (Cambridge: MIT Press, 2003).
[2] Owens, "Where Are We Going, Phil Morse?"; David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics* (Baltimore: Johns Hopkins Univ. Press, 2002) ; David A. Grier, *When Computers Were Human* (Princeton: Princeton Univ. Press, 2005) ; Akera, *Calculating a Natural World* ; Andrew Hodges, *Alan Turing: The Enigma* (New York: Touchstone, 1983); Agar, *The Government Machine*.

computing in the United States. The proliferation of electronic digital electronic computing accompanied the expansion of the Cold War.[3] Digital electronic computing was a product of the Cold War in the United States, and, conversely, digital electronic computing contributed to the emergence of new cultures during the Cold War.[4] Moreover, the social and institutional contexts of the Cold War are important for a better understanding of innovations and the business history of computing.[5] As for the Soviet Union, the other super power, Slava Gerovitch has provided a picture of the social meanings of electronic digital electronic computing in the Soviet Union during the Cold War. These studies of the Cold War computing in the United States and the Soviet Union are extremely insightful in revealing how the social meanings of and physical design of computing technology were co-constructed with the broader ideologies or discourses prevailing in the two countries.

The Cold War, as the historical context of the emergence of digital electronic computing, had its specific facets in specific places. If the Cold War was an international phenomenon, and if electronic computing was intertwined with political discourse and societal changes in the

[3] William Aspray, "International Diffusion of Computer Technology, 1945-1955," *IEEE Annals of the History of Computing* 8, no.4 (1986): 351-60; Stuart W. Leslie, *The Cold War and American Science: the Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia Univ. Press, 1993) ; Edwards, *The Closed World*; Jennifer Light, *From Warfare to Welfare: Defense Intellectuals and Urban Problems in Cold War America* (Baltimore: Johns Hopkins Univ. Press, 2003); Akera, *Calculating a Natural World*.

[4] These cultures include the discourse on the closed world, the open world, and the green world, collaborative culture, alternative uses of military technology, convergences and divergences of knowledge in institutional contexts, and postmodernist ways of organizing technological systems. Edwards, *The Closed World*; Janet Abbate, *Inventing the Internet* (Cambridge: MIT Press, 2000); Fred Turner, *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism* (Chicago: Univ. of Chicago Press, 2006); Akera, *Calculating a Natural World*; Thomas P. Hughes, *Rescuing Prometheus* (New York: Vintage Books, 2006).

[5] Ross Knox Bassett, *To the Digital Age: Research Labs, Start-up Companies, and the Rise of MOS Technology* (Baltimore: Johns Hopkins Univ. Press, 2002); Christopher Lécuyer, *Making Silicon Valley: Innovation and the Growth of High Tech, 1930-1970* (Cambridge: MIT Press, 2006); Martin Campbell-Kelly and William Aspray, *Computer: A History of the Information Machine* (2nd ed. New York, Basic Books, 2004; originally published in 1996); Martin Campbell-Kelly, *From Airline Reservations to Sonic the Hedgehog: A History of the Software Industry* (Cambridge: MIT Press, 2003).

United States and in the Soviet Union, was the same true in places in which people desired digital electronic computers? This is the question this dissertation aims to answer.

The recent studies of computing with diverse geographical focuses reflect computing historians' growing attention to the politics of digital electronic computing in different places during the Cold War period. William Aspray's 1986 analysis of the international diffusion of early computers indeed successfully drew scholarly attention to the technology transfers and diffusion of digital electronic computers across countries prior to 1955.[6] Especially, James Cortada's work is especially representative in this field.[7] Also, the long-standing tradition of examining Japan's early digital electronic computing potentially provides scholarly resources for understanding the local conceptualization of the social and cultural meanings of digital electronic computing technology.[8] However, recently, Eden Medina's work has contributed to a historiographical shift which pays attention to the relationships between the history of digital electronic computing and the politics of a developing country, Chile. Her research on the Chilean government' Cybersyn project has illustrated that the acquisition and use of computing technology offered a promising site from which to understand multiple international and domestic Chilean societal issues, such as the state's development approaches, the public's reactions to the state's policies, and how the state situated itself in the world economy in the

[6] William Aspray, "International Diffusion of Computer Technology, 1945-1955."
[7] James W. Cortada, "Patterns and Practices in How Information Technology Spread around the World." *IEEE Annals of the History of Computing* 30, no.4 (2008): 4-25.
[8] Hidetosi Takahasi, "Some Important Computers of Japanese Design." *IEEE Annals of the History of Computing* 2, no. 4 (1980): 330-37; Shigeru Takahashi, "Early Transistor Computers in Japan." *IEEE Annals of the History of Computing* 8, no.2 (1986): 144-54, "A Brief History of the Japanese Computer Industry Before 1985." *IEEE Annals of the History of Computing* 18, no.1 (1996): 76-79 and Sigeru Takahashi, "The Rise and Fall of Plug-Compatible Mainframes." *IEEE Annals of the History of Computing* 27, no.1 (2005): 4-16; Chigusa Kita, "From Technological Mimesis to Creativity: Early Online Rail Reservations in Japan," (presented in the Annual Meeting of The Society for the History of Technology, Oct. 17-21, Washington DC., 2007); Hyungsub Choi and Chigusa Kita, "Hiroshi Wada: Pioneering Electronics and Computer Technologies in Postwar Japan." *IEEE Annals of the History of Computing* 30, no.3 (2008): 84-89.

1970s. Corinna Schlombs's work and the recent special issue of *IEEE Annals of the History of Computing*, titled *A World of Computers*, have addressed the importance of understanding the history of digital electronic computing internationally.[9] Ross Basset's research has explored a group of Indian elites' interests in introducing digital electronic computing from the United States to India, despite India's nonalignment policy.[10]

Paying attention to "places" helps historians to better understand the nature of the emergence of digital electronic computing. This dissertation, thus, broadens the history of digital electronic computing from the conventional places of computing-related knowledge and technology production, such as US university labs, to the places where actors actively engaged in introducing digital electronic computing to new geographical locations—in many cases, developing countries.

Closed-World Discourse and Development Discourse

Specifically, to explore the relationship between the Cold War and digital electronic computing technology in Taiwan, my analysis is inspired by Paul Edwards's elaboration of the "closed-world discourse." Edwards has pointed out that military concerns about communications, control, and command shaped a specific language, a worldview, and a set of practices. Edwards

[9] Eden Medina, *Cybernetic Revolutionaries: Technology and Politics in Allende's Chile* (Cambridge: MIT Press, 2011); "The State Machine: Politics, Ideology and Computation in Chile, 1964–1973," PhD diss., MIT, 2005; Corinna Schlombs, "Toward International Computing History," *IEEE Annals of the History of Computing* 28 no.1 (2006): 107-8, and "Productivity Machines: Transatlantic Transfers of Computing Technology and Culture in the Cold War," PhD diss., Univ. of Pennsylvania, 2010; Jeffrey R. Yost, ed., *A World of Computers*, Special Issue of *IEEE Annals of the History of Computing* 30, no.4 (2008).

[10] Ross Knox Bassett, "Aligning India in the Cold War Era: Indian Technical Elites, the Indian Institute of Technology at Kanpur, and Computing in India and the United States," *Technology and Culture* 50, no.4 (2009): 783-810.

called this specific language "closed-world discourse," in which the communism-and-capitalism struggle "defined all relationships between the U.S. and U.S.S.R." The notion of "closed-world discourse" explains two things. First, in the United States, the Cold War's military confrontation created new defense strategies, which encouraged the proliferation of knowledge production concerning digital electronic computing, such as cybernetics, information theory, and artificial intelligence. For example, Edwards pointed out that, for the research on Whirlwind computers, university scientists and engineers transformed and also were transformed by the strategic thinking of the Air Force. In order to persuade the Air Force that digital electronic computing was worthy of researching, university scientists and engineers created a language of automated command and control to describe the breadth and the depth of a digital computer's functions. In turn, the Air Force conceptualized new ideas about air defense and the potential of digital computers.[11]

Second and conversely, the proliferation of new disciplines, such as cybernetics, information theory, and artificial intelligence, reinforced the proliferation of digital electronic computers. To put it simply, the materiality of computers and the epistemology of digital electronic computing were not simply tools to deal with the military and ideological confrontation between the US and the Soviet Union. At the same time, the embedded ideas in digital electronic computers, such as ideas about modeling, simulation, surveillance, feedback, and information, reinforced and nurtured that confrontation.[12]

[11] Edwards, *The Closed World* and "From 'Impact' to Social Process: Computers in Society and Culture."
[12] Ibid.

As it played out, the Cold War in Taiwan entailed at least two dimensions: not only the military but also the economic-development wars with communist China. Taiwan was colonized by Japan from 1895 to 1945. After the Second World War, Chiang Kai-Shek's army and the Kuomintang (the Nationalist Party, hereafter KMT) gained the sovereignty of Taiwan. While Mao defeated Chiang Kai-Shek in mainland China, Taiwan, an island that is separated from the Eurasian Continent, became the perfect place for Chiang Kai-Shek to escape from the Communists' military attack. The government of the Republic of China, led by Chiang Kai-Shek, thus moved to Taipei in 1949. While US president Harry Truman had declared that the military conflict between Chiang and Mao was a civil war and that the United States would not intervene in it, the Korean War ultimately changed his policy toward Taiwan, which was sometimes called "Free China," as opposed to "Communist China," during the Cold War.

The political leaders and their followers at this time in Taiwan hoped both to regain sovereignty over the mainland and to establish a prosperous "Free China" in Taiwan. They hoped this prosperity would contribute to two outcomes: first, the superiority of Taiwan's economic performance over communist China could showcase the correctness of Chiang Kai-Shek's anti-communist stance; second, this same superiority might improve the Taiwanese government's chances of taking back the mainland, or at least this was the opinion held by the followers of Chiang Kai-Shek. In this context, the practice of digital electronic computing in Taiwan during the Cold War was neither about achieving technological breakthroughs nor part of a Big Science project. Instead, the foremost issue for Taiwanese technocrats, scientists, and engineers was how to successfully use new computing machines and related knowledge from the

United States, and eventually build a manufacturing industry relevant to digital electronic computers, for strengthening the economic development of Taiwan.

Extending Paul Edwards' notion of "closed-world discourse," I propose that a type of *development discourse* worked in tandem with closed-world discourse to shape the acquisition of digital electronic computers and the proliferation of electronic-computing practices in Taiwan. The closed-world discourse in Taiwan refers to the ideas that some Taiwanese historical actors disseminated and that rested on a simple premise: improving Taiwan's economic performance was a solution to the communism-and-capitalism struggle among the United States, Taiwan, and China. In this dissertation, development discourse refers to the ideas that according to the characteristics of the industrial sector of a country, countries worldwide can be categorized as the underdeveloped country, developing country, and developed country. Based on the two sets of discourse, a group of Taiwanese scientists, engineers, and technocrats were interested in creating an electronics industry to improve Taiwan's economic performance and strengthen an industrial sector, and their means was bringing the knowledge and artifacts of "electronics science" and digital electronic computing from the democratic United States to "democratic China."

The Concept of Development

In this dissertation, the term 'development' refers to "the economic advancement of a region or people."[13] This conception of development emerged prior to the Cold War and, indeed, can be traced back to the era of colonialism. For example, Suzanne Moon focuses on the agricultural aspect of development, and defines development in the Dutch East Indies in the first

[13] "Development, *n.*" *OED Online.* Oxford Univ. Press. http://dictionary.oed.com/

half of the 20th century as "those efforts that were specifically meant to improve the lives of indigenous people in the Indies." Many of these efforts involved technological interventions in agriculture. Before the end of the Second World War, colonial governments in general benefited from the economic or industrial development of their colonies, and at the same time, these governments gained legitimacy in their civilizing mission, which ostensibly was the basis of colonial governments' sovereignty over colonies.[14] Nevertheless, this conception of development was not advocated exclusively by colonial governments, as both colonial governments and colonized elites pursued achievements for regional or national development.[15]

Needless to say, the notion of development here is directly related to the notion of modernity. Suman Seth has pointed out that the scholarly attention to the issue of when modernity had arisen in different societies is related to nineteenth-century physics' and biology's obsession with progressivism.[16] In his book on "a conceptual history of growth in postwar forms" in Japan, Scott O'Bryan briefly noted that economic "growth" is a concept borrowed from biological sciences.[17] National economic development also derives from "the life stages of humans," as the economies of underdeveloped countries are expected to grow and to mature.[18]

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[14] J. Victor Koschmann, "Constructing Destiny: Royama Masamichi and Asian Regionalism in Wartime Japan," in *Pan-Asianism in Modern Japanese History: Colonialism, Regionalism and Borders*, eds. Sven Saaler and J. Victor Koschmann (London: Routledge, 2007), 185-99; Suzanne M. Moon, *Technology and Ethical Idealism: A History of Development in the Netherlands East Indies* (Leiden: CNWS Publications at Leiden Univ., 2007). Gyan Prakash, "Technologies of Government," in *Another Reason: Science and the Imagination of Modern India* (Princeton: Univ. Press, 1999), 159-200. Michael Adas. *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance* (Ithaca: Cornell Univ. Press, 1989) and *Dominance by Design: Technological Imperatives and America's Civilizing Mission* (Cambridge: Belknap Press, 2006).

[15] Prakash,"Technologies of Government."

[16] Suman Seth, "Science, Colonialism, Postcoloniality," a talk presented in spring 2011 new conversations series at the Institute of Comparative Modernity, Cornell University, April 26, 2011.

[17] Scott O'Bryan, *The Growth Idea: Purpose and Prosperity in Postwar Japan* (Honolulu: Univ. of Hawaii Press, 2009). See page 172.

[18] Kate Manzo, "Modernist Discourse and the Crisis of Development Theory," *Studies in Comparative International Development* 26, no. 2 (1991): 3-36; Akhil Gupta, *Postcolonial Developments: Agriculture in the Making of Modern India* (Durham: Duke Univ. Press, 1998), see page 41.

The Cold War was another heyday for the ideas of development.[19] Historian David Engerman borrowed the term "the Romance of Economic Development" from a Russian economist's comment on Russia's economic planning in the 1930s to describe the worldwide enthusiasm for the economic development during the Cold War.[20] Anthropologist Akhil Gupta argued that "a regime of development" began to operate when the World Bank and the International Monetary Fund were created at Bretton Woods, New Hampshire in 1944, as the establishment of these institutions signaled the beginning of a new form of capitalism.[21] According to anthropologist Arturo Escobar's analysis, "two-thirds of the world's peoples were transformed into poor subjects in 1948 when the World Bank defined as poor those countries with an annual per capita income below $100."[22]

In addition to new ways of categorizing countries, technical aid was a new invention emerged alongside these post-war conceptions of development. Point Four of Truman's Inaugural Address in January 1949 helped construct the idea that "underdeveloped areas" urgently required aid from richer countries and the United Nations. The Inaugural Address emphasized the importance of setting up a collaborative program through the United Nations to

[19] Nils Gilman, "Modernization Theory: the Highest Stage of American Intellectual History," in *Staging Growth: Modernization, Development, and the Global Cold War*, eds. David Engerman, Nils Nilman, Mark H. Haefele, and Michael E. Latham (Amherst and Boston: Univ. of Massachusetts Press, 2003), 251-70.
[20] David C. Engerman, "The Romance of Economic Development and New Histories of the Cold War," *Diplomatic History* 28 (2004): 23-54.
[21] Gupta, *Postcolonial Developments*, 39.
[22] Arturo Escobar, *Encountering Development: The Making and Unmaking of the Third World* (Princeton: Princeton Univ. Press, 1995).

make "the benefits of our scientific advances and industrial progress available for the improvement and growth of underdeveloped areas."[23]

Post-war academia marched in lockstep with this conception of development. To Michael E. Latham, these conceptions of development have belonged to the modernization theories informing the focuses of three social-science fields. In the field of sociology, Talcott Parsons's structural functionalist theory posits that "the concept of modernization" is the primary analytical theme for studying "an entire process of social change, encompassing both the past of the West and the future of the 'developing' world." In the field of political science, political modernization has dominated the research of "the political systems of 'developing' areas."[24] As to the field of economics, its academic knowledge production of modernization theories has focused directly on development. W. Arthur Lewis's 1954 article "Economic Development with Unlimited Supplies of Labour" crafted the distinction between a capitalist economy and a subsistence economy: subsistence economies contribute their "unlimited" supplies of labor to capitalist economies, and exemplify an early stage of development.[25]

Numerous economists have participated in studying how poor countries may develop their own economy to become rich countries. In particular, Walt Whitman Rostow's theory of the stages of economic growth was widely accepted during the Cold War. Historian Mark H.

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[23] Harry S. Truman, "Inaugural Address of Harry S. Truman, January 20, 1949," in *Foreign Aid and American Foreign Policy: A Document Analysis*, ed. David Baldwin (New York: Frederick A. Praeger Publishers, 1966), 60-62. Originally from: *Public Papers of the Presidents of the United States: Harry S. Truman* (Washington, DC: Government Printing Office, 1964), 112-16.

[24] Michael E. Latham, "American Social Science, Modernization Theory, and the Cold War," *Modernization as Ideology: American Social Science and "Nation Building" in the Kennedy Era* (Chapel Hill: Univ. of North Carolina Press, 2000), 21-68.

[25] W. Arthur Lewis, "Economic Development with Unlimited Supplies of Labor," *Manchester School of Economic and Social Studies* 22 (1954): 139-91.

Haefele pointed out that, at an economic conference at Princeton in 1954, conference attendees avidly discussed the lack of "an appealing story for the non-Soviet economic trajectory."[26] As early as 1956, Rostow proposed the concept of "take-off" and identified the approximate take-off time-point for countries including Great Britain, France, Belgium, the United States, Germany, Sweden, Japan, Russia, Canada, Argentina, Turkey, India, and China (in the order from the earliest take-off date to the latest one, according to Rostow).[27] His analysis in a 1956 journal article constituted the basis for his famous 1960 book, *The Stages of Economic Growth: A Non-communist Manifesto*.[28] He had elaborated on similar ideas about stages of take-off and self-sustaining growth in his early book entitled *An American Policy in Asia* (1955). The 1956 article constructed and delineated a "history" of economies in different countries, whereas the 1955 book used the concept of different stages to stress that the United States should help Asian nations attain economic growth. It is important to note that Rostow's term "take-off" is obviously a rocket or aeronautical metaphor. Rostow was not the only economist to periodize stages of economic development in the 1950s, but in the Taiwanese context, Rostow was one of the most famous economists to theorize stages of economic growth.

Rostow compared the histories of countries by positioning them "allochronistically."[29] This type of comparison assumes that every country in the world eventually will achieve the same status of development and that every country goes through stages of poverty, underdevelopment, and development, as a child does. The comparison also reinforced the

[26] Mark H. Haefele, "Rostow's Stages of Economic Growth," in *Staging Growth*, 81-106.
[27] Walt Whitman Rostow, "The Take-off Into Self-sustained Growth," *The Economic Journal*, 66 (1956): 25-48; "Chapter 7: An Economic Policy in Free Asia," in *An American Policy in Asia* (MIT Press and John Wiley & Sons, 1955), 43-52. Similar ideas can be found in an even earlier publication, "Chapter 4," *The Process of Economic Growth* (New York: Norton, 1952), 102-5.
[28] Rostow, *The Stages of Economic Growth, a Non-Communist Manifesto* (Cambridge: Cambridge Univ. Press, 1960)
[29] Gupta, *Postcolonial Developments*, 10; Itty Abraham, *The Making of the Indian Atomic Bomb — Science, Secrecy and the Postcolonial State* (London: Zed Books, 1998), see page 28-29.

modern invention of "history" in which different regions' respective stages of development grew synchronized after the rise of modernity and colonialism.

To characterize underdeveloped countries as being in an economic stage analogous to the stages of a child's growth is to assume that underdeveloped countries pursuing the ends of development should follow the means of development established by the developed. In this allochronistical history, mimicry seems to be the best strategy for underdeveloped countries.[30] Nevertheless, central to this practice and discourse of mimicry is a consistent "failure of mimicry," according to Homi Bhabha. Bhabha used a consistent "failure of mimicry" to refer to postcolonial nation-states and citizens' enthusiasm for possessing things that prevail in the so-called developed countries.[31] Gyan Prakash's historical analysis of colonial India reveals that the legitimacy of the British colonial government was established on the rhetoric of a civilizing mission, in which the British were supposed to bring "Reason" to India. Nevertheless, the presumption of colonialism rested precisely on the idea that the colonized would never be able to possess Reason and, thus, had to be subject to a colonial government.[32] In the post-1945 classification of underdeveloped, developing, and developed countries, the exceptionalism of those originally developed countries has not faded away: it is still common for one to state that recently developed countries are almost the same as and yet very different from the originally developed countries.[33]

Development Discourse

[30] Gupta, *Postcolonial Developments*, 40.
[31] Homi Bhabha, *The Location of Culture* (New York: Routledge, 1994).
[32] Gyan Prakash, "Science 'Gone Native' in Colonial India," *Representations* 40 (1992): 1-26.
[33] Gupta, *Postcolonial Developments*, 290.

Scholars have used "development discourse" to refer to the ideologies, institutions, apparatuses, ideas, academic knowledge production, and identities surrounding "development." Many scholars use the term in a Foucauldian way, in which they acknowledge that "discourse" captures the multi-layered mechanism of development, particularly at the levels of practice, narrative, and identity.

In James Ferguson's 1990 book on development in Lesotho, development is a "dominant problematic" that "work[s] in practices" and produces unintended consequences.[34] To Ferguson, the development apparatus working upon Lesotho included the conceptual apparatus and the institutional apparatus. Institutions such as the World Bank first constructed Lesotho as a less developed country (LDC); then, development experts implemented development projects in Lesotho to improve on its LDC status. To Ferguson, Foucault's concept of discourse is helpful because discourse not merely encompasses rhetoric and intention, but also generates practices and intended and unintended consequences.[35]

Whereas Ferguson's research focuses on the discourse that was imposed on Lesotho, Arturo Escobar's articulates the making of the Third World after 1945. In his 1995 book *Encountering Development*, he emphasizes that development is a regime of representations and that the Third World is a constructed product of this regime. Nevertheless, Escobar's definition of development is also related to the Foulcauldian concept of discourse. In his book, he stated that,

[34] James Ferguson, *The Anti-Politics Machine: Development, Depoliticization, and Bureaucratic Power in Lesotho* (Minneapolis: Univ. of Minnesota Press, 1994). See page xiv.
[35] Ibid., 18-19.

> Thinking of development in terms of discourse makes it possible to maintain the focus on domination—as earlier Marxist analyses, for instance, did—and at the same time to explore more fruitfully the conditions of possibility and the most pervasive effects of development.[36]

To Escobar, it is important to understand development as "an encompassing cultural space." In his framework, development includes the following three axes,

> The forms of knowledge that refer to it [development] and through which it comes into being and is elaborated into objects, concepts, theories, and the like; the system of power that regulates its practices; and the forms of subjectivity fostered by this discourse, those through which people come to recognize themselves as developed or underdeveloped. The ensemble of forms found along these axes constitutes development as a discursive formation, giving rise to an efficient apparatus that systematically related forms of knowledge and techniques of power.[37]

To Akhil Gupta, the postwar conceptions of development are clearly reflected in efforts to categorize hundreds of millions of people and their countries as "underdeveloped." Many institutions such as the World Bank and the International Monetary Fund contributed to this categorization. In Gupta's 1998 book *Postcolonial Developments*, development discourse includes the Indian government's strategies about economic development and a development

[36] Escobar, *Encountering Development,* 5-6.
[37] Ibid., 10.

apparatus operated by international organizations.[38] However, "rather than arguing that 'development' becomes a means to recolonize the Third World," Gupta sought to "demonstrate that [development] enters a series of relationships that institutes a new form of government rationality."[39] Among this new series of relationships, Gupta stressed "underdevelopment," which had become "a form of identity in the postcolonial world." Central to this identity are the narratives about "the economic position of a nation-state relative to others." The identity is exactly a "self-awareness of this temporal lag and spatial marginality" and a "complex articulation of 'backwardness'."[40] Gupta delineated the postcolonial condition of villagers' agricultural practices and discourse in Alipur, India. He demonstrated that, when farmers talked about the relationship between their farming techniques and the green revolution, they internalized, reified, and stabilized notions of "developing countries" and "the West." Therefore, the concept of "non-Western" is not a residual but a constitutive category.[41]

These understandings of development discourse can help clarify the practices of Cold War-era Taiwanese computers users. As a dominant Cold War ideology, development discourse was supported by numerous institutions, and was participated in and reproduced by a diverse variety of people. Although scholars have used "development discourse" to refer to the ideologies, institutions, apparatuses, ideas, academic knowledge production, and identities surrounding "development," specifically, this dissertation lays out the development discourse which has been shaped by the following dimensions: United Nations' technical-aid programs, the widely circulated classificatory system identifying developed, developing, and underdeveloped

[38] Gupta, *Postcolonial Developments*, 12-13, 39.
[39] Ibid., 33.
[40] Ibid., ix, 11,104.
[41] Ibid., 9.

countries, computer-assisted economic-knowledge production, and the self-identity of Taiwanese computer users.

Gabrielle Hecht in her recent edited book, *Entangled Geographies: Empire and Technopolitics in the Global Cold War,* has pointed out that it is important to unpack science and technology in development studies (and that it is equally important to deconstruct developments in the study of science and technology).[42] As development-focused scholars such as Escobar, Ferguson, Latham, and O'Bryan pay more attention to the concept of development than science and technology, I have found Edwards' elaboration of discourse helpful to this dissertation's focus on technology. Following Paul Edwards' approach, in this dissertation, I explore development discourse in relation to the material aspects of technological practices regarding digital electronic computing.

Furthermore, unlike Escobar and Ferguson, Edwards' definition of 'discourse' emphasizes scholarly disciplines. Edwards is interested in new disciplines, such as cybernetics and artificial intelligence, which have involved digital electronic computers and emerged during the Cold War. In this dissertation, in terms of the emergence of new scholarly disciplines, I discuss econometric knowledge production, which was central to development discourse in Taiwan.

Throughout the dissertation, I focus on the idea that the industrial sector was central to modernizing Taiwan or to directing Taiwan toward a more developed condition. Although only

[42] Gabrielle Hecht, ed., *Entangled Geographies: Empire and Technopolitics in the Global Cold War* (Cambridge: MIT Press, 2011).

one part of development, the industrial sector occupies an important space in engineers' participation in Taiwan's national development. Beginning in the mid-1950s, a group of Taiwanese technocrats, engineers, and scientists believed that introducing Taiwan to cutting-edge expertise in "electronics science" (i.e., electrical engineering) and digital electronic computers would strengthen the development of Taiwan's industrial sector, which would include an electronics-manufacturing industry (at that time, Taiwan had a chiefly agricultural economy). In this sense, I treat the "development discourse" as a reflection of a group of Taiwanese people's sense of self-identity. This dissertation aims to understand how Taiwanese engineers, scientists, technocrats, and computer users talked about Taiwan's development status. I argue that these social groups' discussions, narratives, and interpretations concerning Taiwan's development further reinforced and strengthened development discourse, as an overarching apparatus. Moreover, Taiwanese technocrats, engineers, scientists, and ordinary computer users' interpretations of the developmental status of their country shaped their perceptions of the importance of possessing, using, and manufacturing computers.

Put more simply, this group of technocrats, engineers, and scientists' interests in strengthening an industrial sector was related to Rostow's stages of economic growth theory. Nevertheless, I am not asserting that these individuals and their respective social groups had either carefully read Rostow's or other economists' books and articles or conclusively decided to follow Rostow's prescription for economies yet to take off. Instead, in this dissertation, I treat the idea that Taiwan's economic development required an expansion of Taiwan's industrial sector as a popular and widely accepted "common sense" idea circulating among Taiwanese technocrats, engineers, scientists, and other relevant social groups from the 1950s to the early 1980s. I

especially would like to note that only a multi-volume series of books could even begin to trace the entangled conceptualizations of growth, development, the industrial sector, and modernization theories produced by both scholarly institutions and World Bank-like international institutions during the Cold War; after all, people from significantly different backgrounds embraced and further reproduced these ideas at multiple levels. As I focus on Taiwanese computer users in this dissertation, I note that developing Taiwan through a strengthening of its industrial sector was a common sense, collective belief—a presumption embraced by engineers, technocrats, scientists, and computer users throughout several decades. To these social groups, the industrial sector was the most essential dimension of Taiwan's economic development because the sector was most relevant to their profession or, at least, to the technology with which they were familiar.

Last, regarding countries' efforts to attain a better development stage, some scholars, unlike Rostow, have emphasized that a society's agricultural sector is essential in the process of strengthening an industrial sector.[43] Similarly, some Taiwanese bureaucrats, social groups, and scholars believed that the effect of the agricultural sector on Taiwan's economy was greater than that of the industrial sector. However, the engineers, technocrats, and scientists discussed in this dissertation did not directly participate in debating with other social groups over the importance of the industrial sector.

Working with Computers

[43] For a history of the debate over the importance of the agricultural sector to economic development, see Gupta, "Agrarian Populism in the Development of a Modern Nation," *Postcolonial Developments*, 33-105.

The second analytical theme of this dissertation involves the question of what exactly would the technological practices be in a country whose citizens were seriously aware of the "developing" status of their country. It is not easy to condense a comprehensive answer to this question in a short phrase, yet the title of this dissertation reflects just such an attempt: "working with computers." To be specific, a so-called developing country's technological practices include a series of histories of introducing, using, building, and tinkering with computers. I have chosen four cases (discussed in chapters 3 through 6) to illustrate the characteristics of technological practices in the context of a so-called developing country.

In chapter 3, I examine the process in which NCTU professors, students, and technicians worked with two visiting professors from the United States to set up a computing center, equipped with an IBM 650 and an IBM 1620 computer, at the NCTU campus from 1962 to 1964. The technological practices of this period were structured in a UN technical-aid program, which was a site where a group of Taiwanese engineers, technocrats, and scientists advocated expanding the industrial sector of Taiwan's economy. In chapter 4, I discuss events that transpired in 1964, when a Cornell econometrician relied on both NCTU's 1620 computer and the first generation of programmers in Taiwan to form an economic-planning project for a Taiwanese government agency, the Council for International Economic Cooperation and Development (CIECD). The digital electronic computing practices in this project contributed to the production of development-related knowledge.

Chapter 5 discusses the attempts undertaken from 1968 to 1971 by members of an NCTU graduate program to build a minicomputer from scratch, despite being able to buy an already-

assembled minicomputer from various US suppliers. Participants of this project aimed to tap into Taiwan's domestic mass-manufacturing capacity relative to computers. Conversely, their project benefited from foreign electronics manufacturers in Taiwan's Export Processing Zone, which was an institutional invention for increasing capital investment in developing countries. Chapter 6 explores two intriguing phenomena that surfaced between 1980 and 1984: why many of Taiwan's computer users preferred to build their own microcomputers and how this preference initiated a series of debates about whether legal institutions allowed Taiwanese companies to make Apple compatibles. In this chapter, I show that the protagonists, by mobilizing the discourses of development or modernization, legitimized or delegitimized one's building of one's own computer.

All of the four cases involve Taiwanese computer users' efforts to successfully introduce Taiwan to the practices and knowledge related to digital electronic computing, which was based on US experts and US-based companies. Drawing from among the diverse facets of Cold War technological exchanges, this dissertation clarifies how different social groups in a recipient country (i.e., Taiwan) participated in and interpreted their country's active acquisition of new technological practices for the improvement of that country's "developing" status. In chapters 3 and 4, I emphasize the active role of engineers, technocrats, and scientists in Taiwan, as a recipient country in a technical-aid program, and their modeling after the existing successful practices of digital electronic computing; in chapters 5 and 6, I emphasize the active role of users and their practices of building and tinkering with technology, still in a social setting of introducing technology from one location to another. My emphases are based on two streams of

historiography reviewed in the following sections: the role of the recipient country in technological exchanges and the role of users and their practices of tinkering with technology.

The Local Practices of the Recipient Country in Technological Exchanges

Science and technology scholars have studied the travels of scientific and technological knowledge and practices within or across societies and used different terms to describe the relevant activities, such as 'diffusion', 'technology transfer', 'traffic', 'circulation', and 'going native'.[44] These travels are central to the construction of science and technology, as well as to that of societies and polities.[45] The Cold War was a heyday for the travels of science and technology across nation-states, and in particular, technical-aid programs were a critical and popular format at that time.

Scholars have studied some characteristics of the overarching structure that facilitated technical-aid programs during the Cold War. Both John Krige and Michael Adas have worked on conceptualizing the ideas of US dominance or hegemony, which prompted scientific and

[44] In creating these terms, scholars referred to their diverse research questions and the historiographical or theoretical contexts in which they participated. For 'diffusion', see George Basalla, "The Spread of Western Science," *Science* 156 (1967): 611-22. For the field of the history of computing, see William Aspray "International Diffusion of Computer Technology, 1945-1955," and James W. Cortada, "Patterns and Practices in How Information Technology Spread around the World." For a historiographical review of technology transfer, see Bruce Seely, "Historical Patterns in the Scholarship of Technology Transfer," *Comparative Technology Transfer and Society* 1 (2003): 7-48. For terms such as 'traffic' and 'circulation', see Warwick Anderson and Vincanne Adams, 'Pramoedya's Chickens: Postcolonial Studies of Technoscience,' in *The Handbook of Science and Technology Studies*, eds. Edward J Hackett, Olga Amsterdamska, Michael Lynch and Judy Wajcman, (Cambridge: MIT Press, 2007), 181-203, and Roy MacLeod, "Introduction," *Osiris (Special Issue: Nature and Empire: Science and the Colonial Enterprise)* 15 (2000): 1-16. Gyan Prakash uses 'going native' to describe the knowledge flows that the British empire wanted to bring to the colonized and to describe the impossibility of this enlightenment project. See Gyan Prakash, "Science 'Gone Native' in Colonial India," *Representations* 40 (1992): 1-26

[45] For example, historians of colonialism have demonstrated that the travels of science and technology were constitutive of the inter-dependence among empire building, colonial expansion, and the scientific and technological practices across colonies and metropolises. For a review of the historiography of this issue, see Suman Seth, "Putting Knowledge in its Place: Science, Colonialism, and the Postcolonial," *Postcolonial Studies* 12 (2009): 373-88.

technological exchanges among the United States and its allies during the Cold War.[46] Bruce Seely has reviewed various institutions and players, including UN, US, and Soviet government agencies, and US university centers, all of which promoted large-scale technology transfers during the Cold War. Furthermore, Donna Mehos and Suzanne Moon have proposed "the portability of experts and expert knowledge," which international organizations such as the United Nations constructed to cope with the decolonialization and technopolitics of the Cold War.[47]

Beyond technical-aid programs, some scholars have focused on business-related exchanges and interactions between East Asian companies or individuals and US companies or individuals during the Cold War.[48] Hyungsub Choi's research shows that while Japanese electronics-manufacturing companies strived to initiate technology transfers by paying licensing fees to US companies, Japanese companies developed their strategies by carefully considering their "needs, capabilities, and the political and economic environment."[49] In William Aspray's research on the invention of the Intel 4004 microprocessor, one of the earliest microprocessors, he pointed out that two Japanese engineers in 1971 contributed to its conceptualization and materialization. To Aspray, invention includes such aspects as "conceptualization, logical design, engineering, fabrication, capitalization, and marketing."[50] Aspray's and Choi's research have

[46] Michael Adas, *Dominance by Design: Technological Imperatives and America's Civilizing Mission* (Belknap Press, 2006); John Krige, *American Hegemony and the Postwar Reconstruction of Science in Europe* (Cambridge: MIT Press, 2006).
[47] Donna Mehos and Suzanne Moon, "The Uses of Portability: Circulating Experts and the Technopolitics of Cold War and Decolonization," in *Entangled Geographies: Empire and Technopolitics in the Global Cold War*, ed. Gabrielle Hecht (Cambridge: MIT Press, 2011), 43-74.
[48] For a review of this school of research, see Bruce Seely, "Historical Patterns in the Scholarship of Technology Transfer."
[49] Hyungsub Choi, "Technology Importation, Corporate Strategies, and the Rise of the Japanese Semiconductor Industry in the 1950s," *Comparative Technology Transfer and Society* 6, no. 2 (2008): 103-26.
[50] William Aspray, "The Intel 4004 Microprocessor: What Constituted Invention?" *IEEE Annals of the History of*

highlighted the active roles played by Japanese companies in their acquisition of transistor technology from US companies.

Along a similar line, some scholars have been interested in the autonomy and agency possessed by the recipient country of either a technology transfer or a failed technology transfer. But their emphasis on a recipient country's autonomy does not assign a romanticized agency to the recipient country. Instead, the scholars have analyzed the complicated interactions of social groups within a recipient country or between the transferring and recipient countries. For example, Suzanne Moon has shown that Indonesian technologists, when identifying appropriate agricultural practice and machinery sponsored through international technical aid, based their decisions on their own ideas about Indonesia's path toward a self-sufficient economy, rather than on the takeoff-economy model promoted by US officials. Ross Bassett's research has pointed out that, despite India's non-alignment policy, a group of US-aligned elites believed that India would benefit from technological and economic ties to the United States, and these elites thus extended US-based digital electronic computing to India in the 1960s.[51] Seong-Jun Kim and John DiMoia's articles on atomic energy in South Korea emphasize that scientists and their interactions with domestic political figures and American consultants shaped the introduction of atomic energy to South Korea during the Cold War.[52]

Computing 19, no. 3 (1997): 4-15.

[51] Ross Knox Bassett, "Aligning India in the Cold War Era: Indian Technical Elites, the Indian Institute of Technology at Kanpur, and Computing in India and the United States."

[52] Seong-Jun Kim, "Technology Transfer behind a Diplomatic Struggle: Reappraisal of South Korea's Nuclear Fuel Project in the 1970s," *Historia Scientiarum* 19, no.2, (2009): 184-93 [Special issue entitled "Beyond Differences: International Comparison on Nuclear Histories in Japan, Korea, and the United States]; John DiMoia, "Atoms for Sale? Cold War Institution-Building and the South Korean Atomic Energy Project, 1945-1965," *Technology and Culture* 51, no. 3 (2010): 589-618.

Underlying these technical-aid programs and exchanges, replicating science and technology in post-colonial countries was a central issue to actors in these countries during the Cold War. Stuart W. Leslie and Robert Kargon's research on Indian and Iranian universities modeled after MIT exemplifies the difficulty that various countries experienced in this replicating process.[53] Tae-Ho Kim's and Chihyung Jeon's research emphasizes that those efforts to own and replicate science and technology coincided with the building of a particular type of national identity, or with the modernization of the nation.[54] To Itty Abraham, postcolonial countries' efforts to possess science and technology are a "modern fetish." His research on the history of nuclear research in India demonstrates that Indian scientists' and political figures' enthusiasm for possessing atomic energy reflects the belief, widely held in India (a post-colonial state), that for it to acquire science and technology would be for it to assert its authority and capability as a state possessing power akin to that of the previous colonizing state. Abraham argues that the postcolonial state is not merely endlessly anxious about being behind, but also is reliant on massive "technological artifacts—dams, steel mills, new cities, nuclear reactors—objects embodying a different rationality, which would transform traditional landscapes through their sheer power."[55]

In this dissertation, particularly chapters 3 and 4, I introduce the active role of engineers, technocrats, and scientists in Taiwan's recipient-country status relative to a technical-aid program in the 1960s. I do not romanticize their practices as unique or innovative, though I do

[53] Stuart W. Leslie and Robert Kargon, "Exporting MIT: Science, Technology, and Nation-Building in India and Iran," *Osiris* 21 (2006): 110-30
[54] Tae-Ho Kim, "New Rice for Unification and Independence: Tongil Rice and South Korean Agronomy in the 1970s," (Paper presented in the Annual Meeting of the Society for the History of Technology, Lisbon, Portugal, October 11-14, 2008); Chihyung Jeon, "A Road to Modernization and Unification: The Construction of the Gyeongbu Highway in South Korea," *Technology and Culture* 51, no.1 (2010): 55-79.
[55] Itty Abraham, *The Making of the Indian Atomic Bomb*.

acknowledge that they had to think hard and creatively to struggle with their dependence on the United Nations and on IBM as the sole providers of both mainframe computing technology and related funding in Taiwan. I argue that Taiwanese engineers, technocrats, and scientists' participated in development discourse (as an overarching apparatus) and the mutual construction of development and digital electronic computing technology.

The Role of Users and their Practice of Tinkering with Technology

The focus of chapters 5 and 6 is on the active role of Taiwanese computer users' practices of building and tinkering with minicomputers and microcomputers by referencing established technology in the United States. As perceived by some Taiwanese actors, Taiwan's building and tinkering with digital electronic computing technology would enable the island-state to join the ranks of developed countries.

Scholars have been meticulously investigating the history of technology to avoid neglecting some actors' agency in the development of technological systems[56] or the consumption junction.[57] To Thomas Hughes, "large technological systems" include components beyond technological artifacts—system builders, engineers, financiers, workers, organizations, research programs, laws, firms, and so on. These components interact with one another. In contrast to Hughes' comprehensive approach and his implicit focus on system builders,

[56] Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: John Hopkins Univ. Press, 1983); "Edison and Electric Light," in *The Social Shaping of Technology: How the Refrigerator Got Its Hum*, ed. Donald MacKenzie and Judy Wajcman (Philadelphia: Open University Press, 1999, first published in 1985), 50-63; and "The Evolution of Large technological Systems," in *The Social Construction of Technological Systems*, ed. Wiebe Bijker, Thomas P. Hughes, and Trevor J. Pinch (Cambridge: MIT Press, 1987), 50-80.
[57] Ruth Schwartz Cowan, "The Consumption Junction: A Proposal for Research Strategies on the Sociology of Technology," *The Social Construction of Technological Systems*, ed. Wiebe Bijker, Thomas P. Hughes, and Trevor J. Pinch (Cambridge: MIT Press, 1987), 261-80.

constructivist user studies (user studies with a focus on the social construction of technology) address various social groups' interpretations or modifications of technology, which sway and direct possible technological choices.[58] Scholars who have shifted their attention from producers' innovations to other realms of technological systems have noticed more and more diverse people, such as mediators, hobbyists, and amateurs, participating in technological systems.[59]

Some scholars have directly used the term 'tinkering' to refer to users' modification and replication of technological artifacts. *Oxford English Dictionary* defines the term 'tinker' as "to work at something (immaterial) clumsily or imperfectly, esp. in the way of attempted repair or improvement; also more vaguely, to occupy oneself about something in a trifling or aimless way; to trifle, potter."[60] Nevertheless, in technology studies, the term 'tinkering' refers to users'

[58] Trevor J. Pinch and Wiebe Bijker, "The Social Construction of Facts and Artifacts: Or, How the Sociology of Science and the Sociology of Technology Might Benefit Each Other," in *The Social Construction of Technological Systems* , ed. Wiebe Bijker, Thomas P. Hughes, and Trevor J. Pinch (Cambridge: MIT Press, 1987), 17-50. Originally published in *Social Studies of Science* 14, no.3 (1984): 399-441. Ronald Kline and Trevor J. Pinch, "Users as Agents of Technological Change: The Social Construction of the Automobile in the Rural United States," *Technology and Culture* 37, no.4 (1996): 763-95.

[59] For a review of recent user studies, see Nelly Oudshoorn and Trevor J. Pinch, "User-Technology Relationships: Some Recent Developments," in *The Handbook of Science and Technology Studies, Third Edition*, ed. Edward J. Hackett, Olga Amsterdamska, Michael Lynch, and Judy Wajcman (Cambridge: MIT Press, 2007), 541-566 and Oudshoorn and Pinch, *How Users Matter. The Co-Construction of Users and Technologies*, ed. Nelly Oudshoorn and Trevor J. Pinch (Cambridge: MIT Press, 2003), 1-25. On amateurs and hobbyists, see Susan Douglas, *Inventing American Broadcasting, 1899-1922* (Baltimore: Johns Hopkins Univ. Press, 1989) and Kristen Haring, *Ham Radio's Technical Culture* (Cambridge: MIT Press, 2006). On invisible labor, see Gregory J. Downey "Virtual Webs, Physical Technologies, and Hidden Workers: The Spaces of Labor in Information Internetworks," *Technology and Culture* 42 (2001): 209-35 and *Telegraphy Messenger Boys: Labor, Technology, and Geography 1850-1950* (New York: Routledge, 2002). On mediators, see Trevor J. Pinch, "Giving Birth to New Users: How the Minimoog was Sold to Rock and Roll," in *How Users Matter. The Co-Construction of Users and Technologies*, ed. Nelly Oudshoorn and Trevor J. Pinch (Cambridge: MIT Press, 2003), 247-70; Atsushi Akera, "Voluntarism and Occupational identity," *Calculating a Natural World*, 249-74; Carolyn M. Goldstein, "From Service to Sales: Home Economics in Light and Power, 1920-1940," *Technology and Culture* 38, no. 1 (1997): 121-15; Ronald R. Kline, *Consumers in the Country: Technology and Social Change in Rural America* (Baltimore: John Hopkins Univ. Press, 2000); Ronald R. Kline "Agents of Modernity: Home Economists and Rural Electrification in the United States, 1925- 1950," in *Rethinking Women and Home Economics in the 20th Century*, ed. Sara Stage and Virginia Vincenti (Ithaca: Cornell Univ. Press, 1997), 237-52; Joshua M. Greenberg, *From Betamax to Blockbuster: Video Stores and the Invention of Movies on Video* (Cambridge: MIT Press, 2008); Christina Lindsay, "From the Shadows: Users as Designers. Producers, Marketers, Distributors, and Technical Support," *How Users Matter*, 29–50; Rachel Maines, *Hedonizing Technology: Paths to Pleasure in Hobbies and Leisure* (Baltimore: Johns Hopkins Univ. Press, 2009).

[60] "Tinker *v.*" *OED Online.* Oxford Univ. Press. http://dictionary.oed.com/

creative practices—whether purposeful or aimless—involving a variety of technologies. Yuzo Takahashi used the term 'tinkering' as an analytical category in his article published in a 2000 issue of *Technology and Culture*.[61] To Takahashi, tinkerers were local repair-people, hobbyists, and small-scale manufacturers of radio parts and television receivers in Japan in the 1950s and the 1960s. Tinkering practices would include the repair services offered by small-scale local shops or individual hobbyists, and shops' and individual hobbyists' manufacturing of radio or television receivers. It is precisely because of these tinkerers that more and more technical artifacts were produced, leading to the expansion of technological radio and television systems. Later, in 2005, Kathleen Franz's book *Tinkering* was published, its title describing automobile consumers' modification of their own cars for travel or comfort in the United States from about 1900 to the 1930s.[62] Users' tinkering with automobiles was situated in a wider culture of the early twentieth century that encouraged individual ingenuity. However, the creativity of tinkering was constrained by manufacturers' responses; indeed, by the end of the 1930s, manufacturers had become less and less interested in users' innovations. Thereafter, users' innovations had little or no significant effect on car design. Furthermore, recent sound studies scholars have expressed an interest in the concept of tinkering: sound studies have found that tinkering with musical instruments is an important aspect that shapes musical cultures.[63] Though similar to studies on hobbyists and amateurs, studies on tinkerers emphasize users' intervention in hardware.

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[61] Yuzo Takahashi, "A Network of Tinkerers: The Advent of the Radio and Television Receiver Industry in Japan," *Technology and Culture* 41, no. 3 (2000): 460-84.
[62] Kathleen Franz, *Tinkering: Consumers Reinvent the Early Automobile* (Philadelphia: Univ. of Pennsylvania Press, 2005).
[63] For example, see Trevor J. Pinch and Karin Bijsterveld, "Sound Studies: New Technologies and Music," *Social Studies of Science* 34, no. 5 (2004): 635-48, (special issue, ed. Karin Bijsterveld and Trevor J. Pinch), and " 'Should One Applaud?' Breaches and Boundaries in the Reception of New Technology in Music," *Technology and Culture* 44, no.3 (2003): 536-59; Trevor J. Pinch and David Reinecke, "Technostalgia: How Old Gear Lives on in New Music," in *Sound Souvenirs: Audio Technologies, Memory, and Cultural Practices*, eds. Karin Bijsterveld and Jose van Dijick (Amsterdam Univ. Press, 2009).

I use the concept of tinkering to emphasize Taiwanese computer users' modification of technological artifacts and the users' informal production of technological artifacts. Tinkering includes the practices of adapting, modifying, assembling in an innovative manner, and otherwise working creatively with technologies. Chapters 5 and 6 of this dissertation explore the practices of building computers from scratch by using available components, and the practice of tinkering was central to the practice of building. Chapter 5 looks at a university team that ambitiously planned to build a minicomputer; some of the Taiwanese computer users noted in chapter 6 were similar to hobbyists whereas others were business people. I regard the two chapters as exemplifying computer-oriented tinkering practices, regardless of their potential patriotic, business, or technophile functions.

The themes addressed in chapters 5 and 6 are characteristic of Taiwanese minicomputer users' and microcomputer users' tinkering practices, yet the know-how underlying this tinkering inevitably rested on Taiwanese people's experiences stemming from the introduction of and then the proliferation of mainframe computers in Taiwan in the 1960s, a subject discussed in chapters 3 and 4. Both chapters 3 and 4 exemplify Taiwanese computer users' emulation of the existing digital electronic computing practices in other parts of the world. Brooke Hindle in 1981 proposed the concept of emulation, which refers to the practice of modeling an object after someone's existing technological work: this process, crucial to apprenticeship and a predecessor to inventions, is categorically different from mimicking or copying, where there is no intention of learning the mechanisms underlying a new machine.[64] To Hindle this concept of emulation best describes the process in which eighteenth century America inventors, mechanics, and

[64] Brooke Hindle, *Emulation and Invention* (New York: New York Univ. Press, 1981).

artisans used spatial thinking to comprehend and re-design European machines.[65] Emulation refers to a non-verbal process of understanding new machines; that is, a practice involving the "mental manipulation of images and ideas" in the interest of "copying them and then searching for undreamed conceptions—and building them." Emulation takes place prior to "the trial and construction and even the repair and modification of machines."[66] It is important to note that Hindle's concept of emulation explains the rise of a new generation of artisans, mechanics, and inventors in the late eighteenth century. Hindle emphasizes that innovations require supportive social contexts, while other historians of technology in the 1970s were more interested in heroic inventors or the problem-solving process within one particular invention. Hindle's concept of emulation shares some similarities with Harry M. Collins's concept of tacit knowledge in his book *Changing Order*. While Collins uses the concept of tacit knowledge to discuss the capricious nature of the knowledge transfer of laser-building skills, Hindle emphasizes that the process of innovations consists of imitating and then building new artifacts with tacit knowledge accumulated during exercises in trial and error.[67]

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[65] According to Hindle, Robert Fulton and Samuel Morse, who contributed to major breakthroughs in the development of steam boats and the telegraph, began their careers as artists, which allowed them to sharpen their capabilities in terms of spatial thinking, studying existing technological artifacts, and building new machines. Beyond the capability of spatial thinking, Fulton, Morse, and other inventors frequently traveled to England and Europe and were well-informed concerning recent technological changes in England and Europe. Moreover, immigrant artisans and mechanics from England and Europe provided Fulton and Morse with necessary crafts and skills. Because of these advantages, Fulton and Morse were able to work on improving contemporary designs of steam boats and electro-magnetic devices.

[66] Brooke Hindle, *Emulation and Invention*, ix.

[67] Tacit knowledge was originally proposed by Michael Polanyi to describe "the skill of the scientist" that "can be passed on only by example from master to apprentice." Based on Michael Polanyi's definition of tacit knowledge, Collins has proposed that TEA laser scientists relied on tacit knowledge to build TEA lasers. He defines tacit knowledge as knowledge that is unable to be articulated and requires middle people to pass on from one laboratory to another. The middle person has to be someone who has built a laser successfully, and a laser-building scientist "would not be likely to succeed without some extended period of contact with the informant." In Collins's research, tacit knowledge is knowledge produced and re-produced in a process of trial and error attempts or debugging. Collins is concerned with the capriciousness of knowledge transfers in scientific experiments, as he argues that after a scientist successfully carries out a scientific experiment, the capriciousness is ignored and the formality of science is "crystallized." Harry M. Collins, "The TEA Laser," *Changing Order: Replication and Induction in Scientific Practice* (Chicago: Univ. of Chicago Press, 1992, originally published in London; Beverly Hills: Sage, 1985), 51-78. Michael Polanyi, *Personal Knowledge* (Univ. of Chicago Press, 1974; originally published in 1958), see page 52-3.

The terms ‘tinkering’ and ‘emulating’ do not constitute scholarly jargon, which would conceal or replace such activities as introducing, using, and building technology. The two concepts are central to the activities of introducing, using, and building computers, as tinkering and emulating are the implicit practices taking place when one location gains familiarity with a technology hailing from another location. The two concepts clarify how people in a location that is new to a technology can intervene in and modify it there. Furthermore, the concepts of tinkering and emulating help scholars re-examine the assumption that technological artifacts are easily transferable to a new location. A variety of actors, institutions, artifacts, and practices become involved in the process whereby a technological system expands from one location to another. In this dissertation, I emphasize that Taiwanese mainframe, minicomputer, and microcomputer users constituted one of the most important social groups to popularize digital electronic computers. Taiwanese computer users modeled their own practices after successful technological practices while building and tinkering with digital electronic computers. Tinkering and emulating practices were the means by which Taiwanese computer users participated in transforming Taiwan from a developing country to a developed country.

Local Knowledge?

The second analytical theme of this dissertation concerns the technological practices attributable to a country whose citizens were seriously aware of the “developing” status of their country. I pay attention to technological practices (in particular to emulating and tinkering) that have characterized Taiwan’s local and historical contexts; however, I do not claim that these technological practices are “Taiwanese,” “Chinese,” or “American,” even though historical

actors who are discussed in this dissertation have made assertions to this effect. Postcolonial scholars have pointed out that, when advocating and highlighting the incommensurability between "Western knowledge" and "the Rest's knowledge," researchers inevitably reinforce the separations between the two, as the separations were the essential part of Western exceptionalism and colonialism.[68] Itty Abraham has pointed out that self-reliance and autonomy were merely "watchwords" in the development of atomic bombs in India in the 1950s. These watchwords were not precise at all, as India relied on "expertise and designs" from Britain, Canada, the United States, and France.[69] Taiwanese historical actors discussed in this dissertation indeed were anxious about the arrival of the historical moment in which Taiwanese individuals or social groups would build computers domestically. However, from an analytical viewpoint, it is difficult to determine whether a technology can be fully "Chinese" or "Taiwanese." Instead, in this dissertation, I demonstrate that these Taiwanese actors were trying to connect their technological practices to the development status of Taiwan or Free China.

As Taiwanese engineers, technocrats, scientists, and computer users enthusiastically sought to transform the status of Taiwan from a developing country to a developed one, they produced a type of national identity and reinforced the nationalism expected by the Taiwanese government. Nationalism explains some of the practices and discourses delineated in this dissertation, and I acknowledge that the development discourse, the post-colonial nation-state, and technology reinforce one another's legitimacy. Nevertheless, this dissertation prioritizes an analysis of technology and development, rather than technology and nationalism. Furthermore, the research strategy I chose for the scope of this dissertation is due partly to the complicated

[68] For a discussion of the rejection of incommensurability, see Suman Seth, "Putting Knowledge in its Place: Science, Colonialism, and the Postcolonial."
[69] Itty Abraham, *The Making of the Indian Atomic Bomb*.

ethnical relationships underlying Taiwan's nationalism. Many engineers, technocrats, and scientists, discussed in chapters 2, 3, and 4, chose to leave China for Taiwan when Mao and his communist forces took over China around 1949. At the same time, the Chiang Kai-shek government started to establish a Taiwan-based dictatorship that imprisoned and executed a large number of Japan-educated intellectuals born or raised on the island prior to 1949. The confrontations (and also possible collaborations) between China-born and Taiwan-born residents in Taiwan have lasted from 1949 to now, dominating the discourse and perhaps miscommunication regarding what counts as legitimate national identities. At the end of chapter 4, I briefly introduce a group of students that challenged Chiang Kai-Shek's sovereignty over Taiwan, but their actions amount to merely one of the many incidents making up the history presented in this dissertation; here, I discuss only a small selection of engineers, technocrats, scientists, and computer users and their ideas and practices relative to development, so this dissertation does not offer—and is not meant to offer—a complete picture of the relationship between technology and national-identity formation in Taiwan.[70]

Methods

[70] The national identity of university engineers and scientists discussed in this dissertation did not reflect other social groups' identities in Taiwan at that time; moreover, university engineers and scientists' identity did not necessarily reflect Taiwanese educated intellectual's identity at that time, either. At the surface level, the institutional history of the Taiwanese universities and colleges in the 1950s, the Chiang Kai-Shek government did not abolish colonial-originated universities and did inherit the entire 'colonial' educational infrastructure. For example, Taipei Imperial University, established in 1928 by the Japanese colonial government, was renamed as National Taiwan University in 1945, and was the only university in Taiwan till 1954. Three other public colleges, established prior to the Second World War, resumed their operation, specializing in agriculture and in engineering in the 1950s. Nevertheless, in terms of the organizing of administrators, faculty members, and staff, the elite immigrants from China replaced Japanese principals, professors, and instructors. Taiwan-born elites were sometimes not qualified for these positions, because they were less likely to be promoted as administrators or faculty members in the colonial period. Even worse, the Chiang Kai-Shek government massively arrested and executed Japanese-educated elites, young students and Marxists in 1947. Under Chiang Kai-Shek's dictatorship, one would prefer not to publicly reveal one's nation-related or culture-related identity. In this context, the ethnical relationships between Taiwan-born elites and China-born elites, in relation to their national identities, were extremely complicated. Put simply, this dissertation only touches upon a small group of university scientists and engineers' national identities, and does not claim that it provides a complete picture of engineers' or scientists' national identities in Taiwan during the Cold War.

For this dissertation, I have surveyed professional journals, visited archives, and collected oral histories. First, I have examined archives from a variety of institutions in the United States and in Taiwan. My dissertation research has drawn on archival sources concerning United Nations technical-aid programs, US aid to Taiwan, US computer corporations' activities in Taiwan, and archival documents and oral histories concerning US technical-aid experts, Taiwanese engineers, bureaucrats, and a variety of computer users. In the United States, I have been to the National Archives in Maryland, the United Nations Archives and Records Management Section in New York City, the Charles Babbage Institute in Minneapolis, Minnesota. In Taiwan, I visited and accessed the archives of the Ministry of Foreign Affairs and of the Council for United States Aid in Taiwan at the Institute of Modern History at Academia Sinica, the archives of institutional correspondence among various government agencies at Academia Historica, university records at the National Chiao-Tung University (NCTU) Museum, and university records at National Cheng-Kung University and National Taiwan University.

Second, I read academic journals regarding computing and engineering to understand the relationship between the discourse of development and technology. I read academic journals regarding computing and engineering to understand how universities and the industry used mainframe computers and minicomputers from 1966 to 1975. I have surveyed computer-hobbyist magazines and newspaper articles and collected oral-histories from a variety of microcomputer users. These journals and magazines include, but not limited to, *Taiwan Engineering*, *Science Bulletin National Chiao-Tung University*, *Monthly Journal of Taipower's Engineering*, *Computer Research Quarterly*, *Information and Computers*, *Electronics & Radio-*

TV Technical Monthly, and *0 & 1 Technology*. For a list of journals consulted, please see appendix B.

Third, I conducted oral- history interviews with (1) two U.S. emeritus professors, whom the United Nations invited to teach at NCTU in Taiwan in 1962 and 1963, (2) Taiwanese emeritus professors and retired engineers who were either students or young faculty members at NCTU in the early 1960s, (3) the participants of the minicomputer-building project at NCTU circa 1970, (4) a variety of microcomputer users. For a list of informants, please see appendix A.

For the Romanization system of Taiwanese names in this dissertation, I have used the spelling individuals used when signing their names in English-written archival documents or publications. In Taiwan, the Wade-Gilos system is a widely-used system for Romanization, and indeed, a majority of the Taiwanese discussed in this dissertation romanized their names according to this system. In cases where no personal translations are available, I have followed the pinyin system, which is widely used in contemporary academia. Similarly, for titles of articles and books cited in the footnotes, I follow the pinyin system if authors did not provide English translations.

CHAPTER 2

NEGOTIATING FOR A COLD WAR TECHNICAL-AID PROGRAM IN ELECTRONICS SCIENCE AND DIGITAL ELECTRONIC COMPUTING, 1959-1962

> Only studies in the field of electronics promote atomic research; only the promotion of research in electronics fortifies national defense; only use of electronics creates advanced industries; only development of electronics creates high civilization. (Original in Chinese)
>
> —The caption for the cover picture, *The Voice of NCTU (National Chiao-Tung University) Alumni*, 61, December 1957, 7.

Beginning in the second half of the 1950s, a group of Taiwanese technocrats, engineers, and scientists drew their attention to "electronics science" and introduced Taiwan to the study of electronics science and digital electronic computing. Among the diverse reasons for this effort was the belief that introducing Taiwan to cutting-edge expertise in electronics and digital electronic computers would strengthen the development of industrial sectors, such as an electronics industry, in the island, which had a chiefly agricultural economy at that time. These technocrats, engineers, and scientists' efforts later contributed to the arrival of a UN technical-aid program and the first two digital electronic computers (IBM computers) in Taiwan in the early 1960s.

'Electronics science', or *Dian-Zi-Ke-Xue* (電子科學), was a term that this group of Taiwanese technocrats, engineers, and scientists used when referring to emerging electrical-engineering fields in the United States, such as microwave telecommunications, servo

mechanisms, transistor circuits, semiconductors, and digital computing. Given the Taiwanese government's lack of interest in and funding of research institutes in general in this time period,[1] the social group—most of whose members had graduated from China's pre-WWII Chiao-Tung University—started to apply in 1958 for sponsorship from a United Nations technical-aid program: the objective was to receive funding for a university graduate program that would strengthen electronics-science research, which itself would involve the acquisition of Taiwan's first digital electronic computer (an IBM computer). With aid approved by the United Nations in 1960, Chiao-Tung-educated technocrats, engineers, and scientists decided to establish the Training and Research Centre for Telecommunications and Electronics on the National Chiao-Tung University (NCTU) campus. This UN-NCTU technical-aid program recruited American professors and distributed financial resources and material resources among three overlapping institutions: NCTU's Institute of Electronics (i.e. a graduate program in electronics), the Training and Research Centre, and NCTU's computing center. The United Nations approved approximately $ 334,000 US dollars, and the Taiwanese government had to contribute to $ 278,000 US dollars. The funding was a big amount of money given that the per capita income in Taiwan for the year 1961 was $ 153 US dollars.[2]

This chapter studies the development discourse that prompted and shaped a UN technical-aid program established in Taiwan during the Cold War, and, in particular, explores how Taiwanese bureaucrats, engineers, scientists, and UN officials defined legitimate formats of

[1] See J. Megan Greene, "Starts and Stops," *The Origins of the Developmental State in Taiwan* (Harvard University Press, 2008), 14-46; and Tsui-Hua Yang, "Hu shi dui tai wan ke xue fa zhan de tui dong shu shu du li meng xiang de yan xu Hu-Shih's [Advocating and Promoting Science: A Vision of Academic Independence]," *Han xue yan jiu [Chinese Studies]* 20 (2002): 327-52. See page 332.

[2] "News Section," *Telecommunication Journal* 28, no. 2 (1961): 74; the information about per capital income is from the survey conducted by Taiwan's Directorate General of Budget, Accounting and Statistics, Executive Yuan (which is an equivalent of the Cabinet or the Council of Ministers), see http://ebas1.ebas.gov.tw/pxweb/Dialog/statfile9L.asp

technological exchanges at the turn of the 1960s. The first section of this chapter reviews the development discourse that dominated late-1950s Taiwan and that prompted Chiao-Tung-educated technocrats to apply for the UN-NCTU technical-aid program. The second section, focusing on the social meaning of electronics science, introduces the reader to Chiao-Tung alumni's views on electronics science's significance at ideological, military, and infrastructural level. (I should note that this study concerns how Chiao-Tung-educated civilians, rather than military personnel, considered electronics science's military applications.)

Third, and central to this chapter, is an analysis of how Taiwanese engineers, scientists, and technocrats worked with one another as well as negotiated with UN-affiliated officials to shape the UN-NCTU technical-aid program's contribution to the Taiwanese economy. I continue to use 'development discourse' to refer to the two social groups' different but related ideas about the ends and means of building an electronics-manufacturing industry. I explore the 'mutual orientations' undertaken by UN-affiliated officials and the Chiao-Tung educated technocrats, engineers, and scientists from 1958 to 1964, by analyzing draft proposals for the UN-NCTU technical-aid program and correspondences between and within the two groups. The last section of this chapter is a brief description of the arrival of the first digital electronic computers in Taiwan in 1962. In terms of time periods, this chapter covers the application process of the UN-NCTU technical-aid program from its initiation in 1958 to the United Nations' approval in 1960 and the preparation for the program during 1961 and 1962.

This chapter's use of the term 'mutual orientation' stems from a concept proposed by Paul Edwards in his analysis of the history of the Semi-automatic Ground Environment (SAGE)

project, in which the Air Force funded the building of Whirlwind computers at MIT. To answer the question of why Americans built early digital computers, Edwards pointed out that the research on Whirlwind computers involved not merely university scientists or the military, but also complex social and intellectual interactions between universities and the Air Force. University scientists and engineers transformed and also were transformed by the strategic thinking of the Air Force. University scientists and engineers constructed a language of automated command and control to describe the breadth and the depth of a digital computer's functions. At the same time, the Air Force envisioned ideas regarding air defense and the related potential of digital computers. Edwards's emphasis on the mutual orientations between university scientists and engineers and the Air Force indicates that both social groups defined social meanings of Whirlwind computers, and constructed this new type of technological artifacts.[3] Although UN-affiliated officials and Chiao-Tung alumni did not build a technological artifact in Taiwan in the 1960s, they still discussed and decided the social meanings of electronics science, engineering education, and electronic industry when they planned to introduce Taiwan to the cutting-edge electrical engineering research.

Chiao-Tung Alumni

The Chiao-Tung alumni on whom this chapter focuses include the head of the Bureau of Telecommunications in Taiwan, a Columbia University researcher, the president of the state-owned petroleum monopoly in Taiwan, a Sperry Gyroscope engineer, and a Syracuse University professor. A characteristic shared by the Taiwanese advocates of electronics science was that they had graduated from Chiao-Tung University in China before moving to Taiwan with Chiang

[3] Edwards, *The Closed World* and "From 'Impact' to Social Process: Computers in Society and Culture."

Kai-Shek's government. Chiao-Tung University was a prestigious public university founded in 1896, and the first university in China to offer undergraduate programs in electrical engineering in 1907.[4]

After Mao took over China in 1949, Chiao-Tung University did not immediately continue to operate in Taiwan. As many Chinese chose to leave communist China around 1949 and either settled in Taiwan or immigrated to countries such as the United States, a group of China-born and Chiao-Tung-educated technocrats, engineers, and scientists became de facto members of an important informal network frequently expressing their opinions on the technological policies and the engineering education of post-1949 Taiwan. These alumni have held reunions regularly in Taiwan, the United States, Japan, and other places as early as the 1950s. They have also organized a monthly newsletter entitled *the Voice of NCTU Alumni* since April 1952.

In 1957, many Chiao-Tung alumni, including some serving in important posts in the Ministries of Education, National Defense, Economic Affairs, and Transportation and Communications, persuaded the Chiang Kai-Shek government to 'resume' the operation of their prestigious Chiao-Tung University in Taiwan. The new university was called "National Chiao-Tung University" (NCTU) in Taiwan. In June 1958, the Institute of Electronics (i.e. a graduate program in electronics) was formally founded as the *only* program at NCTU, and it also became Taiwan's first master's program in a science, technology, or engineering field.[5]

[4] The pre-WWII Chiao-Tung University included several different colleges, located in Tangshan, Beijing, and Shanghai in China. In this dissertation, I use Chiao-Tung University to refer to the university operating from 1896 to 1949 in China, and use National Chiao-Tung University or NCTU to refer to the university established in 1958 in Hsinchu, Taiwan. Particularly, I use Chiao-Tung alumni to refer to those who graduated from Chiao-Tung University in China.

[5] During this period, Taiwan's college-level electrical-engineering education existed merely in two public universities and one public vocational school, all of which had been established by the Japanese empire prior to the

As historians have pointed out, in the 1950s, the Chiang Kai-Shek government was not interested in and not financially capable of sponsoring research institutes in general.[6] The two exceptions that the government was willing to fund concerned agricultural research (because of its economic value) and nuclear-physics research (because of its military applications). In fact, the latter was partially carried out with the United States' blessing in 1955 after the United States had advocated atomic energy's peaceful use. With this background, the Chiang Kai-Shek government established National Tsing-Hua University and set up a graduate program in nuclear physics there. National Tsing-Hua University was also a university that had originated in China (in 1911) and had concentrated on science education.[7] In contrast to the government-initiated resurrection of the pre-WWII Tsing-Hua University, Chiao-Tung alumni's organization and mobilization were extraordinary.

The alumni's advocacy was successful in that it eventually breathed life back into their alma mater, now based in Taiwan. Moreover, the advocacy was unusual when compared to other intellectuals' advocacy of science during the same time period. Consider, for example, Hu Shih, a U.S.-based and China-born intellectual who had studied under John Dewey and was a Cornell

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Second World War. The first college-level electrical-engineering program in Taiwan was under National Taiwan University, one of the nine imperial universities established and supported by the Japanese colonial empire. The second and the third college-level electrical-engineering programs in Taiwan were under National Cheng-Kung University and under the Provincial Taipei Institute of Technology (which was a vocational school). Taiwan was colonized by Japan from 1895 to1945.

[6] See Megan, "Starts and Stops," and Tsui-Hua Yang, "Advocating and Promoting Science: A Vision of Academic Independence."

[7] In 1955, Chiang Kai-Shek signed a bilateral agreement on peaceful use of atomic energy with the United States. After signing up for the agreement, Chiang Kai-Shek met with the Ministry of Military and decided to locate the nuclear reactor in the campus of National Tsing-Hua University (NTHU). In December 1955, Executive Yuan (the Cabinet or the Council of Ministers) set up a committee to 'resume' the operation of NTHU in Taiwan, and Executive Yuan decided that the first graduate program would be a graduate program in atomic energy. Li-Yu Fu, "Mei yuan shi qi tai wan zhong deng ke xue jiao yu ji hua zhi xing cheng yu shi shi nian biao (1951-1965) [A Chronology of the Initiation and Implement of the Secondary Science Education Project under the U.S. Aid in Taiwan (1951-1965)]," *Chinese Journal of Science Education* 14, no. 4 (2006): 447-65.

alumnus: Hu Shih tried hard to persuade the Chiang Kai-Shek government to increase governmental funding in scientific research in the 1950s. Hu Shih was worried that Free China was suffering from cultural, scientific, and economic "stagnation," and his worry could be traced back to his expectation—held since the beginning of the twentieth century—that China would, or at least should, become a powerful state.[8] Compared to Hu Shih's prominent social and cultural status, Chiao-Tung alumni's mobilization at the governmental level rested chiefly on those technocratic alumni who were serving in ministries or were employed in state-owned enterprises.

Having successfully established the graduate program in electronics in 1958, Chiao-Tung alumni capitalized on the advantages of momentum by continuing their fund-raising among Chiao-Tung alumni, as the funding from the government was limited. State funds for science education were even tighter after Mao ordered an attack on Kim-Men Island in the Taiwan Strait beginning on August 23, 1958 and lasting for over one month. In this regard, the United Nations technical-aid program can be seen as a part of Chiao-Tung alumni's fund-raising efforts, which I will illustrate later in detail.

Development Discourse

The development discourse attributable to Chiao-Tung alumni rested partly on their participation in Taiwan's economic-development war with communist China. As the superiority of Taiwan's economic performance over communist China's could showcase the correctness of

[8] Hu Shih, "Fa zhan Ke xue de zhong ren he yuan lu [The Responsibility of Developing Science]," *Xin shi dai [New Era]* 1 (February 1962): 3-4.
Hu Shih studied with John Dewey in the 1910s, and advocated replacing Confucianism with Pragmatism when Marxists advocated science and democracy in the May Fourth Movement in China in 1919. When Hu Shih advocated Taiwan-based scientific research and science education during the 1950s, he believed that the state should finance scientific research.

Chiang Kai-Shek's anti-communist stance, many Chiao-Tung alumni were quite convinced that electronics science, *Dian-Zi-Ke-Xue*, including digital electronic computing, had the potential to strengthen the military, infrastructural, and economic aspects of "Free China." The development discourse to which Chiao-Tung alumni and UN-affiliated officials subscribed was related to Walt Whitman Rostow's theory of the stages of economic growth. They believed that, to improve Taiwan's economy, it was important to develop and strengthen its industrial sector, which would supersede its agricultural sector, and direct Taiwan's economy to "take-off." An electronics-manufacturing industry would strengthen the development of Taiwan's industrial sector, and it would require a large number of domestic engineers and scientists to create the industry. In addition, when Taiwanese companies would be able to manufacture electronics products, the national economy would be improved by exporting domestically-manufactured merchandises or at least by decreasing the overall expenses on importing merchandises.

The concept of take-off has been discussed in Taiwanese media since 1960. Chong-Rong Yin first published an article on August 7, in *Economic News Daily,* discussing the previous decade's development of the Taiwanese economy and the economy's near-future take-off potential.[9] Yin was a Chiao-Tung alumnus, a prominent economic policy-maker, a then-president of the Bank of Taiwan (a currency-issuing central bank) and a frequent contributor to *The Voice of NCTU Alumni*. In 1960, the September and October issues of *The Voice of NCTU Alumni* re-printed Yin's aforementioned article.[10] (As an aside, this re-printing shows that, although a large portion of Chiao-Tung alumni were trained as engineers or scientists, *The Voice*

[9] Chong-Rong Yin, "Tai wan jing ji shi nian lai de fa zhan zhi jian tao [A Discussion of the Economic Development during the Past Decade]," *United News Daily*, August 7, 1960, 2, 3, 5.
[10] Yin, "Tai wan jing ji shi nian lai de fa zhan zhi jian tao [A Discussion of the Economic Development during the Past Decade (Part 1)]," *You Sheng* (hereafter *The Voice of NCTU Alumni*) 94 (September 1960): 1-6; "A Discussion of the Economic Development during the Past Decade (Part 2)," *The Voice of NCTU Alumni* 95 (October 1960): 5-8.

of NCTU Alumni also published articles concerning the humanities and the social sciences.) In this article, Yin pointed out that industrial production in Taiwan had not been ready to shift Taiwan from a chiefly agricultural economy to a chiefly industrial economy. He stated,

> Since the end of the Second World War, the world economy has been pursuing prosperity in all regards. Some regions that are [economically] behind are trying to catch up to countries that are advanced; advanced countries want to develop even further. The world has become an arena of economic development. A country's power, international status, and living standards are decided by competition in this arena. Doubtless, we have participated in this economic competition since 1949. (Original in Chinese)

Yin's ideas represented the dominant discourse in Taiwan at this time: to strengthen and broaden Taiwan's industrial economy constituted the foremost goal shared by policymakers and like-minded Taiwanese. In this overarching context, the majority of Chiao-Tung alumni who are discussed in this chapter believed that electronics science could contribute to economic development according to at least three cumulative steps: nurturing a large number of domestic engineers and scientists, building an electronics-manufacturing industry, and strengthening an industry-based economy that would supersede the agricultural economy in importance.

The United Nations' technical-aid programs also rested on this idea that experts could engineer a nation-state, particularly a post-colonial state, so that it would "take-off," evolving from an agricultural society to an industrialized society. In the 1950s, the United Nations became a major facilitator of this effort, funding postcolonial nation-states' efforts to attain economic

growth. Countries such as the United States and the Soviet Union also provided economic and technical aid to countries worldwide. For the United States, this policy has been ongoing since Truman's Point Four Program in 1949.[11] To promote "the economic development of the less developed countries," the United Nations in 1950 started its Expanded Programme of Technical Assistance and Technical Assistance Administration (TAA), which was run by the Technical Assistance Board (TAB) of the Economic and Social Council.[12] Beginning in 1959, the United Nations launched the Special Fund to supplement the existing technical aid provided by the Expanded Programme of Technical Assistance.[13]

In *The Priorities of Progress*, a 1961 pamphlet on the United Nations Special Fund, Managing Director Paul G. Hoffman stated that the Special Fund was geared toward a "full partnership between the advanced and the less developed countries in the mobilization of money, men and equipment for approved projects."[14] In particular, the Special Fund was supposed to assist less developed countries' "accelerator projects" in order to spread "the 'seed' effects" of international funds. The pamphlet also listed three illustrative projects supported by the Special Fund: the "Volta River flood plain survey in Ghana," the "vocational instructor training center in Colombia," and the "central mechanical engineering research institute in India." The 1963

[11] The Point Four of Truman's Inaugural Address in January 1949 emphasized the importance of setting up a collaborative program through the United Nations to make "the benefits of our scientific advances and industrial progress available for the improvement and growth of underdeveloped areas." See Harry S. Truman, "Inaugural Address of Harry S. Truman, January 20, 1949," in *Foreign Aid and American Foreign Policy: A Document analysis*, edited by David Baldwin (New York: Frederick A. Praeger Publishers, 1966), 60-62. Originally from: *Public Papers of the Presidents of the United States: Harry S. Truman* (Washington, D.C.: Government Printing Office, 1964), 112-16.

[12] David Webster, "Development Advisors in a Time of Cold War and Decolonization: the United Nations Technical Assistance Administration, 1950–59," *Journal of Global History* 6 (2011): 249–72; See page 9 in *Yearbook of the United Nations1948-49* (The United Nations, 1950) and page 6 in *Yearbook of the United Nations* 1950 (The United Nations, 1951).

[13] "Chapter III the Economic Development of Under-developed Countries," in *Yearbook of the United Nations 1958* (The United Nations, 1959), 131-42.

[14] See Paul Hoffman, "The Critical Role of Special Fund," in *The Priorities of Progress* (The United Nations, 1961), 4-5.

pamphlet was named *Target: An Expanding World Economy*, the first page of which was a picture of two mechanics inspecting the engine on an aircraft featuring the UN Special Fund's name and logo. Echoing this picture, the next page contained a section of texts entitled "the United Nations Special Fund Helps to Prepare Countries for Economic 'Take-off'."

Taiwanese governmental officials had been taking advantage of US and UN aid to obtain funds geared toward domestic-development projects, such as building dams, improving railway infrastructure, and extending sewage systems.[15] In this context, the UN-NCTU technical-aid program in question was similar to the numerous other UN or US technical-aid programs insofar as all the programs had, as their stated mission, improvement of the island's infrastructure; however, there was a striking difference. The UN-NCTU technical-aid program that this study discusses had, as its focus, cutting-edge science, mainly because it was advocated by Chiao-Tung alumni– a social group with unique technological-education background.

Electronics Guard the Free World and Free China: Electronics Science's Potential Military and Telecommunications Applications

Gisson Chi-Chen Chien, a Chiao-Tung alumnus and the head of the Bureau of Telecommunications in Taiwan, learned of the establishment of the United Nations Special Fund in 1958. He then discussed his interest in applying for the Special Fund with administrators at the International Telecommunication Unions, where he served as a government representative and

[15] In general, the process of applying for U.S. and U.N. technical-aid programs involved several organizations at the international level and, in Taiwan, at the domestic level. Both the United Nations and the United States set up offices located in Taiwan and in the "Far East" to take care of the administration of aid distribusion. The Taiwanese government also set up special offices in charge of applying for, carrying out, and supervising aid programs.

attended ITU meetings.[16] The United Nations technical-aid program to Taiwan was mainly drafted by Chien and his colleagues working for the Bureau of Telecommunications. The Bureau of Telecommunications was a governmental agency in charge of telecommunications research to support the government's various levels of telecommunications projects, such as telephone systems. This research was of particular importance because many telecommunications providers were government-owned enterprises. Originally, Chien planned to apply for support from the UN Special Fund with an eye toward improving the training of telecommunications personnel in Taiwan. Personnel of the Bureau of Telecommunications who were also Chiao-Tung alumni helped Chien to write the June 1959 Chinese version of the draft proposal for the UN-NCTU technical-aid program. According to the version, Chien expected to apply for a technical aid program that would help train and educate Taiwanese scientists and engineers in fields such as

> …long-distance direct dial-up telephone systems, electronics-assisted flight systems, cutting-edge radar systems, semiconductors, servo systems, electronic control systems, wireless frequency meters, solar-battery applications of telephone systems to rural areas, multiple-line microwave telecommunications, transistor circuits, and transistorized telegraph carrier systems.[17] (Original in Chinese)

This 1959 proposal was similar to the set of recommendations made by another Chiao-Tung alumnus, Tsen-Cha Tsao, in 1956. Tsao then worked at Columbia University and had both taught in universities in China in the 1930s and served as an official in a number of government

[16] Gisson Chi-Chen Chien, "Jiao da dian zi suo yu lian he guo ji shu xie zhu [The Graduate Program in Electronics and U.N. Technical Assistance]," *The Voice of NCTU Alumni* 98 (1961): 4-7.
[17] "Shen qing lian he guo ji shu xie xhu te bie ji jin ji hua shu [An Application for U.N. Technical Aid]," June 1959, Ministry of Foreign Affairs Files, 635.31 0200, Institute of Modern History, Academia Sinica, Taiwan (hereafter MFA files).

agencies, mostly related to telecommunications. In 1956, he wrote an article for the celebration of the 60th anniversary of Chiao-Tung University. This article helped inspire Chiao-Tung alumni to petition for the establishment of their alma mater in Taiwan.[18] In this 1956 article, Tsao reviewed the recent progress in four fields of engineering science that had exercised "a profound influence on human life." The four fields were electronics science, servo-mechanisms, nuclear engineering, and digital electronic computers, all of which figured into Chien's Chinese version of the proposal, drafted in June 1959.

When elaborating on the application of digital electronic computers, Tsao stated,

> "Large-scale power plants in the United States could use digital computers to save labor and time in the process of printing bills for millions of customers every month. As for the military, because it is important to act swiftly in military actions, the application of digital computers in the military is noteworthy. Using analog simulators and digital computers, it only takes 0.0017 seconds to calculate the ballistic trajectory of a missile and to attack that missile." [19](Original in Chinese)

Many of the telecommunications fields mentioned in the aforementioned draft proposal and in Tsao's article could serve military purposes. Beginning in the 1950s, Chien, Tsao, and many of their contemporaries wanted to ensure Taiwan's security during the Cold War by promoting electronics research in such fields as radar, microwave communications, and servo

[18] "Jiao tong da xue she li dien zi yan jiu suo [National Chiao-Tung University Establishes a Graduate Program in Electronics]," *The Voice of NCTU Alumni* 61 (December 1957): 1-3. See page 1.
[19] Tsen-Cha Tsao, "Hua shi dai de mu xiao yu hua shi dai de gong cheng ke xue [Higher Education and Engineering Science in a Pivotal Era]," originally published in 1956, reprinted in *Gong cheng yu ke xue [Engineering and Science]*, (Zhing-hua Books, 1964), 54-66.

mechanisms, which could improve domestic telecommunications and defense systems. For example, two satellite radar dishes graced the cover of the December 1957 issue of Chiao-Tung University's alumni newsletter; the sentence below the photo reads "Electronics have guarded the free world."[20] Three months later, the cover of the February 1958 issue featured an aircraft on its way to land on a battleship and a transmitter-receiver that consisted of 78 vacuum tubes, which represented a part of a tactical air navigation system. On the margins of this cover was the declaration,

> Only studies in the field of electronics promote atomic research; only the promotion of research in electronics fortifies national defense; only use of electronics creates advanced industries; only development of electronics creates high civilization.[21] (Original in Chinese)

This type of language appeared in several of Chiao-Tung University's alumni newsletters, Chien's proposal, and Tsao's letter, and it generally indicates that the alumni considered Taiwanese scientists and engineers to be critical to research that could strengthen Taiwan's national defense.

The interest that mostly civilian Chiao-Tung alumni had in the possible military applications of electronics science and digital computers originated from the enthusiasm some civilians wanted to contribute to Taiwan's national defense in the Cold War setting. There was indeed some military assistance provided by the United States to Taiwan. The United States and

[20] "Feng mian shuo ming [Cover Picture]," *The Voice of NCTU Alumni* 61 (December 1957): 7; "Feng mian shuo ming [Cover Picture]," *The Voice of NCTU Alumni* 63 (February 1958): 33.
[21] [Cover Picture]," *The Voice of NCTU Alumni* 61 (December 1957): 7.

the Chiang Kai-Shek government signed the Sino-American Mutual Defense Treaty in 1954 to ensure their military alliance's formal parameters. As early as April 1951, the U.S. Military Assistance Advisory Group stationed itself in Taiwan and began providing military assistance to Taiwan. Beyond this basic fact, however, historians still have not clearly identified the military aspects of the Taiwan-bound U.S. technical assistance.

Electronics Science's Significance in the Ideologically Dichotomized Confrontation between Capitalists and Communists during the Cold War

Chiao-Tung alumni, especially those who were technocrats, believed that NCTU should take part in the free world's electronics-related research and development. As discussed earlier, the view that "electronics have guarded the free world" was, in 1957, a message that *The Voice of NCTU Alumni* espoused when arguing that electronics applications contributed significantly to strengthening the non-communist camp's military defense against the communist camp.[22] In 1958, Chiao-Tung Alumni's US chapter used similar language to describe this specific importance of NCTU. After the US chapter collected US$100,000 as part of the startup fund for establishing a graduate program in electronics at NCTU, Tsen-Cha Tsao on behalf of the US chapter wrote to S. M. Lee, the director of NCTU's graduate program in electronics, and Hung-Hsun Ling, a former president of Chiao-Tung University, to inform them of the related recommendations made by the US chapter in a recent meeting. The letter stated,

> The graduate program in electronics at National Chiao-Tung University and the graduate program in nuclear physics at National Tsing-Hua University exemplify that Free China

[22] Ibid.

> has made a resolution to emphasize scientific research and to execute it. Since the Soviet Union launched a satellite (Sputnik), the United States and all free [non-communist] countries have understood that we need to train as many scientific researchers as we can, in order to fight for the freedom of human beings. We all have to collaborate to collectively achieve efficacy herein. If we can propose a concrete and reasonable plan [for establishing the graduate program at NCTU], we shall be able to earn sympathy from the United States, sympathy that will perhaps enable us to obtain assistance from the United States.[23] (Original in Chinese)

Tsao argued that the overall scientific research in non-communist countries was a collective achievement. He also explicitly pointed out that the graduate program had to "contribute to the research of the free world."[24] He not only acknowledged the ideological boundary between non-communist and communist scientific research, but also suggested that Chiao-Tung alumni rhetorically use that boundary to mobilize assistance from the United States, especially considering that the Soviet Union's achievements significantly threatened the United States.

Similarly, two Chiao-Tung alumni who were technocrats in Taiwan interpreted the technical-aid program as an opportunity to take part in the free world's research and development of electronics. Hung-Hsun Ling, a former president of Chiao-Tung University and then president of Chinese Petroleum Corporation, brought up this shared responsibly among the

[23] "Liu mei tong xue hui nu li xie zhu chou jian dian zi yan jiu suo [US Alumni Help Set Up the Graduate Program in Electronics]," *The Voice of NCTU Alumni* 63 (February 1958): 3-5. Tsao reiterated the same ideas in "Jiao da yan jiu suo cheng li yi nian yi hou [One Year After the Establishment of the Graduate Program in Electronics]," *The Voice of NCTU Alumni* 82 (September 1959): 28-29.
[24] "US Alumni Help Set Up the Graduate Program in Electronics," 4.

free world on two different occasions in which he gave speeches to members of National Chiao-Tung University. The first occasion on which he encouraged alumni, faculty members, and students to contribute to the free world's research and development of electronics took place during the May 1962 public display of Taiwan's first digital electronic computer. In April 1963, while attending ceremonies celebrating the sixty-seventh anniversary of Chiao-Tung University's establishment, he made similar remarks echoed by Chi-Chen Chien, the head of the Bureau of Telecommunications in Taiwan. [25] Ling stated,

> All the faculty members and students in the graduate program in electronics should work together to pursue achievements in electronics research, collaborate and exchange information with higher educational institutes in the free world, shoulder the responsibility of developing electronics in the free world, and build an electronics industry for Free China.[26] (Original in Chinese)

"Catching up" in the Realm of Scientific Research

In contrast to Chiao-Tung alumni's belief that they should contribute to the free world was their acknowledgement that, across the globe, practitioners of scientific research should compete with one another, regardless of whether they belong to the capitalist camp or the communist camp.

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[25] Chian, "Mu xiao jiao tong da xue yan jiu suo zhi zhan wang [The Future of Our Alma Mater]," *The Voice of NCTU Alumni* 124 (April 1963): 3-15.
[26] See page 2 in "Mu xiao liu shi liu zhou nian xiao qing [Alma Mater Celebrates 66th Anniversary]," *The Voice of NCTU Alumni* 113 (May 1962): 1-4. See page 3 in "Qi yue fen tong xue lian yi hui [Alumni Meeting, July]," *The Voice of NCTU Alumni* 117 (September 1962): 1-4. Hung-Hsun Ling,"Ke xue yan jiu fa zhan de yi mian guan [One Aspect of Scientific Research and Development]," *The Voice of NCTU Alumni* 125 (May 1963): 9-10.

In May 1957, *The Voice of NCTU Alumni* published the article "Atoms and Electronics," in which the author, Chien, argued that electronics-science researchers should profit from the widely recognized importance of existing nuclear research. He first identified electronic instruments essential to nuclear research and nuclear reactors, and then reviewed the United States' recent application of computers and transistors to missile launching and missile detecting, to aircraft-navigation systems, and to military-related data processing.[27] He pointed out that "our country's science" was "backwards." Acknowledging that "science can help improve human beings' wealth," he stated that Taiwan should "catch up (*Zhui-Gan*) with current advances and should thereby avoid being excluded from 'the civilization of science'."[28]

In December 1957, the editor of *The Voice of NCTU Alumni* put together a special issue to introduce the important of electronics science for promoting the establishment of the National Chiao-Tung University in Taiwan, the editor concluded,

> We have to explain the uses of electronics science to the general public so that they can understand the importance of such research. They will be able to understand that our country has to catch up [with this research] as soon as possible (*Ji-Qi-Zhi-Zhui*). It is time to set up the graduate program in electronics![29] (Original in Chinese)

In 1959, Tsao commented on the scientific competition between the United States and the Soviet Union, concluding that the competition among counties was now "decided by a country's advantages in terms of its science," in the September issue of *The Voice of NCTU Alumni*. He

[27] His examples included the SAGE project and equipment distribution planning in Fort Huachuca.
[28] Chien, "Yuan zi yu dian zi [Atoms and Electronics]," *The Voice of NCTU Alumni* 54 (May 1957): 2-4.
[29] "Bian Zhe De Hua [Editor's notes]," *The Voice of NCTU Alumni* 61 (December 1957): 45.

pointed out that a country had to make "unmatched achievements in science, applied science, and equipment [technology]" so that the country could secure itself from enemies' attacks and achieve the status of "peace."[30]

In April 1961, *The Voice of NCTU Alumni* featured an article by a Chiao-Tung alumnus, Qin-Bo Ye. Entitled "One Step Further (*Geng Shang Ceng Lou*)," which implies making progress in Chinese, the article proposed that his alma mater should establish a graduate program in applied mathematics. Ye commented that "the Taiwanese government is no longer willing to remain in a subsidiary position and is ready to pursue [Taiwan's] 'scientific take-off'." He then asserted that applied mathematics is an important step in Taiwan's attainment of scientific take-off, and that this step should follow the recent establishment of graduate programs in atomic physics and in electronics at National Tsing-Hua University and National Chiao-Tung University, respectively.[31]

The term "scientific take-off" exemplifies Chiao-Tung alumni's discourse regarding their pursuit of improvements in Taiwan's scientific research, and reflects trenchant similarities between this discourse and the broader concurrent discourse regarding economic development. While countries in the capitalist camp were in a partnership of sorts, pursuing economic and scientific improvements, these same countries competed with one another to attain their own take-offs and to obtain advantages over partner-states.

[30] Tsao, "One Year after the Graduate Program in Electronics Established]," 29.
[31] Qin-Bo Ye, "*Geng shang ceng louzeng she ying yong shu xue yan jiu suo chu yi* [One Step Further: A Recommendation for Establishing a Program in Applied Mathematics]," *The Voice of NCTU Alumni* 100 (April, 1961): 30-31.

Electronics Science's Contribution to Taiwan's Economic Development:
Taiwanese Technocrats' Quest for a Research Institute Serving Basic Scientific Education

Beyond military and telecommunications applications, Chiao-Tung University-educated engineers, scientists, and technocrats believed that both electronics research and electronics applications might help improve Taiwan's economy. Specifically, these alumni wanted to nurture a large number of Taiwan-based domestic engineers and scientists who could strengthen the study of electronics on the island. (As mentioned earlier, the group's definition of 'electronics' included digital electronic computers.) The idea was that a large number of domestic engineers and scientists would be able to create an electronics-manufacturing industry, thus facilitating Taiwan's shift from an agriculture-based economy to an industrial economy. There were at least three cumulative steps leading to the realization of this idea: training a large number of domestic engineers and scientists, building an electronics-manufacturing industry, and achieving an industrial economy, as opposed to an agricultural economy.

Gisson Chi-Chen Chien believed that all three steps would necessarily rest on basic scientific education involving university laboratories equipped with the "latest equipment" and facilities. Noting that Taiwan had vigorously pursued "economic and industrial developments" after 1949, Chien wanted to establish a university research institute for "young scientists," "technologists," and "the brilliant youth who [had] already received their bachelor's degrees," so that these to-be-trained "specialists in the electronic field" could "render service in all industries."[32]

[32] "The Expansion of Electronic Research Institute and Establishment of Telecommunication Advanced Training Centre," June 1959, MFA files, 635.31 0200.

Dated June 1959, the drafted English translation of the Chinese-language proposal was entitled "The Expansion of Electronic Research Institute and Establishment of Telecommunication Advanced Training Centre" and enumerated some key points:

> 1. The expansion of this research institute…will serve to lay a sound foundation for the basic scientific research and development in various branches of electronics in order to solve to-day' [sic] and to-morrow's [sic] urgent problems with which the various sponsoring agencies have been confronted.
>
> 2. In addition, advanced studies in the [sic] electronic and radio engineering are designed to enable the talented candidates to pursue their work leading to the advanced degree in science so that they would be proficient not only in modern theories as well as the up-to-date techniques in telecommunications, but also in the use of the latest equipment.[33] (Original in English)

The Chinese version and the English version of the draft proposal (and later draft proposals) did not specify the means by which the trainees of this future research institute could contribute to or "render service" to industries. This type of vague connection between engineering education and the industrial sector can be found in other contemporary discourse. For example, in 1959, the aforementioned economist Chong-Rong Yin, a prominent bureaucrat and a Chiao-Tung University alumnus, commented that the training of engineers conducted in the graduate program in electronics at NCTU "started the development of [the] domestic

[33] Ibid.

electronics industry." Yin mentioned that the fields receiving attention at the newly established NCTU and including design of auto-control devices, design of remote-control devices, and digital electronic computing could improve industrial manufacturing in the long term. Although he brought up applications of electronic devices, he did not specify the devices on which the university or companies in Taiwan might conduct research.[34]

Chien argued that the future research institute should be located at NCTU and that the institute should improve Taiwan's current "small-scale production of the transistorized telephone carrier sets." Chien and another scientist, S. M. Lee, had earlier discussed the idea that NCTU should manufacture some electronic components *domestically*. In April 1958, when Chien learnt of the fact that Taiwan Sugar Corporation had rented unit record equipment (accounting machinery) from IBM, he commented,

> It would be great to have manufacturers of computing devices donate computers to the graduate program in electronics at National Chiao-Tung University. But, perhaps, in the near future, the graduate program may begin by purchasing parts to design and manufacture small-scale computing devices.[35] (Original in Chinese)

When the graduate program in electronics at NCTU celebrated its first anniversary in 1959, S. M. Lee, the director of the graduate program, with master's and Ph.D. degrees from MIT and Harvard University, expected that "the graduate program will purchase parts to design

[34] Chien, "Atoms and Electronics," 22-23.
[35] Chien, "Dian Zi Yan Jiu suo de qian zhan [The Future of the Graduate Program in Electronics]," *The Voice of NCTU Alumni* 65 (April 1958): 9-11.

and manufacture small-scale computing devices to meet researchers' demands."[36] Lee's estimation of the future of the graduate program was quite optimistic; two years later, he even envisioned a tougher task for this graduate program. In 1961, after discovering that the United Nations had approved the technical-aid program, he told journalists that "three years later, Chinese scientists will be able to use computers we manufacture ourselves." This statement was his evaluation of the positive effects that NCTU's rental of an IBM 650 computer through the UN-NCTU aid program would have on the scientists and the industry Taiwan.[37]

Both Chien and Lee were optimistic about the process by which their "brilliant youth" would establish an electronics-science industry, though the two commentators did not discuss the means in detail. Nevertheless, they were sure that their invitation of foreign "distinguished physicists and three technical experts", through a technical-aid program, to NCTU was one effective way to train the "brilliant youth." The 1959 draft proposal stated,

> After the invited research scientists come here to furnish the leadership for the electronic research and to advice [sic] us on matters of [sic] sound training system, it would not take very long time [sic] for our country to develop a team of talented young specialists in this field. Moreover, it cannot be denied that recently a number of competent college graduates who could not afford to study abroad and did feel very much down-hearted will have an adequate place for doing research works.[38] (Original in English)

[36] S. M. Lee, "Dian Zi Yan Jiu suo jiao xue fang zhen yu jin hou fa zhan [The Directions and Development of the Graduate Program in Electronics]," *The Voice of NCTU Alumni* 82 (September 1959): 11-14.
[37] "Dian zi ji suan yi jiao da dian zi yan jiu suo ji hua yu shi yue zhuang zhi [NCTU Will Set Up an Electronic Computer in October]," *The Voice of NCTU Alumni* 104 (August 1961): 23.
[38] "The Expansion of Electronic Research Institute and Establishment of Telecommunication Advanced Training Centre," 5.

In sum, Chien and his contemporaries believed that it was important to offer young college-educated youth an engineering education that could boast of a faculty including distinguished foreign experts. Outfitted with impressive training, the young engineers would powerfully benefit Taiwan's various engineering-related industries. Despite this optimism, UN-affiliated officials had different viewpoints and were interested in seeing Chien and Lee elaborate at great length on the connections between this proposed research institute and the electronics industry.

The UN Emphasis on Practical Engineers and Manufacturing Devices

Chien, working with the Ministry of Foreign Affairs in Taiwan, sent the 1959 draft proposal to two entities for review—the International Telecommunication Union (ITU) and the United Nations. ITU, established in 1865, started helping the United Nations review and carry out technical-aid programs in the 1950s.

On January 12, 1960, after reviewing Chien's proposal that requested a technical aid program to Taiwan, Jean Persin, a senior counselor at ITU, wrote a letter to the managing director of the UN Special Fund in New York City to express ITU's wholehearted support of the proposal.[39] Beyond ITU's informal approval of the proposed UN-NCTU technical-aid program, Jean Persin stressed the emphasis that ITU and the United Nations had been placing on industrial applications. Persin's emphasis stood in contrast to the basic scientific education proposed by

[39] Jean Persin to W. A. Lewis, Jan 12, 1960, MFA Files, 635.31 0200.

Chien. First, Persin pointed out that Chien's proposal went beyond a scenario in which the proposed technical-aid program would train students to become telecommunications engineers.

> It is true that the aims of the institute go somewhat beyond telecommunication properly so called, since the institute would train electronic physicists apart from engineers, and would give them a general scientific education. But telecommunication is developing in such a way that ever closer cooperation is required between the scientific theorists and the practical engineers. In this sense the institute in question would meet the demands made of it. (Original in English)

Persin euphemistically characterized Chien's emphasis on general scientific education and kindly ignored Chien's preference for the training of both physicists and engineers over the training of "practical engineers." Nevertheless, Persin generally expressed his confirmative support of the proposed technical-aid program. He acknowledged, in particular, the possible future contributions that the proposed technical-aid program could make to the "manufacturing of telecommunication equipment." Persin stated,

> The technical training thus given would, we consider, improve telecommunication in the country and would further the production of the electronic equipment required for improvement of telecommunication media. The description given also shows that China will be able to find work for all graduates of the institute, so that their training would be put to good use.[40] (Original in English)

[40] Ibid.

The UN's Emphasis on "Immediate and Direct Results for Economic and Social Development"

The UN Special Fund formally approved the proposed technical-aid program in May 1960. Tsing-Chang Liu, Director of the Treaty Department of the Ministry of Foreign Affairs in Taiwan was informed of this decision by Sir Alexander MacFarquhar, Regional Representative for the UN Technical Assistance Board and Special Fund for the Far East.[41] Thereafter, ITU and government representatives in Taiwan worked on finalizing the "Plan of Operation" for this aid program.

According to the available drafts of the Plan of Operation, ITU stressed that the proposed research institute at NCTU should "provide shorter training courses at a high level for scientists and technicians already engaged in the industry," in addition to offering engineers and physicists post-graduate courses.[42] The phrase "already engaged in the industry" was deleted by Taiwanese officials from different Ministries, S. M. Lee, and a manager from the state-owned electricity monopoly when these individuals met together to revise and edit the Plan of Operation in August 1960. When V. R. Sundaram, Chief of the Technical Assistance Department of ITU, went to Taiwan to finalize the Plan of Operation in November 1960, both he and the Taiwanese side chose to make it clear that NCTU was going to offer short-term courses for people from the industry.[43]

[41] Sir Alexander MacFarquhar to Tsing-Chang Liu, May 31, 1960, MFA Files, 635.31 0200.
[42] The three draft proposals were written on July 12, in August or September, and on November 9, 1960, respectively. See MFA Files, 635.31 0200.
[43] Ibid.

The emphasis on the connections between technical-aid programs and the industrial sector of the recipient country was related to the "efficacy" of aid programs. When T. E. Pigot, Deputy Regional Representative for the UN Technical Assistance Board and Special Fund for the Far East, visited Taiwan around July 1961, Pigot specifically pointed out that United Nations' technical aid was expected to bring about an "immediate and direct" effect. Secretaries in the Ministry of Foreign Affairs , who reviewed technical-aid proposals submitted by other Ministries used to compose a memorandum attributing to Pigot the following assertion:

> Any project which does not lead to immediate and direct result [*sic*] for economic and social development will not be entertained by the U.N. Special Fund.[44] (Original in English)

This expected efficacy of proposed projects reflects the main purpose of the establishment of the United Nations Special Fund, as the Fund was designed to supplement such existing technical-aid and economic-aid programs as the Expanded Programme of Technical Assistance, which was run by the Technical Assistance Board of the Economic and Social Council. *Yearbook of the United Nations 1958* stated,

> The Special Fund is thus envisaged as a constructive advance in United Nations assistance to the less developed countries which should be of immediate significance in accelerating their economic development by, inter alia, facilitating new capital

[44] Memorandum, July 4, 1961, MFA File, 635.31 0208.

investments of all types by creating conditions which would make such investments either feasible or more effective.[45] (Original in English)

Taiwan's Acknowledgment of the UN-NCTU Technical-aid Program's Contribution to Industry

The above section has described the communications between Sundaram, Pigot, Persin, the Ministry of Foreign Affairs, S. M. Lee, and Chien. The processes of reviewing draft proposals and revising the Plan of Operation indicate that ITU, the United Nations, and the Taiwanese sides had to negotiate with one another in order to meet the goals of the Special Fund and the demands of the Taiwanese side. Nevertheless, the emphasis placed by the United Nations and ITU on the practical industrial applications of the UN-NCTU technical-aid program to industry remained a highly espoused emphasis during the implementation of the technical-aid program.

After obtaining the funding from the Special Fund, NCTU established on its campus the Training and Research Centre for Telecommunications and Electronics. In this endeavor, NCTU invited three American professors to stay in Taiwan for one year, beginning in the summer of 1962, and another professor and a Bell Laboratories engineer to stay in Taiwan for one year beginning in the summer of 1963. From October 1962 to the end of 1963, NCTU offered six short-term training courses in fields such as microwave electronics, digital electronic computers, and modern communications systems, taught by these experts and by recent NCTU graduates.[46]

[45] "Chapter III the Economic Development of Under-developed Countries," 131-142.
[46] The Ministry of Foreign Affairs to NCTU, October 29, 1963, and S. M. Lee to the Ministry of Foreign Affairs, November 20, 1961, MFA File, 635.31 0202.

To recruit trainees for these short-term training courses, NCTU usually advertised through government agencies to personnel from the Ministries of Defense, of Transportation and Communications, and of Economic Affairs, which managed several state-owned monopolies, such as China Petroleum Corporation, Taiwan Sugar Company, and Taiwan Power Company.[47] Because of NCTU's recruitment strategy, the trainees of these courses consisted mostly of graduate students, university scientists, and scientists and engineers from government agencies or from state-owned enterprises; only a small portion of trainees hailed from private enterprises.

In October 1963, J. N. Corry, Regional Representative for the UN Technical Assistance Board and Director of Special Fund Programmes in the Far East, visited Taiwan and expressed his curiosity about where former trainees were employed.[48] Rather than tell Corry where trainees were working *after* their completion of courses in NCTU's Training and Research Centre, NCTU and Tsing-Chang Liu (in Taiwan's Ministry of Foreign Affairs) took an alternative, two-pronged approach: (1) he made a chart presenting a breakdown of trainees' jobs *before* the trainees had taken the courses, and (2) he argued that all post-course trainees were "back to their respective original posts."[49] The chart dealt with the 154 trainees who took training courses between October 1962 and the end of 1963: regarding these trainees' pre-course vocations, 36 had been serving in the military, 22 had been students at universities other than NCTU, 19 had been working at Taiwan Power Company, 15 at China Petroleum Corporation, 15 at the Bureau of Telecommunications, 4 at Taiwan Sugar Corporation, 2 at Taiwan Fertilizer Corporation—and a mere 2 trainees had been working at one of two private-sector enterprises (Hua-Seng Electronics,

[47] See recruitment advertisements in MFA File, 635.31 0202.
[48] The Ministry of Foreign Affairs to NCTU, October 29, 1963.
[49] Tsing-Chang Liu to J. N. Corry, November 25, 1963, MFA Files, 635.31 0202.

which appears to have manufactured radio sets, and Taiwan Cyanamid Company, which belonged to American Cyanamid Company).[50]

In December 1963, Corry wrote Tsing-Chang Liu, who worked in Taiwan's Ministry of Foreign Affairs. In the letter, Corry declared that he and the Managing Director of the United Nations Special Fund were satisfied with the chart's information and that the United Nations should require such information upon trainees' completion of an aid program. As Corry did not explain why merely two trainees were from the private industry, perhaps he was content with the overwhelming percentage of trainees from state-own enterprises, which to some extent counted as industry. Moreover, Corry stated that he was interested "of course in learning what happens to the post graduate students once they have secured their higher degree." He wanted to know how many recipients of a master's degree would enter an industry and how many would become instructor or researchers. [51]

Corry's request for statistical analysis of trainees' post-training employment resulted in figures that NCTU used to advertise its accomplishments regarding its engineering education in the 1970, when the Chinese Institute of Engineers (a professional association) published its 1970 volume of *The Previous Year's Engineering Accomplishments*.[52]

[50] S. M. Lee to the Ministry of Foreign Affairs, November 20, 1961.
[51] J. N. Corry To Tsing-Chang Liu, December 6, 1963, MFA Files, 635.31 0202.
[52] "Gio li Jiao tong da xue gong xue yuan fu she lian he guo dian zi dian xin xun lian yan jiu zhong xin dai xun ji shu ren yuan tong ji biao [Trainee Statistics, NCTU's Training and Research Centre for Telecommunications and Electronics], in *Yi nian lai de gong cheng jian she gai kuang [The Previous Year's Engineering Accomplishments]*, (Zhing guo gong cheng shi xie hui [Chinese Institute of Engineers], 1970), 92.

Another example illustrating the UN-NCTU technical-aid program's effects in connecting NCTU to industry was a comment made by S. M. Lee, the director of NCTU's graduate program in electronics. In August 1964, on an occasion honoring two Chiao-Tung alumni, S. M. Lee pointed out that, before implementing the technical-aid program, he had not regarded digital electronic computers as capable of contributing to industry. He stated,

> During the past three years, we used funding from the United Nations to obtain a considerable amount of equipment. We can proudly say that we have electronic computers in Taiwan now. NCTU was a forerunner in this effort. We did not envision that electronic computers could serve so many functions in industry…. Now we train people who work in such fields as transportation and telecommunications and who work for such institutions as Taiwan Power Company and China Petroleum Corporation…. In May, we held a workshop on the electronics industry, and currently, many companies including the China Electrics and Aluminum Corporation are interested in working with us.[53] (Original in Chinese)

Chiao-Tung Overseas Alumni's Acknowledgment of the UN-NCTU Technical-aid Program's Potential Contributions to Industry

The above paragraphs have described how the United Nations and S. M. Lee and Chien discussed the way in which the UN-NCTU technical-aid program had been contributing to industry in Taiwan. In addition to their work with the United Nations, S. M. Lee and Chien

[53] See page 17 in "Ying hai wai gui lai liang guo shi [A Welcome to Two Overseas Alumni]," *The Voice of NCTU Alumni* 140 (August 1964): 10-20.

collaborated with Chiao-Tung alumni who were residing in the United States, and the objective of this collaboration was to format and design the training courses. An interesting point is that the Chiao-Tung alumni were split regarding which roles the proposed NCTU research institute should play in Taiwan. Some Chiao-Tung alumni argued that NCTU should focus on conducting industrial research, and some expected that NCTU should lead the research in electronics science in Taiwan.

C. C. Wang, a Chiao-Tung alumnus and then a Sperry Rand engineer, suggested that a Cornell professor in electrical engineering, G. Conrad Dalman, serve as a UN expert for the UN-NCTU technical-aid program for one year, beginning in the summer of 1962. Dalman made a trip to Taiwan, but before he did so, Wang wrote to Hui Huang, a former general manager of Taiwan Power Company and then an IMF administrator, to discuss the possibility of starting vacuum-tube manufacturing in Taiwan. He pointed out that the future of the Taiwanese economy perhaps could rely on the manufacturing of electronics by taking advantage of the existing low-wage labor in Taiwan and the potential high-level techniques that NCTU might be able to develop. Wang urged Huang to discuss this issue with the aforementioned economic bureaucrat Chong-Rong Yin as a way to raise capital. In particular, as Dalman used to work on vacuum-tube design for years, NCTU should take advantage of his one-year visit to Taiwan to start engaging in the small-scale manufacture of vacuum tubes on campus.[54] What follows are two examples representing Chiao-Tung alumni's efforts to help the technical-aid program be successful in its duties and to come up with ideas about the roles that NCTU should play, given the university's access to substantial UN support.

[54] "Zhi de gong kai de ji feng guo wai you ren lai shu [Letters from Overseas Alumni]," *The Voice of NCTU Alumni* 120 (December 1962): 1-6.

Wang's idea was shared by another two alumni with whom he stayed in contact with. First, when he wrote the aforementioned letter to Huang, Wang was working with Tsen-Cha Tsao, who at this time occupied a research position at Columbia University. Wang hoped to purchase equipment that would enable Dalman to teach and conduct research in Taiwan. Wang argued that NCTU should initiate research geared toward the manufacture of electronics. Tsao talked to Wang about the matter:

> It is difficult for Taiwanese college students with high-level engineering training to find jobs in Taiwan, because the industrial development in Taiwan is backwards…. I hope the graduate program in electronics may improve the level of industry in Taiwan…. Isn't it the case that the exodus of National Chiao-Tung University's graduate students to the United States for the purpose of studying runs counter to outcomes that our University would like to see? The Taiwanese economy would not benefit from these [US-based] graduate students. Thus, it is important to develop our electronics industry and our graduate program at the same time. The education and training offered by the graduate program should meet the local demand. (Original in Chinese)

Wang and Tsao expected the graduate program at NCTU to experiment with the campus-based manufacture of vacuum tubes and to determine whether this production could be expanded to an industrial scale. There was a rationale for how the graduate program might benefit the Taiwanese economy: if the program developed its manufacture of vacuum tubes into an export-oriented industry, Taiwan might experience growth similar to that of Japan and Europe, which

"were implementing this type of policy."[55] Wang also discussed his ideas when meeting with Ta-Chung Liu, a Chiao-Tung alumnus teaching at Cornell University. Wang and Liu wrote a letter to the NCTU President and to S. M. Lee recommending three possible steps that the university could take in the direction of the outlined objective: (1) the university should pioneer research on manufacturing a chosen type of electronics (e.g., vacuum tubes), (2) the university should link it the research to a vocational field in which NCTU graduates could benefit from competitive compensation, and (3) the university should tailor the manufacturing to an export-oriented industry in Taiwan.[56]

Unlike Wang and Tsao, David K. Cheng (who was an alumnus working as an electrical engineering professor at Syracuse University) considered the technical-aid program a chance to improve the "level of science" in Taiwan. NCTU originally considered inviting Cheng to serve as a UN expert for the technical-aid program, but Cheng's schedule did not permit such a visit. Generally, Cheng agreed that the university should pursue electronics manufacturing. But, he pointed out that "manufacturing without ressarch [*sic*] or at least development work does not offer enough challenge to people with postgraduate degrees." He advocated "the preservation, utilization, and development of talents in electronics in Taiwan." The term 'preservation' referred to finding incentives that would encourage college graduates either to stay in Taiwan or to return to Taiwan after completing their master's or doctoral studies in the United States. In the summer of 1962, he wrote a letter to Taiwan-based Chiao-Tung alumni, arguing,

[55] Ibid., 1.
[56] Ibid., 2.

> As conditions stand now, one is afraid to go back [to Taiwan] for fear that highly technical knowledge is not really needed there and that one [who remains in Taiwan] would soon fall behind [other countries' related experts] due [*sic*] to [Taiwan's] stagnation in to-day's [*sic*] world of rapid technological progress.[57] (Original in English)

Cheng's emphases on research and "stagnation" in science and technology, instead of on the industrial sector, were similar to Chien's and S. M. Lee's ideas that the UN-NCTU technical-aid program should nurture "a team of talented young specialists in this field."[58] In line with the United Nations' and ITU's emphasis on practical applications of electronics, Wang, Taso, and Liu argued that NCTU should conduct research necessary for manufacturing and exporting vacuum tubes on an industrial scale.

These letters written by Wang, Tsao, Liu, and Cheng were published in the December 1962 issue of *The Voice of NCTU Alumni*. S. M. Lee commented on these letters by praising these alumni's patriotism, and he again acknowledged that NCTU had a responsibility to help develop Taiwan's electronics industry in particular and Taiwan's economy in general.

Discussion

As the Cold War in Taiwan included both military confrontations with communist China and an economic-development war with communist China, Chiao-Tung-educated engineers, scientists, and technocrats were enthusiastic about introducing Taiwan to the United States'

[57] Ibid., 4.
[58] "The Expansion of Electronic Research Institute and Establishment of Telecommunication Advanced Training Centre," June 1959.

cutting-edge electrical-engineering research. These advocates believed that electronics science could strengthen Taiwan's defense and telecommunications infrastructure. While Chiao-Tung alumni planned to take advantage of the instrumental nature of electronics science for military- and telecommunications-related applications, the alumni aimed to rely on electronics science to succeed in the ideological confrontation between the free world and the communist world. These Taiwanese engineers, scientists, and technocrats recognized their responsibility to participate in the non-communist camp's collective scientific research; they assumed that Taiwan's triumph would rest on the non-communist camp's success in scientific research. Nevertheless, ironically, these Taiwanese engineers, scientists, and technocrats identified with the competitions in scientific research within the non-communist camp.

Consistent with this particular Taiwanese social group's enthusiasm for "scientific take-off" was their belief that electronics science contributed to economic take-off. The group of Chiao-Tung alumni aimed to use the UN-NCTU technical-aid program to help institutionalize electronics-science research at NCTU, and they were interested in inviting US experts to educate Taiwanese engineers and scientists. They believed that this type of engineering education would create a large number of well-trained engineers and scientists, and who would then build an industrial sector in electronics manufacturing.

While Chiao-Tung alumni focused on engineering education itself, UN-affiliated officials emphasized the connections between NCTU and industries. Although both groups hoped that engineering education could help nurture an electronics-manufacturing industry, they held different ideas about how to do it. UN-affiliated officials expected that the university would

involve significant collaboration with existing industries in Taiwan. Through negotiations and mutual orientations during the process of proposal reviews and progress updates, Chiao-Tung-educated technocrats acknowledged the importance of creating connections with the existing industry, and UN-affiliated officials were satisfied with the fact that the UN-NCTU technical-aid program had been training more engineers from the existing state-owned enterprises than the existing private companies.

The UN-NCTU technical-aid program in question was a convergence of several different but intertwined ideas about engineering education and development. These different but related ideas about the ends and means of building an electronics-manufacturing industry illustrate Taiwanese engineers, scientists, and technocrats' participation in the economic-development war during the Cold War era. Electronics science, engineering education, and an envisioned electronics-manufacturing industry were central to Taiwanese engineers, scientists, and technocrats' strategies to cope with this economic-development war; the UN-NCTU technical-aid program helped Taiwanese engineers, scientists, and technocrats participated in this war.

The above discussion has shown that, in Taiwan, there was no strict divide between electronics science and digital electronic computing when Taiwanese engineers, technocrats, and scientists talked about the potential benefits of electronics science to Taiwan. When mentioning digital electronic computers, they would treat electronic-computer applications as a type of electronics-science application. The applications included accounting, ballistic-trajectory calculations, tactical air-navigation systems, and automation.[59] Taiwanese engineers, technocrats,

[59] See "US Alumni Help Set Up the Graduate Program in Electronics," 3-5. For the tactical air navigation system, see "Cover Picture," *The Voice of NCTU Alumni*, 1958. For automation, see Chien, "Atoms and Electronics," 2-4.

and scientists did not consider computers in a more "independent" way until an alumnus, Qin-Bo Ye, recommended establishing a graduate program in applied mathematics with a division in digital electronic computing. He imagined that this division would be responsible for "the design of transmission lines for electric power companies and statistics for nuclear energy experiments."[60] These rather sporadically proposed ideas about digital electronic computers became feasible projects, particularly after 1962, when Taiwan received its first digital electronic computer, an IBM 650. What follows is a brief description of the arrival of this computer to Taiwan in 1962.

From Suspicious Cargo to the Humming Machine

According to a report produced by the United Nations in 1968 for the UN-NCTU technical-aid program, a digital electronic computer was standard equipment for a "modern" electrical engineering school. The 1968 report stated,

> During the period of negotiation [between the United Nations and Taiwanese representatives in 1960] one major addition was made to the project. Since a modern electrical engineering school would have need of an electronic computer for the solution of research problems and since it was considered that training in computer applications, programming and operation would be useful to the country in general, the Special Fund agreed to assist in the establishment of a computer centre at the Institute by covering as

[60] Qin-Bo Ye, "One Step Further: A Recommendation to Establish a Program in Applied Mathematics," 30-31.

part of its equipment contribution the rental of an IBM-650 type computer for the duration of the project.[61] (Original in English)

This "major addition" refers to the fact that, in 1960, Taiwanese representatives obtained permission from the United Nations to *rent* a computer, rather than *purchase* one. In November 1960, V. R. Sundaram, Chief of the Technical Assistance Department of the International Telecommunication Union, visited Taiwan for finalizing the Plan of Operation of the UN-NCTU technical-aid program. He told Taiwanese representatives that the Special Fund office would question why the Taiwanese side planned to rent an IBM computer. He pointed out that the United Nations' aid programs aimed to help recipient countries *obtain* necessary equipment, but *renting* did not mean possessing. Nevertheless, at that time, IBM's standard approach to conducting business was to lease digital electronic computers or accounting machines to its customers. During a meeting with Taiwanese representatives, Sundaram asked them whether they planned to continue to rent the IBM computer after the end of the technical-aid program. S. M. Lee, one of the Taiwanese representatives and the director of the graduate program in electronics at NCTU, answered that they would like to do so, as the computer was important to the future of NCTU. Sundaram thus promised to make an effort to persuade the Special Fund office of the importance of a computer to NCTU. But he also suggested that the Taiwanese side should prepare a backup wish-list of research equipment, in case the Special Fund office would not agree to the rental of an IBM computer.[62] Three months later, in January 1961, Sundaram informed Taiwanese representatives that the United Nations had approved NCTU's rental of a

[61] *Training and Research Centre for Telecommunications and Electronics, Republic of China: Report* (Geneva: International Telecommunication Union, 1968). See page 6.
[62] Memorandum from the Second Meeting for Establishing the Training and Research Centre for Telecommunications and Electronics, November 15, 1960, MFA Files, 635.31 0200.

computer.[63] With this agreement settled, an IBM 650 computer arrived at the NCTU campus in February 1962.

Chao-Wu Lin, who was an NCTU student from 1964 to 1966, heard an anecdote about NCTU's IBM 650 computer: When the IBM 650 computer was being shipped to Hsinchu in 1962, the IBM 650 passed over a bridge guarded by several soldiers. At that time, the bridge was located in Hsinchu and allowed only one-way traffic, so soldiers were sent to help control and manage the traffic. The driver of the truck loading the IBM 650 computer drove at an extremely slow speed to avoid breaking the gigantic and sophisticated machine. The soldiers by the bridge were quite curious about what kind of cargo required this slow speed so they tried to figure out what the cargo was. An administrative staff member at NCTU at that time, Tang-Chin Kao, recalled, "The soldiers were not very happy with the slow speed on a one-way bridge."[64]

The soldiers' reaction might reflect the fact that most Taiwanese were not familiar with what a digital electronic computer was. On the contrary, a group of professionals in Taiwan had expected the arrival of a digital electronic computer since the late 1950s. The next chapter discusses how this group of professionals started to learn to operate and engage with the first two digital electronic computers in Taiwan. What follows is a section about the public display of this 'first' digital electronic computer, an IBM 650, in Taiwan.

[63] Letter from V. R. Sundaram to Gisson Chi-Chen Chien, January 13, 1961, MFA Files, 635.31 0200.
[64] Mei-Ling Lin, "Cheng gong de nan ren he ta bei hou de nu ren lin chao wu xue zhang ji xue sao fang wen ji [An Interview with Chao-Wu Lin]," from a collection of NCTU alumni interviews at NCTU's official website, accessed November 30, 2011, http://www.nctu.edu.tw/alumni/person/p7.html; and Tang-Chin Kao, "Dan bo ming zhi fu wu jiao da san shi nian zhi hui gu [Memories of my Thirty-year of Career at NCTU]," July 24, 2010, Jiao da ren de bu luo [NCTU alumni's website], accessed November 30, 2011, http://blog.alumni.nctu.edu.tw/plate/web/papermsg.jsp?UI=nctu_alumni_voice&PI=13442

The memory units and the processor of the IBM 650 arrived in Taiwan in February 1962, and the peripherals, such as its card reader and punch unit, were scheduled to arrive weeks later.[65] In March, NCTU administrators and alumni began to prepare for the university's 60th anniversary celebration, which would take place the following month. These anniversaries were annual celebratory events serving to encourage alumni to visit their alma mater. The university planned to schedule the computer's debut during that year's anniversary celebration. In the March issue of *The Voice of NCTU Alumni*, a monthly newsletter for the university's alumni, editors advertised the annual event by focusing on the newly arrived digital electronic computer. On a page listing alumni's donations, the editor of this issue wrote, "Are you interested in seeing an [digital] electronic computer? Please join us to celebrate the birthday of our alma mater next month." [66]

Partly because of Chiao-Tung alumni's enthusiasm for anything and everything having to do with their alma mater, and partly because of the general hoopla surrounding the island's first digital electronic computer, the debut of the digital electronic computer successfully attracted the attention of the anniversary celebration's attendees. On the sunny morning of April 8, 1962, eight hundred alumni and their families from Taipei reserved an express train of ten cars for a 90-minute trip to Hsinchu. At the same time, another two hundred alumni travelled to Hsinchu from the middle and south of Taiwan. The celebration ceremony started at eleven o'clock in the room at which the computer was located. NCTU planned to 'activate' the computer to the public to highlight NCTU's ownership of the first computer in Taiwan. The room was crowded with alumni, students, professors, and invited guests, including the IBM manager in charge of IBM's

[65] "Cheng li dian zi ji suan ji zhong xin [Establishing the Computing Center]," *The Voice of NCTU Alumni* 110 (February 1962), 42.
[66] Advertisement, *The Voice of NCTU Alumni* 111 (March 1962), 37

Far East business operations, Gisson Chi-Chen Chien (Director of the Directorate General of Telecommunications in Taiwan), and various well-known government officials who were Chiao-Tung alumni. Around eleven o'clock, the Minister of Education "press[ed] a button to initiate the operation of the computer." Editors of *The Voice of NCTU Alumni* noted, "The computer started to hum and calculate problems, which astonished the spectators." [67]

A ten-minute display of humming calculations kicked off the celebration, and then the spectators moved to a campus library and continued the celebration ceremony. Hung-Hsun Ling, a former president of Chiao-Tung University and the then president of Chinese Petroleum Corporation, made a remark on the responsibility of NCTU to the wider Taiwanese society. He noted that, with resources from the UN-NCTU technical-aid program, NCTU could contribute to the development of electronics science in the free world. In addition to government officials who praised their alma mater, the IBM manager in charge of IBM's Far East business operations gave a talk about the applications of the IBM 650 computers. (IBM opened a branch and started business operations in Taiwan in 1957. At that time, the Taiwan Sugar Company and the Taipei office of the US International Cooperation Administration, which was the predecessor of the United States Agency for International Development (AKA USAID now), rented IBM machines for their data processing tasks.)

The ceremony ended with remarks made by an Chiao-Tung alumnus who worked for the Radio Corporation of America (RCA) in the United States at that time. On the same day, IBM scheduled a film in the afternoon to introduce the IBM 650 computers to Chiao-Tung

[67] "Mu xiao liu shi liu zhou nian xiao qing [Alma Mater Celebrates 66th Anniversary]," *The Voice of NCTU Alumni* 113 (May 1962), 1-4.

alumni. While some Chiao-Tung alumni remained on the NCTU campus to watch the film, other alumni took a bus to the nearby National Tsing-Hua University campus to visit Taiwan's first nuclear reactor, which the Taiwanese government had purchased from General Electric (GE) for educational and research-related purposes.[68]

[68] Ibid.

CHAPTER 3

BUILDING A TECHNOLOGICAL SYSTEM OF MAINFRAME COMPUTERS IN TAIWAN, 1962-1964

By mid-1961, the group of Chiao-Tung-educated technocrats, engineers, and scientists and UN-affiliated officials had arranged a UN technical-aid program that was going to fund the Training and Research Centre for Telecommunications and Electronics on the campus of National Chiao-Tung University (NCTU), which then established the Institute of Electronics to offer master's degrees. As described in the preceding chapter, an IBM 650 computer, the digital electronic computer included in the budgeted equipment list of the UN-NCTU technical-aid program, arrived on the NCTU campus in February and debuted in a public display in April 1962.[1] While chapter 2 focused on Chiao-Tung alumni's advocacy of digital electronic computing, this chapter concentrates on the realization of that advocacy.

The chapter describes the process in which two American visiting professors, NCTU students, faculty members, operators, and technicians worked together to establish and "independently" operate a computing center located in the Training and Research Centre at NCTU. Their effort was central in implementing the technical-aid program from 1962 to 1964. After years of discussion about electronics science and digital electronic computers, this newly established NCTU computing center, equipped with an IBM 650, was able to provide a material and intellectual basis for academic learning in the field of digital electronic computing and for digital electronic computer infrastructure in Taiwan in the following decades. Although the IBM

[1] Because of the institution setting, the two computers were shared by three overlapping institutes: the graduate program in electronics at NCTU, the Training and Research Centre for Telecommunications and Electronics, and NCTU's computing center.

650 was a relatively obsolete model in the US context, it was the first digital electronic computer available in Taiwan. However, it was soon replaced by a newer model, an IBM 1620 computer, in 1964.

This chapter focuses how two American visiting professors and Taiwanese NCTU-affiliated members made the IBM 650 and later an IBM 1620 computer workable, in the social-technical senses, in Taiwan. Central to this chapter are the practices of building a technological system of mainframe computers. I divide this chapter into two parts; this division is not entirely an attempt to periodize this chapter, but to highlight intriguing contingencies that shaped the uses of two different computers in Taiwan. The first part explores how the first US visiting professor, Dean N. Arden, along with NCTU students, faculty members, and IBM engineers, kept the IBM 650 running as a usable technology in Taiwan. I show that different social groups contributed to setting up the NCTU computing center on the basis of the IBM 650 and established a technological system of digital electronic computers in Taiwan. The second part analyzes how the second US visiting professor, William Wesley Peterson, along with NCTU graduate students, faculty members, operators, a technician, and IBM engineers figured out how to use and maintain the IBM 1620. In particular, two things made the story of the IBM 1620 slightly different from that of the IBM 650: First, while renting the IBM 650, NCTU purchased the IBM 1620, which created some space for NCTU members to engage in maintaining the computer. Second, William Wesley Peterson believed that it was his duty to help the computing center "operate without outside help."

MIT's electrical engineering professor Dean N. Arden and another two US professors arrived in Taiwan in the summer of 1962 and started their teaching and advising at NCTU. By

using the IBM 650 computer, NCTU offered at least two training courses for 52 and 36 trainees, respectively, during Arden's one-year visit in Taiwan. Peterson succeeded Arden in the summer of 1963. During his one-year visit in Taiwan, NCTU offered four training courses; the first and second courses relied on the IBM 650 computer. Because NCTU acquired an IBM 1620 computer in February 1964, the third and fourth courses, held while Peterson was in Taiwan, relied on the IBM 1620 computer (see table 1).[2]

[2] Regarding Arden's and Petersons' arrival and departure dates, see 635.31 0202, MFA files.

Table 1: An Overview of Trainees in the First Seven Training Courses in Digital Electronic Computing at NCTU

Course Number	Numbers of Trainees in each Course	Computer Model	UN Expert	Date	Numbers of Trainees by Affiliations	
3rd	52	IBM 650	Arden	Dec. 1962 to Jan. 1963	CPC Military TPC Telecomm. Others	9 11 4 11 17
4th	36	650	Arden	Feb. 1963 to Jun. 1963	CPC Military TPC Telecomm. Others	0 7 0 0 29
5th	17	650	Peterson	Jul. 1963 to Aug. 1963	CPC Military TPC Telecomm. Others	3 1 5 3 5
6th	21	650	Peterson	Oct. 1963 to Dec. 1963	CPC Military TPC Telecomm. Others	2 6 5 2 6
8th	42	IBM 1620	Peterson	Mar. 1964 to May 1964	CPC Military TPC Telecomm. Others	2 8 5 4 23
9th	33	1620	Peterson	May 1964 to Jul. 1964	CPC Military TPC Telecomm. others	0 12 4 5 12
11th	38	1620	None	Nov. 1964 to Dec. 1964	CPC Military TPC Telecomm. others	6 1 3 5 23

Caption:
1. CPC refers to Chinese Petroleum Corporation; TPC refers to Taiwan Power Company; Telecomm. refers to government agencies of telecommunications and transportation.

2. The first, second, seventh, and tenth training courses were for microwave electronics and communications systems, so I do not list them here.

3. This table was organized by the author on the basis of the following three sources: *The Yearbook of Training Courses of Electronic Computers, February-June, 1963* (National Chiao-Tung University, 1963) and *The 11th Yearbook of Training Courses of Electronic Computers, November-December 1964* (National Chiao-Tung University, 1964), page. 19 and "Annex VI List of Training Courses," *Training and Research Centre for Telecommunications and Electronics, Republic of China: Report* (Geneva: International Telecommunication Union, 1968), page 51 (Hereafter *The 1968 UN Report*). There is a discrepancy between the three sources, but I have relied on mainly the information from *The 11th Yearbook,* as it provides more details about trainees' background.

Arden and NCTU's IBM 650 Computer, 1962-1963

In the following section, based on my oral-history interviews and analyses of journal articles, I analyze instructors and trainees involved in the training courses that used the IBM 650 computer and that variously spanned the period from December 1962 to June 1963 during Arden's visit. These instructors and trainees were also early digital electronic computer users in Taiwan.

The instructors at that time included Dean N. Arden and NCTU-educated students, offering their electronic-computing knowledge in the different ways. Arden advised graduate students and worked with NCTU-educated students to teach training courses and to render assistance to those in need of programming-related advice. As for the trainees, the majority in the training courses were from the military, universities, government agencies, and state-owned enterprises (partially because NCTU kept these state-related organizations well-informed and also exclusively gave them partial lodging and tuition waivers; see chapter 2). The diversified background of trainees reflected a variety of uses of the IBM 650 computer in Taiwan. According to available records, the IBM 650 computer became a tool not only for researchers in academic institutions, but also for scientists and engineers in a petroleum company and an electricity company. Nevertheless, it is worth noting that, before they attended the training courses, many of these trainees knew the potential of digital electronic computing to their work but did not have access to digital electronic computers; in this regard, NCTU's acquisition of its first digital electronic computer and NCTU's establishment of its first computing center in Taiwan were especially meaningful. The computer and the center connected different social groups and fulfilled their demands for computing, and eventually prompted the growing of a

technological system of digital electronic computers.

Different social groups, including instructors, trainees, and users, taught, learned, and practiced digital electronic computing after the IBM 650 arrived at NCTU in February 1962. These social groups met at the computing center at NCTU and eventually made the IBM 650 computer and the computing center become workable and useful tools to the first generation of Taiwanese electronic-computer users. My analysis emphasizes that the NCTU computing center was a unique place in Taiwan, as it not only provided computing services as other US university computing centers did at this time, but also became the point of departure for Taiwan's eventual technological system of mainframe computers.

Prior to the arrival of the IBM 650 computer, some Taiwanese social groups had known digital electronic computing from different sources.[3] Beyond that, three NCTU students went to Japan to receive training from IBM's Japan branch. As NCTU was the first institution to offer courses in programming and computer infrastructure in Taiwan, and the technical-aid program sent two American professors to Taiwan, a complicated web of interactions at NCTU helped begin and continue the momentum of the digital electronic computing in Taiwan. The following section illustrates that, at least in this particular Taiwan-based case, the installation of an IBM computer in a new place or institution neither naturally nor spontaneously engendered diverse uses of this new technology, such as engineering, accounting, and statistical analysis.

Instructors of Digital Electronic Computing

[3] By 'different sources' of knowledge, I do not mean different paradigms or epistemological differences.

Dean N. Arden's and the IBM 650 computer's arrival in 1962 signified the official debut in Taiwan of the institutionalization of digital electronic computing education. Just prior to this debut, Arden was a professor in the Department of Electrical Engineering at MIT.[4] During Arden's one-year visit in Taiwan, his offerings to NCTU trainees and graduate students included seminars on such matters as Boolean algebra, memory-circuit design, system-theory research, and system-optimization problems. He served as an adviser on three masters' theses concerning themes similar to the ones addressed in the seminars.[5] During Arden's time there, NCTU students gave him the nickname "A-Ding," which, being a variation of his last name, reflects how Chinese speakers assimilate English pronunciation into a Chinese form by using available Chinese vowels and consonants.[6]

While Arden taught courses mainly on computer architecture, he was also familiar with computer programming. Before starting his professorship, he joined MIT in 1953 in the Division of Industrial Cooperation to help faculty members and students improve programs for an array of mathematical problems.[7] On some occasions, Arden offered similar assistance in programming to Taiwanese scientists and engineers. According to Arden, a group of scientists visited his office at NCTU to consult on the programming of a complicated numerical analysis of elasticity. After a discussion to identify the involved mathematical problems, Arden spent a couple of days writing up programs to solve the related problems. When Arden invited the scientists to visit NCTU again and demonstrated how to make the IBM 650 calculate these problems, according to

[4] It is based on Arden's "Biographical Sketch" on January 1961 from the MIT Museum.
[5] *The 1968 UN Report*, 53, 55. The theses included "The reduction of minimum cost flow problem to the solution of Diode-Source network," "Essential hazards in asynchronous sequential switching matchings," and "Bounds on the error probability of digital modulation systems."
[6] Chi-Chang Lee, oral-history interview, January 7, 2009.
[7] Dean N. Arden, November 10, 2008, oral-history interview; according to the biographical sketch from the MIT Museum, before joining MIT, he was "a methods analyst at the University of Michigan Tabulating Service and a member of the research staff at the Willow Run Research Center."

Arden, the scientists were amazed by the fast speed at which the computer processed the problems. According to Arden, he was told that this group of scientists had been using abacuses to do the calculations, a process that took a considerably longer amount of time.[8]

I interviewed Arden about this whole sequence of events; however, as it had taken place more than four decades earlier, Arden could recall neither the names of the scientists nor the names of the scientists' affiliated institutes. However, from the reports produced for this technical-aid program and submitted to the United Nations, among the research projects that partially relied on the two mainframe computers at NCTU, three projects about elasticity are nameable: "Stresses in a Perforated Circular Ring," "Stresses in a Perforated Quadrant Plate," and "Stresses in a Plate having an Elliptic Notch under Tension."[9] The researcher of all three projects was a leading and prestigious scientist at that time: Chih-Bing Ling, a native of China who received a Ph.D. in aeronautics from the University of London in 1937 and a D.Sc. in applied mathematics and elasticity from the University of London in 1959. Ling moved to Taiwan shortly after 1949 and worked as a researcher in Academia Sinica (the national academy of Taiwan). In 1964, Ling became a professor in the department of mathematics at Virginia Polytechnic Institute and State University.[10]

Ling published the project entitled "Stresses in a Perforated Circular Ring" in a journal in 1974, but did not refer to his use of digital electronic computers in this article. Nevertheless, he pointed out in another of his journal articles, submitted in October 1963 and published in July

[8] Dean N. Arden, November 10, 2008, oral-history interview.
[9] *The 1968 UN Report*, 53.
[10] John W. Layman and Harry L. Johnson eds., "A biographical Sketch of Chih-Bing Ling," in *Collected Papers in Elasticity and Mathematics of Chih-Bing Ling Volume II*, eds. John W. Layman and Harry L. Johnson, (Blacksburg: Virginia Polytechnic Institute and State University, 1979), iii.

1964, that he appreciated Dean N. Arden's "help in preparing Table 3 by using an IBM-650 electronic computer."[11]

Arden and the IBM 650 computer facilitated Ling's research. Ling had relied on human computers (or according to Arden, on an abacus) prior to drafting his 1964 article. Ling's 1964 article was entitled "Evaluation at Half Periods of Weierstrass as'Elliptic Function with Rhombic Primitive Period-parallelogram" and co-authored with Chen-Peng Tsai. Tsai had helped Ling conduct computing since 1952, and Ling acknowledged Tsai's help in "performing the numerical computations" on many occasions. Tsai was a scientific officer in the Aeronautical Research Laboratory in Taiwan as early as 1960.[12]

Owing to the newly available IBM 650 computer, Ling transitioned from using human computers to using digital electronic computers for his research, and did so with Arden's assistance. In 1964, Ling published his article about Weierstrass' Elliptic Function. But, in 1960, he had published an article entitled "Evaluation at Half Periods of Weierstrass' Elliptic Function with Rectangular Primitive Period-Parallelogram" (submitted in 1958). Both the 1960 article and the 1964 article dealt with similar mathematical problems; however, whereas the 1960 article was based on human computing, the 1964 article was based on digital electronic computing. Specifically, in the 1960 article, Ling expressed his thanks to Tsai "for his assistance in

[11] Chih-Bing Ling, "Stresses in a Perforated Circular Ring," *Applied Scientific Research* 29, no. 1 (1974): 99-120; Chih Bing Ling and Chen-Peng Tsai, "Evaluation at Half Periods of Weierstrass' Elliptic Function with Rhombic Primitive Period-Parallelogram," *Mathematics of Computation* 18, no. 87 (1964): 433-40

[12] It is unclear when precisely he started work as a scientific officer. The earliest record I have refers to 1960. See Chih-Bing Ling, "On the Stress in a Notched Strip," *Collected Papers in Elasticity and Mathematics of Chih-Bing Ling Volume I* (Taipei: Institute of Mathematics, Academia Sinica, 1963), 207-212; Chih-Bing Ling and Chen-Peng Tsai, "Stresses in a Slab Having a Spherical Cavity Under Circular Bending," *Collected Papers in Elasticity and Mathematics of Chih-Bing Ling Volume I* (Taipei: Institute of Mathematics, Academia Sinica, 1963), 341-5. See page 212 and 342.

performing the numerical computations" and to professor C.W. Nelson at the University of California, Berkeley "for checking the manuscript and verifying all the numerical values in Table 1 and 2 by independent calculations." Nevertheless, in Ling's papers published after 1964, he acknowledged his uses of digital electronic computers. In particular, he was relying on NCTU's IBM 1620 computer for his research in 1964.[13]

In a phone conversation in 2008, Arden summarized his trip to Taiwan by saying "I showed them the power of the computer."[14] To some extent, this statement is correct, as he was the first instructor in Taiwan to teach this subject. But, beyond Arden, a couple of different social groups also played a role in the introduction of digital electronic computing to Taiwan, upon the arrival of the IBM 650 computer.

In addition to Arden, two instructors, Henry Y. H. Chuang and Hua-Ting Chieh, who graduated from NCTU in 1960 taught training courses in digital electronic computing from 1962 to 1963. Chuang and Chieh graduated from the first class of the master's program in electronics in 1960; this class was, in fact, the first to graduate after NCTU's commencement of operations in Taiwan. They received training from IBM's Japan branch for six months, and then came back to Taiwan to teach digital electronic computing at the same time as Arden was working in Taiwan. Before NCTU could be certain about whether the United Nations would agree to fund NCTU's leasing of the IBM 650 computer, Chiao-Tung alumni organized a fund to buy a digital

[13] For his use of the IBM 1620 computer, see Chih-Bing Ling, "Evaluation at Half Periods of Weierstrass' Elliptic Functions with Double Periods 1 and e^{ia}," *Mathematics of Computation* 19, no. 92 (1965): 658-61; or see page 269 in *Collected Papers in Elasticity and Mathematics of Chih-Bing Ling Volume II*. Furthermore, on page15, 27, 95, 370 in *Collected Papers in Elasticity and Mathematics of Chih-Bing Ling Volume II*, he acknowledged his uses of IBM 7040, 360, and 370.
[14] Dean N. Arden, phone interview, October 4, 2008.

electronic computer for their alma mater and to support three recent NCTU graduates' digital electronic computer training in Japan. (As the United Nations eventually decided to fund NCTU's leasing of the IBM 650, NCTU may have used proceeds from its own alumni fund for such expenditures as the purchase of other equipment.) The two instructors' training in Japan indicates that Chiao-Tung alumni and NCTU were well-prepared for the arrival of the IBM 650 computer.

Henry Y. H. Chuang enrolled in the master's program in electronics at NCTU in 1958 and received his degree in 1960. Chuang remembered that his return to Taiwan from Japan was October 1961, before the IBM 650 computer's arrival in 1962.[15] Chuang and Chieh taught applied mathematics (such as numerical analysis) and computer programming for at least two training courses at the Training and Research Centre, and their photos were placed right next to Arden's in the yearbook for the training course that lasted from February to June 1963. The photographs of Chuang and of Chieh are similar to the one of Arden. Each of the three men is standing in front of a blackboard on which mathematical problems have been scrawled.[16] Chuang left Taiwan in 1963, and went to the United States to study digital electronic computing. He received a Ph.D. in Electrical Engineering from North Carolina State University, taught at the Department of Applied Mathematics and Computer Science of the Washington University in St. Louis and then the Department of Computer Science of the University of Pittsburg, and retired there.

[15] Oral-history interview with Henry Y. H. Chuang, June 7, 2009.
[16] Ibid.; *The 1968 UN Report*, 49.

Trainees and their Previous Knowledge of Digital Electronic Computing

While Chiao-Tung alumni advocated electronics science and digital electronic computing in the late 1950s (see chapter 2), and while Chuang, Chieh, and Arden taught digital electronic computing from 1962 to the summer of 1963 at NCTU, several social groups possessed a certain degree of knowledge of digital electronic computing at the same time. For example, some personnel from the military, Taiwan Power Company, and Chinese Petroleum Corporation (CPC) understood the potential of digital electronic computers at this time, even though they had no access to the new technology.

Among the 126 people who took NCTU's "IBM 650 computer"-reliant programming courses from December 1962 to December 1963, 14 were from Taiwan Power Company, 14 from CPC, and 16 from telecommunications-related government agencies (see table 1). There were 25 trainees from military units in fields such as data processing, intelligence, accounting, technological research, and the military's science and engineering colleges.[17] Henry Y. H. Chuang pointed out that when he talked with military trainees, he found that some of them had used electronic computing devices before, such as code breaking devices, though Chuang had no clue about whether these trainees, in their own military units, had gained access to electronic computers.[18] From the currently available records, it is unclear how the 25 military-affiliated trainees used the knowledge they learnt at NCTU. Nevertheless, it is worth noting that NCTU seemed to engage in general purpose electronic computing prior to the Taiwanese military and

[17] See table 1.
[18] Oral-history interview with Henry Y. H. Chuang, June 7, 2009.

that NCTU perhaps even became a source of knowledge for the military.[19]

Although Chiao-Tung alumni were visionary in bringing electronic-computing education to Taiwan, Taiwan Power Company researchers were already familiar with the potential of electronic computers, because electricity-related engineering required complicated calculations. Prior to having access to NCTU's IBM 650 in 1962, engineers and researchers of the company used analog computers (owned by the company), conducted manual calculations with slide rules and abacuses, and discussed issues about manual calculations, analog computing, and the possibility of using digital electronic computing in the company's technical journal—*Monthly Journal of Taipower's Engineering*.[20] For example, engineer Yuan-Kuan Chen wrote an article that appeared in a 1962 issue of the aforementioned journal and that concerned the application of analog computers to the coordination of hydraulic and thermal power plants' electrical supplies; another example is of engineer Jia-Hui Zhou, who wrote an article that appeared in a 1963 issue of the same journal and that discussed the same coordination problems, but this time in relation to a Japanese company's use of an IBM 650 computer.[21] These two researchers examined the coordination problem to create models for forecasting supply and demand of electricity. Their work was important because both the number and the intensity of Taiwan-bound typhoons are unpredictable and significantly affect the amount of rainfall.

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[19] Historians know little about the history of military uses of digital electronic computing in Taiwan. Archival documents that are not yet publicized may be helpful to provide a more complete picture of this history. For a discussion of classified archival materials, see Michael Aaron Dennis, "Our First Line of Defense: Two University Laboratories in the Postwar American State," *Isis* 85, 3 (1994), 427-55.

[20] Oral-history interview with Yuan-Kuan Chen, Aug. 22, 2009. Yuan-Kuan Chen, "Jian dan bi zhao ji suan ji zhi zu cheng ji qi ying yong [The Applications of Analog Computers]," *Tai Dian Gong Cheng Yue Kan* (Here after *Monthly Journal of Taipower's Engineering*) 144 (1960): 4-30. Chang-Yuan, Zhang, "Liang zhi ji suan chi qiu chi du fa [Using the Slide Rule Method for the Sag of Transmission Lines]," *Monthly Journal of Taipower's Engineering* 145 (1960): 35-8.

[21] Yuan-Kuan Chen, "Dian li xi tong jing ji yun yong gai lun [An Introduction to the Coordination of Power Systems]," *Monthly Journal of Taipower's Engineering* 166 (1962): 18-25.
Jia-Hui Zhou, "Dian yuan jing ji kai fa fang shi yu dian zi ji suan ji zhi ying yong [Electricity Developing and the Application of Electronic Computers]," *Monthly Journal of Taipower's Engineering* 172 (1963): 5-8

Despite their awareness of the potential of digital electronic computers, Taiwan Power Company engineers had rather indirect access to digital electronic computers until the company rented an IBM 360 computer in 1966. Beginning in 1962, not only researchers and engineers but also accountants from the company enrolled in the NCTU training courses to study the uses of the IBM 650 computer. In particular, most of these trainees from Taiwan Power Company belonged to one of two major research-and-development departments in the company: the Department of Planning (*qi hua*) and the Department of High-voltage Research (*gao ya yan jiu suo*).[22] After completing their training courses at NCTU, many of these Taiwan Power Company personnel would work on their company-related engineering or accounting problems at NCTU's computing center.

Among these Taiwan Power Company trainees was Yuan-Kuan Chen, who exemplifies the exchanges of digital electronic computing expertise that took place between NCTU and Taiwan Power Company. Prior to NCTU's acquisition of the IBM 650, Yuan-Kuan Chen published two papers (in 1960 and 1962) on analog computing in *Monthly Journal of Taipower's Engineering*.[23] He then enrolled in an NCTU digital electronic computing training course, lasting from July to August 1963. In December 1963 he wrote another article in *Monthly Journal of Taipower's Engineering*: this one was about how to program an IBM 650, a topic that would have helped introduce digital electronic computing to his colleagues.[24]

[22] Oral-history interview, in February 5, 15, and 25, 2009, with Pin-Yen Lin, who helped me find out which departments these trainees used to work in the Taiwan Power Company.
[23] Yuan Kuang Chen, "The Applications of Analog Computers" and "An Introduction to the Coordination of Power Systems."
[24] Yuan Kuang Chen, "Shu zhi dian zi ji suan ji zhi cheng xu ji hua [Programming on Digital Electronic Computers]," *Monthly Journal of Taipower's Engineering* 184 (1963): 21-27.

When Taiwan Power Company decided, in 1965, to rent an IBM 360 computer, the latest digital electronic computer from IBM at that time, several researchers and engineers who had attended NCTU training courses wrote articles for *Monthly Journal of Taipower's Engineering* to introduce programming principles underlying the IBM 360 and to "help our [their] company prepare for the arrival of the IBM 360."[25]

Taiwan Power Company personnel's experience with NCTU's computing center contributed to the establishment of its own computing center. Other institutions followed a similar trajectory when they rented IBM's digital electronic computers. For example, National Taiwan University (NTU) sent recent graduates to learn programming at NCTU, and in the summer of 1964, NTU formed its own computing center after renting an IBM 1620 mainframe computer. In contrast, another university, National Tsing-Hua University (NTHU), acquired a digital electronic computer for its computing center much later: perhaps because the NTHU campus neighbored the NCTU campus (enabling the former university to rely on the latter university for computing needs), NTHU did not establish a computing center until 1968. A highly prominent member of NTHU's computing center was Tseng-Yu Lee, a faculty member who graduated from NCTU in 1962 and who became a member of NCTU's first generation of computer users. As the hub of the expertise of digital electronic computing in Taiwan, NCTU benefited subsequent Taiwanese computing centers in the 1960s, as the above cases demonstrate.

[25] Hong-Ren Li and Yuan Kuang Chen, "Dian zi ji suan ji dian li chao liu ji suan cheng xu ji qi ying yong (1) [Electricity Programming and its Applications Part I]," *Monthly Journal of Taipower's Engineering* 199 (1965): 4-10; Chiang-Chang Huang, "IBM360 dian zi ji suan ji yun yong zhi ji ben gai nian (1), Using the IBM 360 Part I," *Monthly Journal of Taipower's Engineering* 213 (1966): 34-37; "IBM360 dian zi ji suan ji yun yong zhi ji ben gai nian (2), Using the IBM 360 Part II," *Monthly Journal of Taipower's Engineering* 214 (1966): 33-38.

Chinese Petroleum Corporation (CPC) expressed enthusiasm for the IBM 650 soon after its arrived in Taiwan in February 1962. I-Chian Tsan, the head of the Department of Exploration and Drilling, led his 20 CPC personnel on a visit of NCTU in mid-February 1962.[26]

As mentioned earlier, from December 1962 to December 1963, the 126 people took NCTU's programming courses, which relied on the IBM 650 computer; and of these trainees, 14 were from CPC. After the 1620 computer arrived in 1964, W. Wesley Peterson specifically offered two three-day seminars, entitled "Computer Applications," to 70 CPC engineers and staff in July 1964.[27] With access to the IBM 650 computer and, later, the IBM 1620 computer at NCTU, CPC staff conducted several research projects entitled "Analysis of Reformed Oil," "Computation for Fuel under Different Temperature," "A Geophysical Problem," and "Strategraph Sedimentation."[28]

The transitioning from human computing to digital electronic computing and from analog computing to digital electronic computing also occurred in the career of a CPC geologist, in addition to mathematician Chih-Bing Ling, engineers and researchers at Taiwan Power Company. Pei Jan Lee, the CPC geologist, enrolled in NCTU's training course in digital electronic computing in February 1963, used the IBM 650 computer for his research on sediments, and submitted his article to CPC's research journal, *Petroleum Geology of Taiwan,* in August 1963.[29] Arden, Chuang, and Chieh were the instructors at NCTU when Lee attended courses there. In

[26] "Shi you gong si tan kan chu pai yuan lai suo can guan ji suan ji [Chinese Petroleum Corporation Personnel Visited NCTU for Computers]," *The Voice of NCTU Alumni* 111 (March 1962), 42.
[27] *The 1968 UN Report,* 54.
[28] Ibid., 57.
[29] *The Yearbook of the Training Course of Electronic Computers, February-June, 1963* (National Chiao-Tung University, 1963)

Lee's paper, he pointed out that he had not obtained satisfactory research results until a digital computer had become available in Taiwan[30]:

> A few years ago, the writer noticed that polynominal approximation can be used to filter out some local components of a sedimentary rock, but to compute the polynominal of best fit by the least-squares method was very tedious. The writer stopped studying this method to avoid spending time and money until the high speed digital computer became available in Taiwan for research work.[31] (Originally in English)

A Newer Generation of Instructors and Programmers

After the summer 1962, a group of new instructors joined the computing center. These instructors just received their master's degrees from NCTU. For example, Chi-Chang Lee completed his master's thesis on switching circuits in the summer of 1962 and started to work as Arden's teaching assistant thereafter. After Arden left the center in 1963, Lee started to teach courses on switching circuits and computer operations. From 1965 to 1974, he acted as director of the computing center. Similar to Arden's interactions with mathematician Chih-Bing Ling, Lee's offerings of assistance to variously situated scientists and engineers strengthened their efforts to solve various programming-related problems. Around 1965, Chi-Chang Lee conducted a research project for the Taiwan Railways Administration, and in this endeavour, he used NCTU's IBM 1620 computer to calculate target speeds and distances for a train that is in various

[30] Pei Jan Lee, "Correlation of Sediments by Using an Electronic Digital Computer," *Petroleum Geology of Taiwan*, 2 (1963): 137-47. Pei Jan Lee went to Canada in 1965 and received a Ph.D. degree from McMaster University in 1968. He worked for Home Oil Company in Canada and the Canadian government after his graduation. See "In Memory of Pei Jan Lee," an obituary listed on the website of Overseas Chinese Earth Science and Technology Association, accessed November 30, 2011, http://www.geochina.org/announce/03-20-2000.htm

[31] Lee, "Correlation of Sediments by Using an Electronic Digital Computer," 138.

states of movement.[32]

Tseng-Yu Lee was a frequent visitor of NCTU's computing center. He received his master's degree from the Institute of Electronics (i.e. the graduate program in electronics) at NCTU in 1962, worked—upon graduation—for chemical physicist Chi-Hsiang Wong at National Tsing Hua University (NTHU). Lee went to the NCTU computing center to use the IBM 650 computers for performing least-squares calculations, Fourier synthesis, and difference synthesis to determine the arrangement of crystals' atoms. Apart from his own use of the IBM 650 computer, Tseng-Yu Lee also wrote and shared programming packages for calculating least squares and matrix summation with other computer users. With thousands of data and hundreds of parameters, he used NCTU computers to approximate the locations of atoms. During an oral-history interview, he commented that manual calculations would likely have been impossible.[33] NTHU funded his use of computer time, and according to his memories of those years, he reserved NCTU computers for at least 150 hours while working on one of Wong's research projects.[34]

Lee published two papers, co-authored with Chi-Hsiang Wong, in *Acta Crystallographica* in 1965 and 1969.[35] The latter one was also co-authored with a Taiwanese scholar, Yuan-Tseh

[32] See the annual report of the Long-TermNational Science Development Council (the predecessor of the National Science Council) in Taiwan, published in April 1965; "Ling hong xun jiang zuo shou jie de jiang ren li qi chang fu jiao shou [Chi-Chang Lee Won the First Hung-Hsun Ling Award]," *The Voice of NCTU Alumni* 165 (September 1966), 19; Oral-history interview with Chi-Chang Lee, January 7, 2009.
[33] Oral-history interview with Chi-Chang Lee, January 7, 2009; Chi-Hsiang Wong, Tung-Mou Yen, and Tseng-Yu Lee, "The Crystal Structure of Uranium Chloride π-tricyclopentadienyl," *Acta Crystallographica* 18 (1965): 340-345 (The manuscript was received on 13 January 1964).
[34] Oral history interview with Tseng-Yu Lee, January 7, 2009.
[35] Chi-Hsiang Wong, Tung-Mou Yen, and Tseng-Yu Lee, "The Crystal Structure of Uranium Chloride π -tricyclopentadienyl"; Chi-Hsiang Wong, Tseng-Yu Lee, and Yuen-Tseh Lee [Yuan-Tseh Lee], "The Crystal Structure of Tris (cyclopentadieny) samarium (III)," *Acta Crystallographica* B25 (1969): 2580-4.

Lee, who became a Nobel laureate in 1986 for his research on the dynamics of chemical elementary processes.[36]

Lee's use of computers was not unique at that time. As early as December 1949, the leading journal of crystallography, *Acta Crystallographica*, collected a series of papers to introduce the "the application of punched-card methods in crystalstructure analysis," and these papers were "intended for the benefit of readers not familiar with the use of Hollerith and IBM machines." [37] From 1949 to 1965, there were hundreds of papers published in the journal concerning crystal-structure analyses based on punch-card machineries or digital electronic computers, including IBM 650s and IBM 1620s.

Tseng-Yu Lee insisted that he had learnt computer programming from reading a book, the title of which he did not recall. But he remembered that he had read the book in conjunction with an NCTU course on numerical analysis. When I asked how he had been able to learn on his own, he answered, "I could do debugging later."[38] Lee's remarks could be a slight exaggeration. If one could have learnt digital electronic computing solely from reading a book in Taiwan, Chuang would not have had to receive training at IBM's branch in Japan.

[36] The prize was jointly awarded to Dudley R. Herschbach, Yuan-Tseh Lee, and John C. Polanyi**.** According to the Council for the Lindau Nobel Laureate Meetings, Lee was awarded for his work on using "information derived from angular and velocity measurements of elementary reactions in vacuum to understand the dynamics of chemical reactions." See the website of the Lindau Nobel Laureate Meetings and http://www.lindau-nobel.org and the Official Website of the Noble Prize http://nobelprize.org/nobel_prizes/chemistry/laureates/1986/press.html, accessed November 30, 2011.

[37] See page 341 in E. G. Cox and G. A. Jeffrey, "The Use of 'Hollerith' Computing Equipment in Crystal-Structure Analysis," *Acta Crystallographica* 2 (1949): 341-343. In this paper, Cox and Jeffrey cited Wallace J. Eckert's 1940 book *Punched Card Methods in Scientific Computations* (New York: Thomas J. Watson Astronomical Computing Bureau, Columbia University).

[38] Oral-history interview with Tseng-Yu Lee, January 7, 2009.

Regardless of whether Tseng-Yu Lee learnt digital electronic computing from reading a book or from studying with the aforementioned instructors or from practicing on digital electronic computers or—what is most likely—from some combination of all three approaches, he became an important figure in digital electronic computing in Taiwan, following a career path similar to that of Chi-Chang Lee. Tseng-Yu Lee went to MIT as a visiting researcher in the Department of Mathematics for one year in 1967, and Chi-Chang Lee also went to MIT as a visiting faculty member in the Department of Electrical Engineering in the same year.[39] They were also housemates when they lived in Massachusetts. After returning to Taiwan in 1968, Tseng-Yu Lee became the director of the computing lab at NTHU's Department of Physics. The computing lab was a newly established unit because of NTHU's acquisition of an IBM 1130 mainframe computer, the first computer on the NTHU campus. At this time, Chi-Chang Lee was the director of the computing center at NCTU.

Chuang, Chieh, Arden, and Chi-Chang Lee were not the only members working for NCTU's training courses in digital electronic computing from the summer of 1962 to the summer of 1963. Secretary Da-Fang Li also helped facilitate the functioning of the two training courses in digital electronic computing. S. M. Lee, the director of the NCTU graduate program (see chapters 2 and 3) and Chu-Yi Chang, a dean of NCTU (see chapter 5) oversaw the training courses, but were not directly involved in teaching routines. Hung-Hsun Ling, a former president of NCTU (see chapter 2), had some interactions with Arden, and another two UN experts, G. Conrad Dalman and Henry McGaughan, as Dalman collected a pile of photographs that Ling took with these UN experts in different circumstances such as semi-formal meetings or social

[39] Oral-history interview with Tseng-Yu Lee and Chi-Chang Lee, January 7, 2009; "Mei zhou zong xiao you hui zhi xing wei yuan hui hui yi ji lu [Memorandum of the Recent Chiao-Tung Alumni's US Chapter Meeting]," *The Voice of NCTU Alumni* 181 (January 1968), 19.

gatherings. (Nevertheless, it is unclear whether NCTU hired an operator for the IBM 650 computer.)

Discussion

In order to facilitate Chiao-Tung alumni's efforts to nurture a group of well-trained engineers, the UN-NCTU technical-aid program set up the NCTU computing center to offer electronic-computing training to graduate students and to state-owned enterprise engineers. The NCTU computing center was the hub for Taiwanese scientists and engineers seeking to use computers in the early 1960s. Different social groups, including instructors, trainees from different state-owned enterprises, taught, learned, and practiced digital electronic computing after the IBM 650 arrived at NCTU in February 1962. The uses of the IBM 650 indicate a considerable acceptance of digital electronic computing in Taiwan's universities and state-owned enterprises.[40] As the IBM 650 was the only digital electronic computer in the country, its users included a wide range of social groups who later started new computing centers in other locations. The NCTU computing center became the starting place for the expansion of Taiwan's technological system of electronic digital computers.

In the United States, university computing centers were also an important place to expand the technological system of digital electronic computers.[41] Take MIT as an example. According to historians William Aspray, Bernard O. Williams, and Atsushi Akera, in the early 1950s, digital

[40] Though human computers could have seen electronic computers as a threat, I have not seen historical records that discussed human computers' attitudes to digital electronic computers at that time.

[41] My main purpose of providing an overview of the uses of the IBM 650 and the establishment of computing centers in the United States is not to privilege computer uses in the United States as the sole indicator or baseline when a historian of computing makes a comparison. Rather, I would like to emphasize that, in Taiwan, a wide range of uses were already done merely on one computer in one computing center in Taiwan.

electronic computers were available in US universities merely because of the military's sponsorship. These early digital electronic computers were thus prioritized for work related to defense contracts and industrial problems. To address other university researchers' demands for digital electronic computing, IBM and physicist Philip Morse at MIT worked together to install IBM's then latest computer, the IBM 704, on the MIT campus, thus establishing MIT's Computational Center in 1955. IBM and MIT agreed to have the Computational Center work as a regional facility that would provide computer training and computer time for New England-area colleges. IBM obviously knew well that a university was a perfect place to expand computer use. IBM, in particular, was keen to help universities establish computing centers. From the mid-1950s to 1959, the company donated its IBM 650 to more than fifty universities. In exchange for these computers, universities had to offer courses in data processing and numerical analysis.[42]

In addition to IBM, the National Science Foundation understood the potential of computing centers. Beginning in the 1950s, the Foundation provided grants to support the operations of university computing centers; the Foundations' support to computing centers peaked in the early 1960s. The number of university computing centers increased from forty in 1957 to four hundred in 1964 in the United States. As early as 1960, the Foundation researched the idea of establishing regional centers to facilitate university computing. But it was not until 1968 that the Foundation funded ten regional computing centers, which were based in universities, to support educational uses of computers and to broaden people's and organizations'

[42] William Aspray and Bernard O. Williams, "Arming American Scientists: NSF and the Provision of Scientific Computing Facilities for Universities, 1950-1973," *IEEE Annals of the History of Computing* 16, no. 4 (1994): 60-74; Atsushi Akera, "Research and Education: The Academic Computing Centers at MIT and the University of Michigan," *Calculating a Natural World: Scientists, Engineers, and Computers During the Rise of U.S. War Research* (Cambridge: MIT Press, 2006), 277-311.

access to computers.[43]

The costs of operating computing centers, including acquiring or renting computer facilities, were an important issue for both American university computing centers and the NCTU computing center, all of which served specific roles in computer use directed at education and scientific research. According to Aspray and Williams's research, the early 1960s witnessed an increase of both American universities' demands for computer facilities and the National Science Foundation's financial support to meet the demands. The high cost of computers usually exceeded a given university's ordinary budget, so the funding from the Foundation and other federal agencies (such as NASA) was crucial to universities at that time. In 1963, all federal agencies, including the National Science Foundation, supported "about half of the cost of computing on campus."[44] Specifically, in MIT's case, the institution needed IBM's sponsorship for non-military uses of computers in 1955, though the Whirlwind I computer, one of the early digital electronic computers, was built at MIT. Just as American universities had to rely on outside funding for computing facilities in the 1950s and 1960s, NCTU was fortunate to have secured financial support for Taiwan's first computing center by acquiring the UN-NCTU technical-aid program from the United Nations in 1962. Though, before applying for the technical-aid program, Chiao-Tung-educated technocrats perhaps never studied American universities' attempts to gain access to computers.

Both Aspray and Williams's and Akera's research presents similar general findings: from the 1950s to the 1960s, US universities' computers were initially available to military-contract

[43] Ibid.
[44] Aspray and Williams, "Arming American Scientists," 65.

researchers and then to other university researchers; later on, improvements in engineering education led to computers becoming available to undergraduate students. Nevertheless, the NCTU computing center seems to have been accessible to all types of researchers, regardless of whether the research was being conducted by university researchers or non-university researchers, and this liberal accessibility reflects most of all the fact that the computing center was the only computing center available in Taiwan.

Beyond financial support, there were some specific reasons for US universities' decisions to widen the population of researchers who could access these institutions' computer facilities. According to Akera's research, the establishment of MIT's Computation Center in 1955 was originally a reflection of university administrators' attempt to fulfill researchers' demands for scientific computing. The University of Michigan's Computing Center was established in 1959 because of an improvement in engineering education. (Prior to their establishment of these centers, each of MIT and the University of Michigan owned merely one electronic digital computer because of military sponsored research: the Whirlwind I and the Midac, respectively. The two computers, however, had stimulated researchers' interest in computers, helping to explain researchers' highly competitive quest to acquire computer time, which itself could be highly expensive.) But, of course, once the computer centers opened, these centers broadened the availability of computers to both undergraduates and researchers, who simultaneously witnessed a decline in the fees associated with using computers. In Taiwan, the NCTU computing center served to train on-site engineers, graduate-level students, and university and industrial scientists. Because no computer had existed in Taiwan prior to NCTU's acquisition of the IBM 650, Taiwanese technocrats and NCTU's university administrators did not specifically discuss which

groups should have priority in gaining access to the computer; instead, the technocrats and administrators were concerned primarily about obtaining a computer in Taiwan. While MIT and the University of Michigan used to debate whether they should have their computing centers be *regional* computing centers, Taiwanese technocrats, NCTU's university administrators, and UN-affiliated officials knew from the outset that the NCTU computing center should be a national center.

Taiwan's first computer, obtained in 1962, was the IBM 650 magnetic drum data processing machine; at that time, the computer a relatively obsolete model in the US context. It was announced in July 1953, and its first delivery was in December 1954. By January 1961, there were 1,250 IBM 650 computers manufactured and delivered, but IBM stopped manufacturing the computer in 1962.[45] The IBM 650 computer in Taiwan was replaced, however, by a newer model in 1964. The popularity of the IBM 650 computer on American campuses might explain Chiao-Tung alumni's choice of this model. As mentioned earlier, from the mid-1950s to 1959, IBM donated its IBM 650 computers to more than 50 American universities. The IBM 650 was a popular computer model. For example, Cornell University obtained its first IBM 650 computer in 1956 for Cornell's computing center, where faculty and students used the computer until 1959 for instructional or research purposes related to numerical analysis,

[45] The IBM 650 system at NCTU included an IBM 650 console, IBM 655 power unit, and IBM 533 card read-punch unit. This was the most basic and minimal required components for the IBM 650 system. In September 1956, IBM provided a new system called "the IBM 650 RAMAC," which "combines the inherent data processing capacity of the IBM 650 with the facility for large-capacity random access storage." But what NCTU obtained was the original model. See "Computer Comparison Chart," *Updating Supplement* No. 27, March 1961, published by Automation Consultants Inc. Page no: D24), James W. Cortada Papers (CBI 185), Box 28, Charles Babbage Institute, University of Minnesota, Minneapolis; "IBM 650 Chronology," IBM Archives, accessed November 30, 2011, http://www-03.ibm.com/ibm/history/exhibits/650/650_ch1.html; "IBM 650 Dian zi zi liao chu li ji ying yong jian jie [An Introduction to the IBM 650 Computer]," *The Voice of NCTU Alumni* 117 (September 1962), 40-4; "IBM 650 RAMAC," published by IBM in 1956, Computer Product Manuals Collection (CBI 60), Box 101, Folder IBM 650 RAMAC, Charles Babbage Institute, University of Minnesota, Minneapolis.

statistical analysis, and so on.[46] Another example is Duke University, which obtained an IBM 650 in 1958 to establish a computing center.[47] Individual campus laboratories also used IBM 650s. As for the aforementioned University of Michigan, before it started its computing center, the Statistical Research Laboratory on campus rented an IBM 650 in 1956. Researchers at the University of Michigan grew so accustomed to and were so pleased with the IBM 650 that university researchers found the IBM 704 computer—the computer at the university's newly established computing center—to be inefficient and difficult to program with.[48] On Cornell campus, in 1958, the Animal Science Department obtained its own IBM 650 computer for their research on dairy-records processing.[49]

In 1963, a class of trainees at the NCTU Training and Research Centre put together a yearbook, and in it is recorded a remark from MIT's Dean N. Arden describing his teaching in Taiwan. Cognizant that Taiwanese trainees still had much to learn after their first year of using Taiwan's first digital electronic computer, Arden summarized his experiences at NCTU:

> It has been a pleasure to have the privilege of helping to introduce computers and computer application to Taiwan. The students in the training course at Chiao-Tung University have impressed me by their desire to investigate the new and difficult

[46] The IBM 650 system at Cornell's computing center was replaced by the Burroughs 220 computer in 1959, and a Control Data 1604-160A computer system was installed in 1962. See Richard C. Lesser, "Richard C. Lesser's Recollections: The Cornell Computing Center, the Early Years, 1953 to 1964," written in 1996, in the Website of Oral and Personal Histories of Computing at Cornell, accessed November 30, 2011, http://www2.cit.cornell.edu/computer/history/

[47] Aspray and Williams, "Arming American Scientists," 70.

[48] Akera, "Research and Education."

[49] John W. Rudan, *The History of Computing at Cornell University* (The Internet-First University Press: 2005), accessed November 30, 2011, http://hdl.handle.net/1813/82, see page 272; Lyle Wadell, "History of the Northeast Dairy Records Processing Laboratory, 1948–1985, with Additional Comments by J. D. Burke and H. Wilmot Carter," in the Website of Oral and Personal Histories of Computing at Cornell, accessed November 30, 2011, http://www2.cit.cornell.edu/computer/history

technology of computer programming. Although the technique of programming has been only partially acquired and insight into the many interesting areas and methods of application is still incomplete, there is no doubt that continued practical use of the partial knowledge will perfect the skill and increase the capacity for the successful use of computers in Taiwan.[50] (Original in English)

Peterson and NCTU's IBM 1620 Computer, 1963-1964

Perhaps no one could easily say that one year was enough to introduce digital electronic computing to a new place at that time, so Arden concluded that "the technique of programming" was "partially acquired" and "incomplete." Though Arden did expect that the NCTU students' skills of practically using computers would become perfect in the future, he solely discussed practical uses of computers and did not mention NCTU's potential, future academic-related accomplishments at all. Nevertheless, his comments could be useful to NCTU administrators, especially when they planned to request more financial support from the United Nations; as Arden's comments showed that the UN funds were successful in helping NCTU students begin to develop programming capabilities, more funds might be helpful to NCTU in maintaining that momentum in the future.

While Arden looked forward to the "completeness" of introducing programming to Taiwan, William Wesley Peterson, the second UN expert in digital electronic computing, believed that the "independence" of the NCTU computing center was going to be the best

[50] *The Yearbook of the Training Course of Electronic Computers, February-June, 1963* (National Chiao-Tung University, 1963)

achievement of the UN-NCTU technical-aid program. In the following section, I will briefly discuss Peterson's ideas concerning "independence," and will move on to discuss how he materialized these ideas through educating staff and encouraging NCTU to opt out of IBM's maintenance contract. NCTU purchased a mainframe computer and replaced IBM's maintenance contract with an in-house technician. Through purchasing rather than leasing a computer, NCTU was able to fully utilize the four-year funding from the United Nations. In hiring an in-house technician to maintain the IBM 1620 computer, NCTU aimed to work independently from IBM, "to operate the centre without outside help" and save maintenance expenses at the same time.

The "Independent" Computing Center: William Wesley Peterson

Peterson succeeded Dean N. Arden as a one-year visiting professor at NCTU in August 1963. Peterson was then 39 years old and a professor of electrical engineering at the University of Florida, Gainesville.[51] Peterson had worked for IBM before he joined the faculty of the University of Florida. Peterson saw the independence of the computing center as the foremost goal of his trip to Taiwan. To accomplish this, he prioritized staff training for the center. According to the aforementioned 1968 United Nations Report (hereafter *The 1968 UN Report*), Peterson's view was that the staff of the computing center "should best be left to operate the centre without outside help for several years and thus gain experience and confidence." *The 1968 UN Report* further stated:

> By the end of Dr. Peterson's mission[,] the programming and teaching staff, the operators

[51] Letter from NCTU to the Ministry of Foreign Affairs and Hsinchu Police Office, September 3, 1963, 635.31 0202, MFA files, and "Technical Co-operation, Back from China," *Telecommunication Journal* 31, no. 10 (1964): 271.

> and maintenance personnel of the Institute's [the graduate program in electronics at NCTU] computing centre had developed such a proficiency that he was able to recommend [that] no further outside assistance be provided in the meantime. His view was that they should best be left to operate the centre without outside help for several years and thus gain experience and confidence. Subsequent results have proved the correctness of his recommendation. (Original in English)[52]

As mentioned above, the "centre" here refers both to the Training and Research Centre for Telecommunications and Electronics and to the computing center. Of course, in a broader sense, the Institute of Electronics (i.e. the graduate program in electronics) was part of Peterson's concerns, as well.

Peterson's idea of independence was possibly related to his acknowledgment of the "applied" component of the graduate-level engineering education, in general. Peterson had participated in a workshop held by the Institute of Electronics (i.e. the graduate program in electronics) at NCTU, and discussed possible future cooperative projects between the program and the industry. J. O. McNally, another UN expert in vacuum-tube manufacturing, visiting NCTU at the same time, was invited to this workshop. McNally was then 61 years old and worked for Bell Laboratories. He was Dalman's colleague at Sperry Gyroscope before Dalman joined Cornell.[53] McNally encouraged workshop participants to pursue possible cooperative projects between the university and industry, because he found that this was exactly the direction that higher education in the United States was moving following the Second World War, at

[52] *The 1968 UN Report*, 28.
[53] Letter from NCTU to the Ministry of Foreign Affairs and Hsinchu Police Office, September 3, 1963, 635.31 0202, MFA files. Oral-history interview with Dalman, October 24, 2009.

Stanford and MIT, for example.[54] Peterson echoed McNally:

> If National Chiao-Tung University is a university that teaches merely mathematics, there is no need for it to have some connection with the outside world. But, as it is a university for applied science, it has to pay attention to applications, and it has to stay in touch with the industry. Otherwise, professors will not be able to carry out their teaching, because they don't know what the society wants and what to study.[55] (Original in Chinese)

The "Independent" Computing Center: The Maintenance of the IBM 1620 computer

A significantly different circumstance that Arden and Peterson faced during their one-year visits involved their digital electronic computers: Arden's teaching relied on an IBM 650 computer, and Peterson used both the IBM 650 and the newly acquired IBM 1620 computers. From the time of its installation, the IBM 650 computer was useful. In fact, the computer was under such use as to experience many break-downs, and NCTU had to call IBM engineers for maintenance. As the IBM 650 computer relied on vacuum tubes, it generated a considerable amount of heat during its operation, and this made it extremely unstable when it had run too long or in a space lacking air-conditioning. *The 1968 UN Report* attributed the necessity of air-conditioning to "the tropical conditions existing in Taiwan," but, in fact, heat was an issue for American users of 650 computers.[56] The short-term solution to this problem was to replace

[54] Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (Columbia University Press, 1994).
[55] "Jiao Da Dian Zi Yan Jiu Suo Yu Gong Ye Jie Yan Jiu He Zuo Zuo Tan Hui Ji Lu [Memorandum, a Workshop for NCTU administrators and Industrial Representatives]," *The Voice of NCTU Alumni* 139, (July 1964), 1-7.
[56]See page 372 in Martin H. Weik, *A Third Survey of Domestic Electronic Digital Computing Systems* (hereafter *The BRL Report 1961*), Report No. 1115, March 1961, published by the Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, available at the Computer History Museum Center website, accessed November 30,

overheated and broken vacuum tubes with spare ones. In this Taiwanese case, and others all over the world, the replacement of vacuum tubes was usually performed by IBM engineers. The long-term solution was to replace the entire computer.

Before Arden left Taiwan, he submitted a proposal and persuaded the United Nations to allow NCTU to replace the IBM 650 with a transistor computer—an IBM 1620. *The 1968 UN Report* stated:

> Probably Professor Arden's most important contribution to the development of the computer centre was his recommendation for the replacement of the equipment. He provided a complete list of the equipment to be purchased and assisted in the negotiations with the IBM Company which led to the placing of the necessary order.[57] (Original in English)

At that time, NCTU and Arden decided to purchase the IBM 1620 computer, rather than leasing it, which appeared to be an unusual decision, compared to IBM computer users in other countries. IBM's standard way of doing business at this time was to lease its customers computers and charge them monthly leasing and service fees covering the provision of programs and maintenance.

The funding period of the UN-NCTU technical-aid program might be the main reason for NCTU to make this unusual decision. The UN-NCTU technical-aid program provided only four

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2011, http://ed-thelen.org/comp-hist/BRL61-ibm065.html#IBM-650-RAMAC

[57] *The 1968 UN Report*, 29.

years of funding, ending in 1965, making it wiser for NCTU to decide to purchase the computer outright. Otherwise, at the end of the technical-aid program in 1965, NCTU would have had no money to pay the monthly leasing fee.

The purchase decision led another unusual decision: NCTU and Peterson decided to opt out of IBM's maintenance-service plan and hire an in-house technician to take care of any maintenance issue. This decision was made in the second half of 1963, though the precise time is unknown. It is difficult to estimate how often IBM's costumers opted out IBM's maintenance contract. However, as digital electronic computing was a far more common activity in the United States than in the rest of the world at that time, a US costumer had a better chance of managing without IBM's maintenance-service plan, as this customer could draw on other available resources. In Taiwan, on the other hand, as there was only one computer available from February 1962 to February 1964, and NCTU members and trainees had only begun to learn digital electronic computing in 1962. Thus, to opt out of IBM's maintenance contract in 1963 was an audacious decision for NCTU.

It seemed that NCTU professors and Peterson at this time all agreed to hire a technician responsible for the maintenance of the new IBM computer. There were many possible reasons for them to do so. First, because the technical-aid program began in 1962 and was going to end in 1965, it was wise to hire an in-house technician to take care of the maintenance in order to be prepared for the end of the technical-aid program. Second, this was consistent with Peterson's idea of independence. Peterson wanted to assure that the computing center would be able to function independently after the end of the technical-aid program. According to *The 1968 UN*

Report,

> As the time approached for the delivery of the IBM-1620, Professor Peterson undertook a study of the equipment on the basis of the available documentation and even before it had arrived, developed a capability for its immediate use. By the time it [the IBM 1620 computer] arrived, not only had the teaching staff of the Institute [the graduate program in electronics at NCTU] developed a competence in programming the equipment, but also two girls had been trained as operators. Moreover, so much had been learned about computer maintenance by working on the IBM-650 that Professor Peterson was able confidently to recommend that the Institute itself should take over the maintenance of the 1620 type equipment immediately after the end of the 90-day guarantee period. This has since been done with complete success.[58] (Original in English)

Third, Peterson was not the only person who preferred to hire someone to maintain the IBM 1620, rather than rely solely on IBM's maintenance. It might have been a unanimous decision by NCTU professors and Peterson at this time, because IBM's maintenance-service plan was regarded as an extremely costly expenditure by NCTU's administrators. Chi-Chang Lee recalled that NCTU had negotiated hard with IBM to purchase the IBM 1620 computer, instead of renting it monthly. Emeritus professors Chi-Chang Lee and Tseng-Yu Lee, in their eighties, started to talk in a vehement tone when trying to explain to me how expensive IBM's maintenance services had been and how snobbish IBM salespeople had been at this time. According to the two emeritus professors, in general, when IBM's Taiwan branch sent an engineer to check or fix computers at NCTU, the service fee would be charged from the time the

[58] *The 1968 UN Report*, 28.

engineer left from the IBM office, instead of from the time the engineer arrived at NCTU. They also pointed out that customers could not bargain with IBM because it monopolized the Taiwanese market in the 1960s, and both were unsatisfied with the sale tax charged by IBM. [59]

Fourth, at that time, IBM's Taiwan branch hired Taiwanese engineers (in my interviews, no one mentioned that there was an American engineer at IBM's Taiwan branch.) IBM had Taiwanese engineers to take care of maintenance and installment, but not system engineers. According to Chin-Chi Kao, who was hired by NCTU to maintain the IBM 1620 in 1964, Peterson spent two-thirds of his time on the IBM 1620. I asked whether the University could have requested and paid IBM engineers to help. Kao answered,

> No. IBM's Taiwan branch didn't have any system engineer or software engineer available. It had merely maintenance engineers. Perhaps there were one or two engineers that knew systems, but they might have not known it [compliers] well. If Peterson would not have been there, the machine [the IBM 1620] would not work at all.[60] (Original in English)

Peterson might have sensed the limited technical support the IBM might offer at that moment, and decided that NCTU and he might, therefore, be able to train and rely on an in-house maintenance engineer.

Fifth, Peterson might have been confident that he had the capability to make the computer work and to train NCTU members in general. He might have had no doubt that an in-

[59] Oral-history interview with Chi-Chang Lee, January 7, 2009.
[60] Kao, June 2, 2009, email communication.

house engineer would maintain the computer well. According to Kao, for the IBM 1620 computer, Peterson in fact came up with methods to separately compile sections of a larger amount of program codes. These methods were particularly useful when Yun-Tzong Chen, an instructor, had to write a larger amount of codes for an economic-planning project.[61] (I will discuss Chen's work in the next chapter.) Peterson had previously worked on a project to create a "programming system" for the IBM 650 in the Statistical Laboratory at the University of Florida, circa 1959,[62] and was well-known for his textbook *Error-Correcting Codes*, published in 1961.[63] His confidence and competence in programming and codes seemed to allow him to believe that it was likely that NCTU members could work on the hardware as IBM engineers did.

Sixth, generally speaking, architectures of computers played a role in determining the extent to which people can modify digital electronic computers. The reliability of vacuum-tube computers is intrinsically poorer than transistorized computers. This assertion can be verified from the analysis in *A Third Survey of Domestic Electronic Digital Computing Systems* (hereafter *The BRL Report 1961*), which was overseen by Martin H. Weik and published in 1961 by Ballistic Research Laboratories, Aberdeen Proving Ground, for evaluating the performance of available computers. One may consider the publication a buyer's guide for computers at that time. *The BRL Report 1961* directly pointed out that transistorized computers were easier to maintain than vacuum-tube computers, because "tube count and a knowledge of tube operating characteristics may yield an approximate estimation of some of the problems that may be

[61] Kao, June 2, 2009, email communication.
[62] William Wesley Peterson, Frank Dow Vickers, J. Robert Meachem, and Leonard Stein (the Statistical Laboratory at the University of Florida), "FLATRAN: Florida Translator for IBM 650," Computer Product Manuals Collection (CBI 60), Box 101, Charles Babbage Institute, University of Minnesota, Minneapolis.
[63] William Wesley Peterson, *Error-Correcting Codes* (Cambridge: MIT Press, 1961). Peterson completed the writing of this book at MIT.

encountered in the operation of the system."[64] The numbers of vacuum tubes in early digital electronic computers could be up to twenty thousand, and the IBM 650 had approximately 2,000 vacuum tubes.[65] When one of them burned out, it would be difficult to identify the burned out tubes among such a large number of tubes. The situation could be even more difficult to diagnose in the event of a failed, but not burned-out, tube. *The BRL Report 1961* prepared a table listing the models of computers and their corresponding numbers of tubes.[66] To avoid the hassles associated with efforts to identify the tube needing replacement, computer manufacturers sometimes provided preventive-maintenance routine. Therefore, when the number of tubes decreased, the difficulty in identifying the burned-out or failed tubes decreased. According to *The BRL Report 1961*, because transistors consumed less power than vacuum tubes and because their printed circuits and packaging techniques continued to be improved, "the question of reliability is rapidly being resolved."[67] In sum, the poor reliability of vacuum tubes could create uncertainty or dilemmas for users or engineers seeking to identify a given problem. NCTU members, Peterson, and Arden might acknowledge that it should have been easier for Taiwanese engineers to identify the problematic transistors of the IBM 1620 computer than the problematic tubes of the IBM 650.

The IBM 650 and 1620 computers were not merely technological artifacts, but parts of the larger technological system of digital electronic computers. As noted above, at that time, this system in the United States included NSF's or IBM's financial support to universities, university professors who taught programming courses, users such as students, researchers, and user groups

[64] Martin H. Weik, *The BRL Report 1961*, 1032-1033.
[65] Martin H. Weik, *A Survey of Domestic Electronic Digital Computing Systems*, Report No. 971, published by Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, 1955. See page 64.
[66] *The BRL Report 1961*, 1072-1073.
[67] Ibid., 1033.

that volunteered to contribute and share programs, IBM's programming and maintenance service, IBM as a manufacturer, and other digital electronic computer manufacturers such as Burroughs. In Taiwan, this system included United Nations' funding, instructors such as Arden, Peterson, and Chuang, users such as engineers from state-owned enterprises, and IBM. For the reasons discussed above, including financial concerns such as the technical-aid program's funding structure, NCTU members and Peterson's assessment, their perception of IBM's technical service, and the architectures of computers, eventually NCTU members, Peterson, and Arden decided to purchase the IBM 1620 computer and hiring an in-house engineer to maintain the computer.

The "Independent" Computing Center: Kao's Maintenance of the IBM 1620 computer

Chin-Chi Kao was the person hired by NCTU to maintain the IBM 1620. In the following section, I will briefly introduce his background, his work maintaining the computer, and his career after leaving NCTU.

Kao graduated from the department of Electrical Engineering at the Provincial Taipei Institute of Technology.[68] Before joining the computing center at NCTU in January 1964, Kao had worked at manufacturing palm-held transistor radios for China Electronic Products Corporation, a Taiwanese manufacturer of loudspeakers and radios, beginning in September

[68] It was a vocational school in Taiwan, established by the Japanese colonial government in 1912, during the Japanese colonial period (1895-1945). In general, alumni from the Provincial Taipei Institute of Technology were more likely to stay and work in Taiwan, as opposed to graduates of Taiwan's only two undergraduate programs in electrical engineering, at National Taiwan University and National Cheng-Kung University, who tended to go abroad.

1963.[69] Kao recalled that this was the first Taiwanese company to export electronic products.[70]

To obtain the technician position at NCTU, Kao was last interviewed with Chu-Yi Chang, a professor and Academic Dean at NCTU. Kao, clearly, was outstanding. He first passed a number of tests, including a written test on binary circuits, a test on trouble shooting radio circuits, and a written English test. Kao recalled that Chang handed him a magazine in English and asked him to translate some paragraphs. Kao still remembered that he spotted the term "reliability" in the magazine. Though it was a relatively new term for him and his contemporaries, he had discussed the concept of reliability with his supervisor when working on radio circuit designs.[71]

Kao began to work at NCTU following the New Year vacation of 1964. When the IBM 1620 computer finally arrived on the NCTU campus in February, Kao began to learn the IBM 1620's structure from working with an IBM engineer, De-Yang Cheng. Cheng was sent to install the computer and took care of its maintenance during the first three months following the installation. Kao recalled that he picked up Cheng's expertise in maintaining the computer through observing Cheng installing and later maintaining it. Cheng, a fellow alumnus of the Provincial Taipei Institute of Technology, presented, explained, and tested the functions of different circuit cards and their corresponding slots in the wiring panels.[72] The most important part of the training was how to read the block diagrams on the maintenance manuals that came with the computer, such as the *Customer Engineering Reference Manual: 1620 Data Processing*

[69] The company's full name was *Zhong Guo Dian Qi Qi Cai Kong Si* (中國電氣器材公司).
[70] Oral-history interview with Kao, June 20, 2009.
[71] Oral-history interview with Kao, June 20, 2009.
[72] Oral-history interview with Kao, June 2, 2009.

Systems.[73] In addition to these face-to-face interactions, Kao occasionally phoned Cheng to ask questions.

It is reasonable that Kao could not remember all of the details of a job held five decades before our interview, but he did recall some common malfunctions of the IBM 1620 computers. Each of the abovementioned circuit cards consisted of, at most, six transistors. During the first few months following the arrival of the IBM 1620 computer, Kao identified some malfunctioning circuit cards and had them replaced with spare cards. However, during the first several months, the most frequently occurring problem was malfunctioning of the electromagnetic relays in the computer's input-output unit that supported the standard-equipped typewriter. On the IBM 1620 at NCTU, operators entered commands via this typewriter, which also served as an output device. In addition, the computer had a papertape punch unit as its output device; and a papertape reader an input device, which was connected to the computer via a long cable. Aligning the photocells in papertape reader's readerhead was a major work of Kao's monthly maintenance.[74] Through my interviews with Kao, emeritus professors, and operators at NCTU, we can reasonably conclude that the computing center more or less functioned without direct maintenance service from IBM.

Kao left NCTU in 1966. Beginning in September 1966, he began working for Taiwan Electronics Corporation, which produced television tuners, capacitors and transistors. It was a subsidiary of General Instruments, and was later renamed General Instruments Corporation. It

[73] The NCTU library still has a copy of this reference book; Oral-history interview with Kao, June 2, 2009.
[74] Oral-history interview with Kao, June 2, 2009. Kao pointed out that NCTU also bought an 870 Document Writing System, which arrived at the same time with the IBM 1620 in 1964.

was the first American investment in Taiwan's electronics industry.[75] From then until the end of 1966, Kao returned to NCTU every weekend to help and train a new engineer, Ji-Kwan Zho, who succeeded Kao, since NCTU decided to continue to hire in-house engineers to take care of the maintenance of their mainframe computers.[76]

Kao's maintenance of the IBM 1620 computer can be categorized as emulation, by Brooke Hindle's definition, and did not involve a direct modification of the computer's design. However, it is intriguing that, though his maintenance was an attempt to be independent from the IBM's service, it was necessary for him to learn from an IBM engineer.

One particular episode indicates that there was an unsuccessful attempt by Taiwanese users to tinker with the two NCTU digital electronic computers. (Eventually the tinkering activity did not happen.) When a US-based computer engineering expert, Rue-Chin Tu, visited NCTU for about one year beginning in late summer in 1965, Professor Chu-Yi Chang discussed with Professor Tu the feasibility of connecting the IBM 650's card reader and punch unit to the IBM 1620. At that time, National Taiwan University had already obtained an IBM 1620 computer with the card-read-and-punch unit. In this context, a paper tape punch unit was less convenient and slightly obsolete. Perhaps because the IBM 650 was not functioning well at that time (owning to its vacuum tubes) Chang intended to recycle its old input and output devices to improve those of the IBM 1620. According to Kao, Chang proposed this project as a research topic for graduate students attending one of Tu's courses. However, Chang's plan resulted in no real action when Professor Tu left Taiwan in early summer of 1966. (The plan did not succeed or

[75] The company's full name was *Tai Wan Dian Zi Kong Si* (台灣電子公司).
[76] Oral-history interview with Kao, June 2, 2009.

perhaps no one attempted to do it, since it is not mentioned by any of my informants and no historical record discussed it.) Kao pointed out that it was an infeasible plan.[77]

The "Independent" Computing Center: W. W. Peterson's Teaching

Although, prior to Peterson's arrival in the summer of 1963, it had been decided that the IBM 650 computer was to be replaced with an IBM 1620, it did not happen until February 1964. [78] Peterson was not able, therefore, to use the new IBM 1620 computer until the sixth month of his one-year stay in Taiwan. However, his teaching was not hindered by its absence. Like Arden, he offered training courses for different types of engineers and scientists (see table 1), provided graduate level courses, and advised graduate students. Specifically, he offered a Master's level course entitled "Error Correction Coding" in October, 1963, and served as advisor for a Master's thesis entitled "The Simulation of Control System [*sic*] on Digital Computer."[79] Following the IBM 1620's arrival, he taught two 3-day courses, with NCTU instructors, for 70 Chinese Petroleum Corporation engineers and staff in July of 1964.[80]

After leaving Taiwan in the summer of 1964 and re-settling at University of Hawaii, Peterson maintained contact with instructors and professors in Taiwan. In particular, Chi-Chang Lee helped him to publish a textbook in Taiwan, based on class-notes from one of his eight-week training courses.[81] This book was published only in Taiwan, and he tailored it to Taiwanese

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[77] Oral-history interview with Kao, June 23, 2009.
[78] "*Dian Zi Suo Jin Kuang* [Recent News from NCTU's Institute of Electronics]," *The Voice of NCTU Alumni* 135, (March 1964): 36.
[79] *The 1968 UN Report*, 53 and 55. Peterson's student Chin-Long Chen pointed out that the course title should be "Information Theory."
[80] *The 1968 UN Report*, 53-54.
[81] William Wesley Peterson, "Preface," *Computing with the IBM 1620* (Taipei: Central Book Company, 1966).

readers. When he wrote Lee a letter to discuss logistics of publishing, he proposed that he could "have the notes typed in good form so that it can be published by photo-offset, by the same process used for standard pirating of books in Taiwan." Clearly, he was well informed about the pirating of English books in Taiwan, but remained willing to have his work published there.[82]

However, his teaching activities in Taiwan were not limited to the textbook and courses that could be identified by individual names and start dates. As mentioned above, Peterson emphasized the training of three groups of people: teaching staff, female computer operators, and a computer-maintenance technician. In the following section, I present more descriptions and greater analysis of female operators.

The "Independent" Computing Center: Female Operators

With his ideas for helping the computing center to operate independently, Peterson prioritized staff training above other obligations. According to *The 1968 UN Report* produced by the United Nations, before the arrival of the IBM 1620 computer, Peterson "undertook a study of the equipment on the basis of the available documentation," and "developed a capability for its immediate use." *The 1968 UN Report* stated, "By the time it arrived, not only had the teaching staff of the Institute developed a competence in programming the equipment, but also two girls had been trained as operators" (Original in English). "Teaching staff," here, may refer to faculty members such as Chi-Chang Lee, whom I have introduced in the preceding section. The term "girls" chosen by the authors of *The 1968 UN Report* precisely reflected gendered practices in the NCTU computing center at this time. "Computer operators" refers to people who used and

[82] Private letter from Peterson to Lee, April 20, 1965, collected by Chi-Chang Lee.

operated paper tapes, punched cards, printers, and similar devices to input data into computers, or to collect output data from computers for college students, engineers, or scientists. [83] Mainframe computer operators had been a predominantly female occupation.

Historian David A. Grier has pointed out that, in 1944, the term "girls" replaced "computers" when scientists were talking about computing; "Girl-years" and "kilogirl" were new terms referring to new types of computing labor in the United States.[84] At NCTU around this time, it was common to see the usage of the term "girls" to refer to "operators," as well. When the director of the computing center, Chi-Chang Lee, wrote letters to Peterson, he often referred to "girls" when, in fact, he meant "operators." Among the nine letters that Lee collected privately over more than four decades, the following two excerpts show how he described the re-organization of operators in 1965 and 1966, respectively:

> The computer is still very busy now. Everything is going well. The only trouble is that we don't know whether Ms. Chen can go to Hawaii or not, so that we can't employ another girl in advance.[85] (Original in English)

> We have two girls, Miss Han and Miss Ma, working in our computing center. The former is working very well and the latter cannot work independently so far.[86] (Original in English)

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[83] Jennifer Light, "Programming," in *Gender and Technology: A Reader,* ed. Nina Lerman, Ruth Oldenziel, and Arwen P. Mohun, (Baltimore: Johns Hopkins Univ. Press, 2003), 295-328; originally published as "When Computers Were Women," *Technology and Culture* 40 (1999): 455-83; Thomas J. Misa, ed., *Gender Codes: Why Women Are Leaving Computing* (Wiley-IEEE Computer Society, 2010).
[84] David A. Grier, *When Computers Were Human*, 276.
[85] November 4, 1965, private letter from Lee to Peterson collected by Chi-Chang Lee.
[86] January 18, 1966, private letter from Lee to Peterson collected by Chi-Chang Lee.

This type of usage of "girls" shows the simplification and generalization of operators through emphasizing only their sex. Moreover, from reading the first excerpt in particular, one can see that Lee talked as if operators were a part of the physical facilities connected to the computer. When identifying operators as a mechanical part of a computing center, Lee might reveal two types of ideas behind this language usage. First, operators' jobs were mechanical, and, thus, replaceable. Thus, it reflects a linguistic process of de-skilling. Second, as if it were a 'spare part,' the operator as an occupation was as critical as the computers themselves in computing centers, as computers were expensive and to some extent, rare, in many societies in the early 1960s.

The two operators at this time were Y. C. Chen and Regina Lee.[87] As one may imagine, key-punching was one of the most important tasks for computer operators. In 1964, when economic bureaucrats came to NCTU to utilize the IBM 1620 computer for an economic-planning project, operators had to handle a significant amount of statistical data. (I will discuss the economic-planning project in detail in the following chapter.) In addition to Chen and Lee, two more female workers, according to Kao, were temporally transferred from a governmental agency to NCTU to help with data-entry in the evenings.[88]

Beyond key punching, operators sometimes obtained programming knowledge, since they reproduced programming codes from pieces of paper, written by people requesting to use computers, to punched cards or paper tapes. However, their knowledge of programming has

[87] Peterson, "Preface."
[88] Oral-history interview with Kao, June 2, 2009.

generally been ignored by both their contemporaries and historians of technology. Chiong-Yuan Han, a female operator who succeeded Chen in 1965, noted that a professor (Tseng-Yu Lee, whom I will discuss later) taught her how to recognize errors in programming codes. With this knowledge, if Han identified incorrect codes in college students' assignment, she could help them to fix these mistakes. Through e-mail communications, Chen also confirmed that identifying incorrect codes was precisely a part of her routine job.[89] Nevertheless, though female operators' knowledge contributed to the computing center, their capabilities were not seen as sufficient to work "independently," as Lee pointed out in the quote above.

NCTU emeritus professors recalled that Peterson was especially satisfied with Chen's work performance, and, eventually, she went to study at the University of Hawaii and obtained an undergraduate degree there, soon after Peterson returned to the United States and transferred from the University of Florida to the University of Hawaii. Two NCTU male graduate students of the graduating class of 1964 of the Institute of Electronics followed Peterson to pursuit their Ph.D. degrees there, as well.

Another critical group of female participants in the computing center and at the university were UN experts' female family members. Peterson's then-wife, Marion Peterson, conducted weekly English classes without receiving a salary from NCTU.[90] The class of 1964 yearbook listed Marion Peterson's name, picture, and Bachelor's degree in psychology from the University of Michigan. The class of 1964 clearly tried to recognize her educational contribution to the

[89] July 8, 2009, email communication with Chin-Long Chen.
[90] July 1, 2009, email communication with Chin-Long Chen.

class.[91] "She also introduced us to American culture," said Chin-Long Chen, who graduated from NCTU in 1964, and followed Peterson to study at the University of Hawaii, obtaining the first Ph.D. from the Department of Electrical Engineering there.[92] Marion Peterson's English classes or her introduction to American culture might not have been a necessary element in keeping up the everyday operation of the NCTU computing center, but she and her knowledge was still an important part of the computing center.

Discussion

The second half of this chapter focusd on two decisions made by NCTU members and UN experts: purchasing the IBM 1620 computer and hiring an in-house engineer to maintain the computer. These two decisions were made based on several reasons. First, NCTU administrators perhaps wanted to best utilize their technical-aid funds from the United Nations. Second, W. W. Peterson's ideas about running the computer center independently played a role too. Third, NCTU members and UN experts might not be satisfied with IBM's support for its mainframe computer customers.

Peterson's ideas of independence are related to the developmental status of Taiwan. As an UN expert, he considered that the best scenario of a technical aid program was that the recipient country or organization becomes independent and no longer need to receive aid. However, for the NCTU computing center in the early 1960s, Peterson's ideas of independence could be related to Taiwan's and NCTU's independence from three different sources of assistance: the

[91] *The Yearbook of the Institute of Electronics at NCTU, 1964* (National Chiao-Tung University, 1964), 12.
[92] July 1, 2009, email communication with Chin-Long Chen.

United Nations' funds, UN experts, and IBM. Nevertheless, it was either difficult or unreasonable to block the three different sources of assistance in Taiwan. First, at the same time in the United States, universities sought funds from the US National Science Foundation and others to support their computer uses and computing center; it was reasonable for the NCTU computing center to continue to receive financial support from the United Nations. Second, even though Arden and Peterson left NCTU after their one-year visits, there would be no way to stop the continuing flow of digital electronic computing knowledge, through other channels, from the United States to Taiwan; for example, some students who went to study in the United States visited Taiwan or returned to Taiwan after the end of the UN-NCTU technical-aid program. Moreover, Taiwanese universities relied on digital electronic computing textbooks from the United States. Third, it was possible for NCTU to opt out of IBM's maintenance-service contract, but it might be difficult for NCTU to be entirely independent from IBM, the only mainframe computer company in Taiwan and the most powerful mainframe computer manufacturer in the world at that time.

In contrast to Peterson's advocating of independence, Taiwanese administrators such as Gisson Chi-Chen Chien and S. M. Lee looked forward to a continuous inflow into Taiwan of UN funding and visiting experts in the fields of electronics science and digital electronic computing. In 1964, they applied for another UN technical aid-program, which I discuss in chapter 5.

CHAPTER 4

DIGITAL ELECTRONIC COMPUTING, ECONOMETRIC MODELS, AND ECONOMIC-PLANNING PROJECTS, 1964-1968

In the previous chapters, I have noted that Taiwanese engineers and technocrats produced a discourse articulating the potential of electronics science and digital electronic computing to improve the economy of Taiwan. Relying on the first two computers in Taiwan, college students, professors, and state-owned enterprise engineers visited NCTU to perform scientific calculations or to solve engineering problems in the early 1960s. Beyond engineers and technocrats' expectations, the NCTU computers proved to be useful to Taiwan-based economic bureaucrats as they designed long-term economic-planning projects throughout the 1960s. In this chapter, I discuss a Cornell econometrician, Ta-Chung Liu, and a Taiwanese government agency, the Council for International Economic Cooperation and Development (hereafter CIECD). In 1964, Liu and the CIECD relied on the IBM 1620 mainframe computer at NCTU for producing inter-industry input-output analyses of Taiwanese industries. Liu used the IBM 1620 to produce econometric models, by which the CIECD formed policies concerning the government's investment in different industries. But, at the same time, Liu's work was restricted by the capacity of the IBM 1620 in Taiwan. By delineating Liu's work in Taiwan in this chapter, I plan to argue that development discourse was embedded in and supported by digital electronic computing practices in Taiwan.

The CIECD's Consistent Interest in Digital Electronic Computing

The CIECD, the government agency that invited the Cornell econometrician in 1964 to work within its corridors, had been exposed to the ideas of mechanized data-processing and digital electronic computers before the arrival of the two mainframe computers at NCTU. The CIECD worked under the Taiwanese government to manage US aid from the 1963 to 1965, and its predecessor was the Council for United States Aid (CUSA), managing US aid from 1948 to 1963. US aid to Taiwan included money and surplus agricultural commodities. When US aid came from the US to Taiwan, it needed to go through the following government organizations: ICA (the US International Cooperation Administration) in Washington, ICA in Taipei, and the CIECD. Then the CIECD distributed the aid according to the guidelines discussed with the ICA. ICA was the predecessor of the United States Agency for International Development (AKA USAID now).

The CIECD and its predecessor had taken on the responsibility of US-aid record keeping, and also had produced various forms of economic statistics in order to show the United States how the Taiwanese government distributed US aid, how wisely the aid money was spent, and how effective it was in improving Taiwan's economy. In 1959, the CIECD (then CUSA) requested that a United States' aid agency purchase digital electronic computers to help the CIECD deal with its statistics production. But the United States' aid agency denied the request because "the volume of transactions" was not enough "to justify one electronic computer."[1]

The CIECD's failed attempt to acquire digital electronic computers occurred roughly at the same time at which Taiwanese engineers and technocrats started planning to apply for the

[1] Letter from Wesley C. Haraldson, Director of the ICA, Mutual Security Mission to China, to K. T. Li, May 26, 1959, CIECD Central Files, 36-01-002-027, Institute of Modern History, Academia Sinica, Taiwan (hereafter CIECD Central Files).

technical-aid program that brought the first two mainframe computers to Taiwan. After NCTU successfully leased Taiwan's first IBM mainframe computer in 1962, the CIECD began to consider using the computer for its projects. For example, the CIECD sent at least three staff members to attend the programming courses at NCTU from 1962 to 1963. In 1964, the CIECD invited econometrician Ta-Chung Liu from Cornell University to Taiwan to help form a long-term economic-planning project by using the IBM 1620 mainframe computer at NCTU.

Liu Ta-Chung's Steadfast Anti-Communist Position

Born in China in 1914, Ta-Chung Liu received his B.A. from Chiao-Tung University in China and his Ph.D. in economics from Cornell University in 1940. When the war between the nationalists and the communists in China was reaching its peak in 1948, Liu left China and successfully settled in the United States by working for the International Monetary Fund (IMF) from 1948 to 1958. He became a professor at Cornell University in 1959, where he taught until his death in 1975.

To Liu, and many Chinese who had chosen to leave Mao's China and move to the United States or other countries, the government led by Chiang Kai-Shek in Taiwan was a "new" home country. Liu referred to Taiwan as his "home country" in some of his publications.[2] Many Taiwanese economic policymakers in the 1950s had been Ta-Chung Liu's colleagues or contemporaries in pre-1948 China. From the perspective of these policymakers, Liu possessed two characteristics that would benefit the Taiwanese government. First, Liu had obtained the latest econometric expertise and experience from his work at the IMF and his teaching at Cornell.

[2] Ta-Chung Liu, *Final Report on Economic Planning* (Taipei: CIECD, circa 1964).

Second, Liu recognized Chiang Kai-Shek's government, so he would not hesitate to help the Taiwanese government. For these reasons, Liu visited—and was welcomed in—Taiwan several times, offering the Taiwanese government his advice on economic policies.

The first time he visited Taiwan as an economic-policy advisor was 1954. Along with a US Economic Advisory Group from the IMF, Liu received a formal invitation from the Taiwan government. While the Economic Advisory Group suggested depreciating the Taiwanese dollar and balancing the budget, Liu and his colleague Sho-Chieh Tsiang were not fully satisfied with the Group's "conventional" suggestion, deciding instead to write a separate report that advised the government to adopt a single exchange rate for all industries.[3]

Before I move on to discussing Liu's introduction of newer econometric models in Taiwan, I would like to contextualize the ideological framework of his expertise in econometrics. Liu's professional career was characteristic of his econometric expertise as well as his pioneering analysis of the economy of Communist China. He conducted contracted research projects on the economy of China for the RAND Corporation in the 1950s.[4] In a paper published in 1977 in memory of Liu's contribution to economics, Liu's colleagues indicated that his research had been contributing to a better understanding of the economic performance of such socialist countries as China.[5]

[3] See page 84-88 in Tsu-Yu Chen, ed., *Jiang shuo jie xian sheng fang wen ji lu [The Reminiscences of Dr. S. C. Tsiang]* (Taipei: Yuan-Liou, 1995).
[4] Ta-Chung Liu and Kung-Chia Yeh, *The Economy of the Chinese mainland: National Income and Economic Development,1933-1959 Volume I and II*, Project RAND contract No. AF49 (638)·700, published by The RAND Corporation, April 1963.
[5] L.R. Klein, Marc Nerlove, and Sho-Chieh Tsiang, "Ta-Chung Liu, 1914-1975," *Econometrica* 45, no. 2 (1977): 527-8.

Liu published an article in *American Economic Review* in 1959 to synthesize his research on "the communist economy" in China. The main purpose of this article was to evaluate the "inaccuracies, intentional distortion" in the statistics of the Chinese economy published by the Chinese communists, and to further adjust and estimate the actual performance of that economy.[6] When explaining the success of building "modern, big, capital-intensive plants" in China with assistance from the USSR, he emphasized the importance of the government's use of unpaid forced labor. He further compared the then-contemporary communist regime in China to the "tyranny" in ancient China's Qin Dynasty from 246 BC to 221 BC, when the emperor exploited an enormous population of forced laborers in the construction of the Great Wall. To acknowledge and explain the significant increase in steel and cement production in China from 1952 to 1957, Liu pointed out, "It is difficult to say whether the ancient or the modern 'achievement' is the more difficult. Certainly, the cost in human suffering and sacrifice was great in both cases.**"**[7]

Liu's research on China was a product of his support for Chiang Kai-Shek's government in Taiwan, as opposed to Communist China. According to his friends, Liu even refused to visit China when many Chinese-native or Taiwanese-based scholars followed Richard Nixon there after 1972.[8]

[6] Ta-Chung Liu, "The Non-Russian Communist Economies: Structural Changes in The Economy of the Chinese Mainland, 1933 to 1952-57," *Papers and Proceedings of the Seventy-first Annual Meeting of the American Economic Association* 49, no. 2 (1959): 84-93.
[7] Ibid., 92.
[8] See Yu, Tzong-Shian et al. *Liu da zhong xian sheng kang li zhui si lu [In Memory of Ta-Chung and Ya-Chau Liu]*, Taipei, 1975, published by Ta-Chung and Ya-Chau Liu's friends (original in Chinese).

Similarly, Liu's anti-communism stance was consistent with his campus life at Cornell. One of Liu's friends and colleagues, Tsunghan Hunt Shen, pointed out that Liu had argued against anti-Vietnam War students in a public debate in Bailey Hall at Cornell when the anti-war movement was at its peak there.[9] Shen wrote this anecdotal story in a paper in memory of Liu and in praise of Liu's staunch stance. *Ithaca Journal* covered this event. Held at Cornell on a Friday evening in May 1965, the meeting of 2,000 attendees gave Liu an opportunity to state that "every village in South Viet Nam should be taken over." Liu termed such actions a "basic Peace Corps amplified 100 times by a sense of urgency."[10]

Furthermore, according to Sho-Chieh Tsiang, one of Liu's colleagues, when Liu started chairing the department of economics at Cornell, he led the conservative camp of professors in opposition to the leftist professors on campus. According to economic sociologist Judith Reppy, a graduate student at that time, each of the two camps sometimes held "departmental" meetings without informing members of the other camp.[11] The ideological disputes also reflected themselves in the recruitment of new faculty members. According to Tsiang, Liu successfully fired a young faculty member because Liu considered the individual to have been versed merely in "avant-garde" thoughts taught in the classroom.[12]

Liu's participation in the heated contestations at Cornell was perhaps not much more than one example of the numerous concurrent polarized disputes raging at other US universities. However, Liu's anti-communist stance not only reflected his research on the Chinese communist

[9] Ibid., 96.
[10] *Ithaca Journal*, " 'Teach-In' Draws a Capacity Crowd," May 8, 1965.
[11] Personal conversation on March 29, 2010.
[12] See page 84-88 in Tsu-Yu Chen, ed., *The Reminiscences of Dr. S. C. Tsiang*.

economy and his professional life at Cornell, but also was central to his multiple missions to Taiwan after 1962.

Liu's Trips to NCTU

Liu learned of NCTU's possession of an IBM 650 during his first visit there in March 1962 (soon after the delivery of that computer to NCTU and prior to the CIECD's aforementioned invitation).[13] This visit provided him with knowledge of the computation center at NCTU, and NCTU also received positive comments from Liu on its efforts in acquiring Taiwan's first mainframe computer.

During his 1962 trip, Liu, as a distinguished alumnus, attended a workshop held by the faculty members of NCTU to discuss university education. After learning of the news that an IBM 650 mainframe computer had arrived one month prior to his visit, Liu stated that he was impressed by the university's attempts to improve engineering education in Taiwan. He said that it was amazing that, following Japan, Taiwan owned the second digital electronic computer in East Asia. Though his comment was incorrect because Japan had more than one mainframe computer at this moment, the IBM 650's 1962 arrival in Taiwan was certainly one of the earliest mainframes to operate in East Asia.[14]

Liu shared his experience of having used computers to teach at Cornell and emphasized the wide applications of computers to economics. He stated,

[13] "Welcoming Liu Ta-Chung," *The Voice of NCTU Alumni* 111 (March 1962), 24-25.
[14] "The History of Computers," *Mugendai*, 115 (summer 2004), 53-57 (original in Japanese), accessed November 30 2011, http://www-06.ibm.com.jp/ibm/mugendai/no115/pdf/115m.pdf

> My research and teaching in the US heavily relied on electronic computers. Some complicated mathematical problems that might have taken one week to solve in the past now would take only several minutes. By means of computers, one is able to compute the lowest costs, such as the cost of gas, for a certain condition of production.[15] (Original in Chinese)

Liu's comments show that he had been using computers for his econometric research. Liu's 1962 visit to NCTU better prepared him for his 1964 visit, which rested heavily on the performance of the computers at NCTU as well as on that of his assistants from NCTU. The IBM 1620 computer, installed at NCTU on February 20, 1964, became the essential instruments with which he would carry out his economic-planning project in Taiwan.[16]

In 1964, Liu accepted the invitation from the CIECD and visited Taiwan for five weeks in the summer. In studying Liu's final report to the CIECD, it is clear that he whole-heartedly wanted to improve the performance of Taiwan's economy and make it better than that of Communist China.[17] Liu expected to offer a basis for economic planning in his "home country" and contribute to the long-term development of the Taiwanese economy. He worked on three things there: conducting an inter-industry input-output analysis of industries in Taiwan, establishing econometric models, and revising previous statistics such as previous national-income and economic-growth rates. He completed the input-output analysis by using the IBM 1620 computer at NCTU with assistance from NCTU research assistants and CIECD personnel.

[15] "Welcoming Liu Ta-Chung," *The Voice of NCTU Alumni*.
[16] "Alma Mater Celebrates 66th Anniversary," *The Voice of NCTU Alumni* 113 (May 1962), 1-4.
[17] Ta-Chung Liu, *Final Report on Economic Planning*.

Before Liu's trip from Ithaca, New York to Taiwan, he wrote to S. M. Lee, the director of the Institute of Electronics at NCTU to inquire about the capacity of the computers at NCTU. Many aspects of this letter show that from Liu's point of view, there was not much discrepancy between the technological resources—including material artifacts and human resources—of Taiwan and those of the United States.

First, Liu asked S. M. Lee whether a couple of types of programs were available at NCTU:

> It is nevertheless possible that by August we may be in a position to do some estimating and planning work…. The following three basic types of computing programs may be needed:
>
> (1) Multiple regression and correlation analysis.
>
> (2) Solutions of simultaneous linear equations.
>
> (3) Basic operation in matrix algebra, i.e., matrix additions, multiplications, and inversions. These basic sub-routines should be capable of being put together to form more complicated programs.[18] (Original in English)

These programs were for producing inter-industry input-output analyses and macro-economic models. He then stated that if these programs were not available, he could ask someone at Cornell to work on writing or acquiring the programs.

[18] Ta-Chung Liu to H. M. Li [S. M. Lee], May 25, 1964, CIECD Central Files, 36-01-011-026.

> I would appreciate it greatly if you would be kind enough to tell me at your early [*sic*] convenience whether these computing programs and sub-routines are already available at the Institute. It they are, I would appreciate having brief "writing-up[s]" of these programs and sub-routines (not the actual programs themselves, but a description of the computations they can do). If they are not yet available, I may be able to have someone here [at Cornell University] to work these programs out for us.[19] (Original in English)

The term "yet" in the last sentence of this excerpt shows that Liu expected that NCTU had been keeping an approximate pace with US universities. There are more traces of this attitude in the following paragraphs of this letter. In addition to programs, Liu was concerned about the stability, programming language, and memory capacity of the NCTU computers, as well as whether NCTU programmers could handle the many facets of computing on digital electronic computers. The letter continues,

> For this purpose, I need to know the following: (1) Which of the two computers we have is in the best working conditions [*sic*] (the 650 or 1620)? (2) Do we have the Fortran compiler for these computers?(If we do not have this and have to use the machine languages, then it would be just about impossible to have the programs written and tested in time for use.) (3) Have we added memories to the basic capacity? What is the memory capacity we have currently? (4) Do we have on our staff a programmer who knows elementary matrix algebra (rules for matrix additions, multiplications, and inversions)? Anyone who knows elementary college algebra can learn these basic matrix

[19] Ibid.

manipulations in two weeks or 10 days. (5) What are our input and output facilities (card, tape, print-out, etc., please give [me the] equipment numbers)?[20] (Original in English)

These questions indicate that Liu was going to go to Taiwan alone with his expertise and expected that Taiwan's technical resources would be roughly equivalent to those in the United States. He expected to see in Taiwan a host of computers, programs, and subroutines similar to those in the United States. Also, he anticipated finding local Taiwanese programmers trained in manners similar to those practiced in the US scene. The fourth question, in particular, shows that Liu expected NCTU to be in possession of some staff member or other person capable of handling the programming for him, with only a maximum two-week training session necessary for the person's absorption of the necessary knowledge. Liu's conception of the technological environment at NCTU, thus, was extremely positive.

Chuang Chang, a CIECD official, helped S. M. Lee to answer his questions. Fortunately, NCTU used the FORTRAN compiler and had subroutines for simultaneous equations and matrix operations. But Chang found that NCTU did not have programs for multiple regression simulation. At this time, another university in Taiwan, National Taiwan University (hereafter NTU), which simply rented an IBM 1620 computer in May 1964, had a program for multiple regression simulation. However, Chang was concerned about whether NTU would be able to or willing to lend the program. The official suggested that Liu bring necessary programs or subroutines from the United States, just in case.[21]

[20] Ibid.
[21] Chuang Chang, at the Chung-Hwa Information Processing Center, to the CIECD, June 8, 1964, CIECD Central Files, 36-10-011-026; Jiang Tai-Qi, Director of NCTU Computation Center, to Provost of National Taiwan University, May 7, 1964, University Records, National Taiwan University, Taiwan.

At the end of his letter, Liu added that it takes time to debug so he hoped to hear back from S. M. Lee as soon as possible. He wrote, “The writing of programs, and especially the testing and “debugging” of programs, will take a great deal of time.” Liu’s concern about debugging was reasonable. An unexpected obstacle significantly slowed down Liu’s work on economic planning after he arrived in Taiwan in August—NCTU computers’ memory units were not enough to execute Liu’s and the CIECD’s planned calculations.

The Limited Capacity of the IBM 1620 for Liu’s Inter-Industry Input-Output Analysis

The CIECD had collected the data of industries in Taiwan and categorized them into 44 industries prior to Liu’s arrival on August 12, 1964. With the data, Liu was able to run a macroeconomic model to identify the final demand of the national economy in the coming several financial years. He planned to run a set of 44 by 44 matrices and its inversion, which would show the relationships between 44 industries in Taiwan. This type of work is known as an inter-industry input-output analysis.

An inter-industry input-output analysis uses matrices to represent a nation’s or region’s economy. To produce an input-output analysis, an econometrician will first come up with a desired final demand of a national economy in the coming years. The desired final demand is used to estimate a corresponding economic growth rate. According to the desired final demand, an econometrician makes a corresponding input-output chart to estimate the resources that each industry can contribute to the desired final demand and the desired economic growth rate. With this input-output analysis, government officials consider policy decisions such as how much

funding a government should lend to a particular industry to meet an expected final demand, and how much government investment from industry A to industry B could possibly contribute to an expected final demand for economic growth.

Economist Wassily Leontief was the first person to use digital electronic computers for the inter-industry input-output analysis. Much of his effort was focused on helping the US economy develop. Leontief used a linear equation to represent the inter-relationship between two industries. If there are ten industries in a national economy, an input-output table will consist of 10 simultaneous linear equations. Since Wassily Leontief first established the inter-industry input-output analysis in the United States in the 1930s, it had been used worldwide by national or regional governments and economists to predict the effects of changes of one industry on others. The CIECD and Liu's collaboration represented an early trend towards implementing the inter-industry input-output analysis in countries other than the United States. The US government constructed input-output tables for 1947, 1958, and 1963. In 1967, the US government began to construct input-output tables for every year ending in a '2' or a '7'. According to a review of Leontief's contribution to economics, written by MIT professor Karen Polenske, the Eisenhower administration stopped producing input-output tables between 1947 and 1958 because the tables were thought to be "too closely related to planning in the communist counties."[22]

According to an estimated final demand of the national economy of Taiwan for the coming years, and a constructed inter-industry input-output analysis, Liu would be able to

[22] See page 12 in Karen R. Polenske, "Leontief's 'Magnificent Machine' and Other Contributions to Applied Economics," Erik Dietzenbacher and Michael L. Lahr, eds., *Wassily Leontief and Input-Output Economics* (Cambridge: Cambridge Univ. Press, 2004), 9-29.

predict how much each industry has to contribute to the estimated final demand.[23] With this model, the CIECD could consider policy decisions ranging from how much funding the government should lend to a particular industry to meet an expected final demand to how much investment from industry A to industry B could possibly contribute to an expected final demand.

To assist Liu, NCTU assigned Yun-Tzong Chen to write computer programs. Chen graduated from NCTU in 1962, and worked as a research assistant at NCTU in 1964. Chen had taken Arden's and Peterson's courses, and had offered programming courses in numerical analysis to engineers from state-owned or private enterprises.[24] Also, the CIECD assigned one of its staff members, Tai-Ying Liu, to help Liu's computation work at NCTU.

Liu and the CIECD planned to carry out the computation of a set of 44 by 44 matrices and its inversion; however, the IBM 1620 at NCTU could not perform the task. The IBM 1620 there had a limited memory capacity—its magnetic-core storage unit had merely 20,000 alphanumeric digits. The standard model of the IBM 1620 computers was 20,000 digits, but customers could rent the optional IBM 1623 Core Storage Unit to increase the capacity to 40,000 or 60,000 digits. However, when Arden recommended that NCTU and the United Nations rent an IBM 1620 to replace the IBM 650, NCTU did not obtain the optional memory units, and it was likely because Arden and NCTU only planned to obtain an inexpensive model of the IBM 1620.[25]

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[23] Ta-Chung Liu, *Final Report on Economic Planning*.
[24] Oral-history interview with Chi-Chang Lee, January 7, 2009; Oral-history interview with Yun-Tzong Chen, May 24, 2009.
[25] For NCTU's decisions, see "Plan of Operation," February, 1961, MFA Files, 635.31 0200. For Arden's recommendation, see page 28 in *Training and Research Centre for Telecommunications and Electronics, Republic of China: Report* (Geneva: United Nations), 1968. For the IBM 1620's standard model, see "IBM 1620 Data Processing System," *Updating Supplement* no.25, January 1961, published by Automation Consultants Inc., James

To accommodate to the capacity of the computer, Liu and the team re-categorized the 44 Taiwanese industries to 37 industries, so that they could run a set of 37 by 37 matrices.[26] Among the relevant archival materials that I have surveyed, there is no information indicating which industries were combined or eliminated. However, an adjustment of the number of industries indicates the stochastic nature of econometrical models.[27] For producing the inter-industry input-output analysis, an increase in the number of industries has been a problem vexing econometricians and computer programmers. In particular, since his development of the inter-industry input-output analysis in the 1930s, Wassily Leontief had been negotiating between the capacity of the computing devices to which he had access and the data he had.

As mentioned earlier, solving simultaneous linear equations is the basis of making an input-output analysis. Solving simultaneous linear equations has been a difficult task when the numbers of equations increase. In 1949, Leontief pointed out that the input-output analysis involved an unprecedented volume of numerical operations, compared to the volume of computation in economics and statistics, or even in natural sciences.[28]

Before having access to digital electronic computers, Leontief used punched-card machines to work on his first input-output tables for ten sectors for the 1919 and 1929 US

W. Cortada Papers (CBI 185), Box 28, or *Reference Manual: IBM 1620 Data Processing System*, published by IBM, 1961, Computer Product Manuals Collection (CBI 60), Box 113, Charles Babbage Institute, University of Minnesota, Minneapolis.

[26] A memorandum from the Institute of Electronics at NCTU to the CIECD, Oct. 13, 1964, CIECD Central Files, 36-10-011-026.

[27] For the stochastic nature of and the frequent use of judgment adjustments in models, for example, see Robert Evans, "Soothsaying or Science? Falsification, Uncertainty and Social change in Macroeconomic Modelling," *Social Studies of Science* 27, no.3 (1997): 395-438.

[28] See page 215 in Wassily Leontief, "Recent Developments in the Study of Interindustrial Relationships," *The American Economic Review* 39, no. 3 (1949): 211-25.

economies.[29] In 1947, Leontief presented an article at the Symposium on Large Scale Calculating Machines, organized by Howard Aiken, a pioneer in digital electronic computing. In the Symposium, Leontief pointed out that the Harvard Mark I computer at Harvard University had already been able to handle a 40 by 40 system of matrices. However, he added, "No attempts have been made to invert the matrix."[30] According to historian I. Bernard Cohen's research on Aiken and Leontief, "Leontief may be the first social scientist to have used a computer."[31]

Because computers at this time could not invert large matrices, Leontief had to keep his input-output analysis within a certain number of industries. In May 1949, Leontief published an article in which he constructed a 13 by 13 input-output table for the US economies of 1919, 1929, and 1939, so he divided the US economy into 13 industries.[32] In this article in *American Economic Review*, he wrote,

> What would we do, however, if our computers refused (as they would have a very good reason to if not equipped with large-scale calculators) to solve any system of more than fifty linear equations? The number of individual industries would have to be reduced in this case by a process of reclassification which in this particular instance would actually mean also partial consolidation.[33] (Original in Chinese)

[29] Polenske, "Leontief's 'Magnificent Machine' and other Contributions to Applied Economics."
[30] Page 174 in Wassily Leontief, "Computational Problems Arising in Connection with Economic Analysis of Interindustrial Relationships," *Proceedings of a Symposium on Large-Scale Digital Calculating Machinery* (Cambridge: Harvard Univ. Press, 1948), 169-74. The Symposium was held in January 1947.
[31] Page 207 in I. Bernard Cohen, *Howard Aiken: Portrait of a Computer Pioneer* (Cambridge: MIT Press, 1999).
[32] Wassily Leontief, "Recent Developments in the Study of Interindustrial Relationships."
[33] Ibid., 217.

In July 1949, he had already published another article for a 20 by 20 table for the US economy of 1939.[34] For papers he published in 1951, he produced a 42 by 42 table. In fact, by 1949, the Interindustry Economics Division of the Bureau of Labor Statistics had divided the U.S. economy into 500 sectors. However, because the Harvard Mark II computer still could not handle 500 equations with 500 unknowns, Leontief only ran a system of 42 equations for 42 industries. In his paper for the *Scientific American,* Leontief pointed out that it requires 56 hours on the Harvard Mark II computer for a 42 by 42 table.[35] For the history of this episode, David Lay, a mathematician and the writer of a popular textbook—*Linear Algebra and Its Applications*—stated that "the Mark II hummed and blinked for 56 hours before finally producing a solution [for a 42 by 42 system of equations]."[36]

Leontief and many econometricians consistently looked for computers with better capacities and, at the same time, consolidated numerous industries categorized by data-collection bureaus. In this regard, the difficulty that the CIECD and Liu encountered was not entirely a special case. Nevertheless, this vexing problem appeared in Taiwan in 1964, and was complicated by the need for an econometrician from across the Pacific. The econometrician's cross-Pacific trip required a ready technical environment, including a workable and capable digital electronic computer, programmers, and an appropriate dataset. It was fortunate that the CIECD could offer to the econometrician an IBM 1620 computer and the programmer Yun-Tzong Chen. The computer was a gift of the United Nations technical-aid program, and the

[34] See page 278-79 in Wassily Leontief, "Structural Matrices of National Economies," *Econometrica* 17, Supplement: Report of the Washington Meeting (1949): 273-82.
[35] Wassily Leontief, "Input-Output Economics," *Scientific American* 185, no. 4 (1951): 15-21.
[36] See page 1 in David C. Lay, *Linear Algebra and Its Applications* (Addison Wesley, Third Edition, 2003).

programmer had obtained his expertise through the material and epistemological resources provided by the technical-aid program.

US Aid Money Helped Upgrade the IBM 1620 Computer

Before leaving for the United States in September 1964, Liu recommended that the CIECD purchase more magnetic-core storage units for NCTU's IBM 1620. He wrote a letter to the director of the Institute of Electronics at NCTU, S. M. Lee, saying,

> The work I did for the CIECD was handicapped by the fact that the 1620 has a memory capacity of only 20,000. We had to reduce the scope of our computations in order to have the work done on the 1620. At a cost of only about $15,000, we can double the memory capacity of the 1620 and make it possible to do many research projects beyond the capacity of our present facilities. I have talked both to Messrs. K. T. Li and Philip Chang of the CIECD about this matter. Both of them indicated to me that they would give this matter serious consideration if our [your] Institute submits an application to the CIECD for purchasing the additional memory capacity. I hope very much that our [your] Institute would prepare an application and submit to the CIECD.[37] (Original In English)

[37] Ta-Chung Liu to H. M. Lee (S. M. Lee), Sep. 23, 1964, CIECD Central Files, 36-10-011-026. The per capita income in Taiwan for the year 1964 was $202 US dollar, according to Taiwan's Directorate General of Budget, Accounting and Statistics, Executive Yuan (which is an equivalent of the Cabinet or the Council of Ministers), see http://ebas1.ebas.gov.tw/pxweb/Dialog/statfile9L.asp

Tai-Ying Liu, one of the staff members sent from the CIECD to help Liu's computation work at NCTU, wrote a memorandum to explain why extra core storage units were going to be important for the CIECD's economic planning in the future. He stated,

> The purpose of running an inversion of a matrix is not the end of the economic-planning work, but the beginning of organizing collected data. When we are figuring out policies or plans for each industry, we need to consider the goal and the limitation of macroeconomic projects for the national economy in the first place. We, then, estimate an aimed production and actual capacity of each industry and propose our prioritized concerns on current economic policies. Having these considerations in mind, we adjust the final demand of each industry when inverting the matrix. It is a process done by trial and error. In this way, we will be able to find out the most optimal industrial structure, which is helpful to make economic plans for each industry. However, the process of adjusting is arduous. When we have human labor compute it, it takes a long time and is difficult to obtain the optimal results. However, if the IBM 1620 computer at NCTU could be equipped with sixty thousand positions to its maximum, the computer will be able to carry the repetitive attempts.[38] (Original in Chinese)

At the end of 1964, the CIECD decided to purchase an extra 40,000 positions of core storage units, which would be capable of conducting the computations for 59 industries' input-

[38] Tai-Ying Liu, at the third division of the CICED, to the second division of the CICED, Oct. 29, 1964, CIECD Central Files, 36-10-011-026.

output analyses. The money was budgeted from annual US aid managed and distributed by the CIECD.[39]

The extra 40,000 positions of core storage units were scheduled to arrive in July 1965 and in fact arrived in September 1965. The extra core storage units cost $58,700 US dollars prior to a 60% discount for educational institutions. In addition to the core memory, NCTU requested the automatic division hardware and additional instructions hardware, which cost $670 and $2,400 respectively. With the two types of hardware, users of the IBM 1620 computer at NCTU would not have to write or use subroutines to do computations. According to NCTU's proposal, the two types of new hardware would upgrade computation time to a rate twice or four times faster than it had been. Eventually, NCTU was able to purchase the extra additional core storage positions, core storage adapters, automatic division hardware, additional instructions hardware, indirect addressing hardware, and automatic floating point operations. Automatic floating point operations cost $12,400 US dollars and increased the speed of computing decimal digits.[40]

In the years to follow, producing the input-output analysis to form economic-planning projects became a regular task for the CIECD. In 1964, for the 1965-1968 economic-planning project, Liu produced an input-output table of 37 industries based on the information from 1961. In 1966, for the 1969-1972 economic-planning project, the CIECD created a table of 55 industries based on the information of 1964, since the CIECD improved the capacity of the

[39] K. T. Li, Vice Director of the CIECD, to Chia-Kan Yen, President of the Executive Yuan [the Prime Minister], Dec. 28, 1964, CIECD Central Files, 36-10-011-026.
[40] "A list of Imported Items," written by the Institute of Electronics at NCTU, Nov. 1, 1965; A letter from NCTU to the CIECD, July 8, 1965; A memorandum from the Institute of Electronics at NCTU to the CIECD, Oct. 13, 1963, CIECD Central Files, 36-10-011-026.

computers at NCTU. In 1969, when making an input-output table for 1966, the CIECD produced a table of 75 industries.[41]

Liu's advice on economic policies indirectly encouraged the Taiwanese government to purchase new computers. His 1964 visit is an example in which the CIECD realized the limited capacity of the IBM 1620 computer at NCTU. Moreover, four years afterward, Liu again accepted an invitation from the Ministry of Finance in Taiwan to advise on tax policies. One of the main purposes of this reform was to computerize the information of taxation, which significantly improved the Ministry's ability to audit individual and business tax filings for the purpose of increasing tax revenue. To computerize taxation, the Ministry purchased a CDC 3300 computer with 65,000 memory units to digitalize 8 million tax files in 1969.[42]

Conclusion

It seems that modeling the national economy by digital electronic computers was a revolutionary and unstoppable trend. But, I would like to point out a counter-argument to this revolutionary discourse. Some calculations in this case could still be done manually, and the required human labor might not be more expensive than the high monthly rental fee and other necessary expenses, such as hiring human labor to produce computable data or to write programs. As historian of computing Jon Agar has pointed out scientists or engineers mechanized calculations from existing human-labor tasks to computer programs. But after using digital electronic computers, they started claiming that the tasks could not be done by human labor any

[41] See page 12 and page 31 in Tai-Ying Liu, "A Dynamic National Economic Planning Model: A case Study of the Republic of China," PhD diss., Cornell University, 1974.
[42] The Ministry of Finance in Taiwan, "The Data Processing of Tax files." See http://www.mof.gov.tw/museum/ct.asp?xItem=3742&ctNode=39&mp=1

more. To Agar, this discourse was the indispensible part of the "computer revolution." Furthermore, in this case, the econometrician' modeling of the economy was entirely restricted by the IBM 1620's limited memory capacity. Also, Liu's work could not be completed without assistance from local Taiwanese actors' newly-acquired expertise. [43]

This chapter's description of using mainframe computers to assist in economic-project planning in Taiwan demonstrates that the historical relationship between digital electronic computers and the ideas of development in Taiwan are multi-layered. First, a group of Taiwanese engineers, technocrats, and scientists expected that digital-electronic-computing and electronics-science education would help to strengthen the industrial sector in Taiwan. They also expected that, eventually, the industrial sector would supersede the agricultural sector and would transform Taiwan from a developing country to a developed country. Second, after arriving in Taiwan, the two IBM digital electronic computers at NCTU indeed supported different types of engineering and scientific calculations that facilitated state-owned enterprises' development projects. Third, in this chapter, the IBM 1620 computer helped Liu and the CIECD to produce econometric knowledge for the pursuit of improved economic performance. The materiality of digital electronic computers supported the production of econometric knowledge. Though the econometrician's modeling of Taiwan's economy was restricted by the IBM 1620's limited memory capacity, the CIECD immediately expanded the capacity of the memory after acknowledging the issue. In sum, digital electronic computing in Taiwan derived from the general ideas of development and supported practices involved in the development of Taiwan.

Philip Mirowski has pointed out that digital electronic computers and other types of cyborg science have shaped the development of neoclassical economics. In his book *Machine*

[43] Jon Agar, "What Difference Did Computers Make?" *Social Studies of Science* 36, no.6 (2006): 869-907.

Dreams, he cited a statement from Leontief to illustrate the constructed analogy between the market and computers. Leontief wrote, "The economic system can be viewed as a gigantic computing machine which tirelessly grinds out the solution of an unending stream of quantitative problems."[44] Liu's mission brought the analogy to Taiwan and illustrated the mutual construction of econometrical models and digital electronic computers. Liu was the first person to solve mathematical problems for economic-planning endeavors by taking advantage of the existence of mainframe computers in Taiwan. He brought new econometric models to Taiwan, and as these models required digital electronic computing, his scholarship inevitably highlighted the importance of digital electronic computers, and encouraged Taiwanese bureaucrats to upgrade available computers and to purchase new computers. The cross-Pacific travels of econometric models and digital electronic computing from the US to Taiwan were accidently connected in this case. By "accidently," I mean that Liu's work could have been hindered if the UN technical aid program had not helped NCTU to acquire mainframe computers and had not nurtured a generation of programmers there. The materiality of digital electronic computers supported the production of econometric knowledge. Though the econometrician's modeling of Taiwan's economy was entirely restricted by the IBM 1620's limited memory capacity, the CIECD immediately expanded the capacity of the mainframe computer after acknowledging the capacity issue. In this manner, computers and econometric models reinforced each other's roles in the process of economic planning.

After Liu's sudden death in 1975, Liu's colleagues wrote a paper in *Econometrica* to acknowledge Liu's contributions. They stated,

[44] Wassily Leontief, *Essays in Economics* (New York: Oxford Univ. Press, 1966), 237; Philip Mirowski, *Machine Dreams: Economics Becomes a Cyborg Science* (Cambridge: Cambridge Univ. Press, 2002), 539.

> As econometric modeling spreads from the United States to other developed market economies and to those of developing and socialist nations, it is clear that we know very little about the economy of China. Eventually, we can expect to have input-output and macro-econometric models for China that are the equal of those now being prepared for the USSR and other socialist countries, and it is certain that researchers who achieve success in this endeavor will build significantly on the deep work already done by Ta-Chung.[45] (Original in English)

While econometric modeling was a good tool with which to understand socialist, developed, and developing countries, Liu's engagement with developing an inter-industry input-output table for Taiwan was a product of his anti-communist political ideas and part of the dominant development discourse of the time. Liu produced academic papers to show the failure of the economy in China and helped the Taiwanese government to accomplish a better economy; he was participating in the communism-and-capitalism struggle between the United States, Taiwan, and China. Econometric models and digital electronic computers were his epistemic machines for the Cold War.

Liu and the CIECD's adjustment of the number of industries indicates the stochastic nature of and the frequent use of judgmental adjustments in econometric models. From observing Leontief's and Liu's practices, the numbers of industries divided in a 'national' economy was dependent on the degree of the computer capacity available to them. What really matters, then, seemed to be the periodic production of the input-output analysis itself, rather than which

[45] L.R. Klein, Marc Nerlove, and Sho-Chieh Tsiang, "Ta-Chung Liu, 1914-1975," 527.

industries were included. This periodical production of the national inter-industry input-output analysis allowed a group of government agencies and econometricians to scrutinize and to represent economic activities within defined national boundaries.

The adoption of the input-output analysis in Taiwan indicates the emergence of a new way to visualize Taiwan as an entity and a new way to represent its national economy. With the input-output analysis, policy-makers were allowed to adjust or manipulate the investment in a certain industry in order to create a desired economic result. Of course, this type of adjustment had taken place before Liu's visit in 1964. Since the 1950s, the Chiang Kai-Shek government's policy-makers had started collecting statistics about national income and economic growth rates and debated the interrelationship between two or another limited number of industries. But digital electronic computers offered policy-makers an opportunity to consider more and more subtly divided industries as a whole. The economic activities within a nation's boundary became a simulatable entity.

In 1968, Ta-Chung Liu again accepted an invitation from the Ministry of Finance in Taiwan to offer advice on "tax reform" policies. One of the main purposes of his visit this time was to computerize the information of taxation in order to better audit individual and business tax filings. In March 1969, a group of Taiwanese students calling themselves "concerned Formosans at Cornell" published an open letter to Ta-Chung Liu in the Cornell Daily Sun. The anonymous students pointed out that the tax reform was merely a political stunt orchestrated by the Chiang Kai-Shek regime in an attempt to increase revenue for the Taiwanese military and secret police, especially insofar as US aid to Taiwan had ended in 1965. To these anonymous

students, the government's taxation did not seem to rest on democratic elections. Nevertheless, while the students disapproved of Liu's assistance to the "corrupt and corruptive machine of tyranny," they did not blame the use of digital electronic computers for the tax reform.[46]

[46] *Cornell Daily Sun*, "An Open Letter to Professor Ta-Chung Liu," March 19, 1969.

CHAPTER 5

NCTU'S MINICOMPUTER-BUILDING PROJECT, 1968-1971

This chapter examines a project in which the Institute of Electronics (i.e. the graduate program in electronics) at National Chiao-Ting University (NCTU), although able to buy a minicomputer from various foreign suppliers, built one (see figure 1) from scratch between 1968 and 1971, continuing the discussion of NCTU students' and faculty members' active importation of computing technology after gaining access to mainframe computers (see Chapter 3). In building a minicomputer, NCTU students and faculty members were able to study the architecture of minicomputers, and to experiment with how to manufacture them domestically. This chapter places NCTU's tinkering with minicomputers within the context of the electronics industry and industrial policies in Taiwan.

Preceding chapters have described Taiwanese engineers, scientists, and technocrats' multi-layered enthusiasm for the ability to possess and use digital electronic computers, including an IBM 650 and an IBM 1620. This chapter discusses that, in Taiwan, a group of early computer users attempted to build the artifact itself, mainly because they shifted their focus from the ability to own and use computers to the ability to manufacture computers.

Building a computer from scratch is a distinctive activity that borders on replication, emulation, and creativity, because to build a computer is to infuse into a project a large amount of diverse knowledge. Moreover, to build a computer from scratch is particularly relevant to the East Asian context. Tracing how a computer was built and what types of epistemological input contributed to the process of building has become a "genre" within the history of East Asian

computing. In the 1980's, Hidetosi Takahasi and Shigeru Takahashi published a description of their participation in the design and building of several computers in 1950's Japan.[1] They emphasized hardware design and the components they chose, with little interest in intriguing social contexts, such as the backgrounds of participants, funding sources, and the uses of these computers.[2] Recently, historian Chigusa Kita has written about how the seat reservation system for the Japanese National Railway was designed and began operation in 1959.[3] She has proposed the concept of "technological mimesis" to discuss how a group of designers decided to use Bendix G-15 computers manufactured in the US, and how this project was related to a designer's study at MIT.

In the summer of 1968, NCTU graduate students and instructors started a reading group that met weekly to discuss the possibility of manufacturing an electronic digital computer. This project lasted until June 1971 and produced what participants referred to as a "small-scale" calculator in Chinese, or the "NCTU minicomputer" in English. Participants included Chao-Chih Yang, who was a visiting professor from the University of Alabama at Birmingham, Ching-Chun Hsieh, who was a Ph.D. student at NCTU and obtained a master's degree in Electronics from NCTU in 1966, and Jong-Chuang Tsay, who was a Ph.D. student at NCTU and obtained a Master's degree in Electronics from NCTU in 1968. Other participants included Master's students and technicians. Nevertheless, this chapter focuses on the two Ph.D. students, as they

[1] Hidetosi Takahasi, "Some Important Computers of Japanese Design," *IEEE Annals of the History of Computing* 2, no.44 (1980): 330-37. Shigeru Takahashi, "Early Transistor Computers in Japan," *IEEE Annals of the History of Computing* 8, no. 2 (1986): 144-54.

[2] For example, their articles discusses that, in the 1950s, universities transferred computer-related technology to companies without charging fees, and universities built computers with corporations' assistance. Howebver, it is not clear whether the innovations emerged in the university settings related to military-related purposes.

[3] Chigusa Kita, "From Technological Mimesis to Creativity: Early Online Rail Reservations in Japan" (presented in the Annual Meeting of The Society for the History of Technology, Oct. 17-21, Washington DC., 2007).

contributed to a large portion of this computer-building project.[4] The main funding source for the project was the National Science Council, which was established in Taiwan in 1959.

NCTU members' tinkering practices helped them to complete the building of a calculator. In the following paragraphs, I describe how, after experimenting with several different designs, NCTU members came up with a calculator with their own design of logic units and magnetic-core memory units. In addition, they also attempted to manufacture these units and spent a significant amount of time and energy to wire each component of this calculator. I use 'tinkering' to refer to their practice of building a technological artifact, after countless trial and error attempts, with components that were not manufactured by or assembled in a conventional way. Their production of the calculator was different from the existing successful manufacturers, and was an informal production of a technological artifact. NCTU members' attempt to build a minicomputer was a practice of adapting, modifying, assembling in an innovative manner, and working creatively with technologies.

The computer-building project led by Hsieh and Tsay beginning in 1968 is the first attempt by Taiwanese, in general, or NCTU members, in particular, to build an digital electronic computer from scratch. As noted in chapter 2, when S. M. Lee, director of the graduate program in electronics at NCTU, learned about the United Nations' approval of Taiwan's application for a technical-aid program to bring an IBM computer to Taiwan in the early 1960s, he commented that, with help from the UN, NCTU would be able to manufacture digital electronic computers

[4] *Economic News Daily*, "Di yi bu guo ren zi zhi dian nao shun li wan cheng [The First Domestically-manufactured Computer]," July 17, 1971, 1.

soon.[5] Lee's prediction was not realized until 1971. From the analysis of preceding chapters, the UN technical-aid program, lasting from 1962 to 1965, might merely have introduced NCTU members and trainees to the uses and design of digital electronic computers, and did not directly encourage any of them to build a computer from scratch.

Furthermore, the computer-building project led by Tsay and Hsieh beginning in 1968 was an extraordinary attempt, considering that UN-affiliated officials thought that the manufacturing of small-scale electronics products was not feasible in Taiwan at that time. Taiwanese technocrats and these officials had begun discussing issues concerning the manufacturing of small-scale electronics products in the late 1950s (see chapter 2). Their discussions indicated that both Taiwanese technocrats and UN-affiliated officials believed that it was likely for them to implement some types of programs for incubating a small-scale-electronics industry in Taiwan. However, the manufacturing of mainframe computers, let alone calculators, was never brought up during this period.

In May 1964, when the UN-NCTU technical-aid program was set to end, Gisson Chi-Chen Chien, Director of the Directorate General of Telecommunications in Taiwan (see chapter 2), submitted an application for a new technical-aid program to the United Nations Special Fund section, seeking technical and financial assistance to set up pilot factories to experiment with the manufacturing of "electron tubes, transistors, and other components" in collaboration with NCTU.[6] Following a similar pattern (of his successful application for the UN-NCTU technical-

[5] "Dian zi ji suan yi jiao da dian zi yan jiu suo ji hua yu shi yue zhuang zhi [NCTU will Set Up an Electronic Computer in October]," *The Voice of NCTU Alumni* 104 (August 1961), 23.
[6] "Application to the United Nation Special Fund for the Establishment of a Training Center for Technicians in Telecommunications and Electronics, Directorate General of Telecommunications, Ministry of Communications,

aid program), Chien specified in his 1964 proposal that this newly-proposed technical-aid program would be able to invite experts in each of the following fields: electron tubes, passive network components, circuit design, computer logic and design, and transistors and other semi-conductor devices. Nevertheless, the UN Special Fund section's overall comment on this application was "a little pre-mature."[7] Specifically, when S. M. Lee presented this proposal to John N. Corry, Resident Representative and Director of the Technical Assistance Board and Director of Special Fund Programs in the Far East, in July, Lee emphasized that this newly proposed project would train technicians and engineers, "who will be absorbed by local electronics industries." But Corry doubted whether Taiwan would need so many engineers if the electronics industry "were not highly developed in Free China."[8] Corry's colleague's reply to the application was more explicit. Resident Representative and Director of Special Fund Program in China, Knut H. Winter, stated directly:

> Although there is every possibility that within three of four years there will be a large electronics industry, it is doubtful that the current status of the industry is such that we could make a very firm prediction as to the possible requirements for people trained in the electronic fields. [9] (Original in English)

In retrospect, the computer-building project was more or less an experiment, rather than a project that could have created an industry and employment opportunities for engineers. By

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Republic of China," May 1964, MFA Files, 635.31 0201; and Knut H. Winter, Resident Representative and Director of Special Fund Program in China, to Chih-ming Kao, Director, International Organizations Department, Ministry of Foreign Affairs, Taipei, Republic of China, August 18, 1964, MFA Files, 635.31 0201.

[7] Ibid.

[8] Minutes, Special Meeting held by Ministry of Communications for Applying to the United Nations Special fund, July 7, 1964, MFA Files, 635.31 0201.

[9] Knut H. Winter to Chih-ming Kao, August 18, 1964.

'experiment' I mean that no one in Taiwan had worked on building a digital electronic computer prior to the NCTU minicomputer-building project. Nevertheless, considering that the two United Nations officials were uncertain about the potential of the electronics industry in Taiwan, the scope of the computer-building project led by Tsay and Hsieh beginning in 1968 aimed far higher than their evaluation.

Why did Hsieh and Tsay decide to build a minicomputer from scratch? Both Hsieh and Tsay pointed out that this project provided graduate students at NCTU with an opportunity to study the infrastructure of digital electronic computers when interviewed in 2007 and 2009.[10] An article published by Jong-Chuang Tsay in 1971 in a science-education magazine, *Science Monthly*, reveals several reasons why this group of participants decided to build a computer from scratch. As participants did not keep any notes on the discussion in their periodic meetings in the late 1960s, this 1971 article provided Tsay's interpretation of the minicomputer-building project. Tsay stated:

> The invention and application of the electronic digital computer after WWII has significantly changed industrial production and contributed to other scientific fields. Scientific research in our country is behind (*Luo-hou*); our citizens [*Guo-Ren*] merely obtain knowledge of computers through books and journals, which emphasize theories and seldom mention design and structure. National Chiao-Tung University imported an IBM 650 in 1962 and, to some extent, introduced relevant theories and practices to our country. Currently, there are about 30 digital electronic computers in Taiwan, but this is a

[10] Oral-history interview with Jong-Chuang Tsay, December 18, 2007; Oral-history interview with Ching-Chun Hsieh, May 27, 2009.

number far behind those of advanced countries such as the United States and Japan. To implement good engineering education and scientific research, we cannot be satisfied with merely the ownership of technology and the knowledge of using technology. We have to further pursue the manufacture and the design of technology. To help the national economy and to nurture technologists for the country, and to lay the foundation for the industry, we have to research and manufacture our own and avoid relying on foreigners." (Original in Chinese)[11]

To Tsay, it was important to shift from the capability of owning a technology and the knowledge of using that technology to the capability of manufacturing that technology. Although implicitly discussed, this shift had something to do with the logic that a *country* had to own this set of capacities—owning and knowing how to use and manufacture the technology, which would eventually help to improve the country's technologists as well as its economy and industry.[12] Furthermore, based on this set of capacities, countries could be categorized as *advanced* or *behind*.

Tsay's phrase "relying on foreigners" might imply two types of dependence on "foreigners." First, if some Taiwanese companies or individuals would manufacture computers domestically, it would not only strengthen Taiwan's industrial sector, but also improve Taiwan's economy by exporting domestically-manufactured computers or at least by decreasing the

[11] Jong-Chuang Tsay, "Wo guo di yi bu xiao xing dian zi ji suan ji jian jie jiao tong da xue shou zhi cheng gong [National Chiao-Tung University's Success in Building the First Domestically Electronic Digital Computer],"*Ke Xue Yue Kan* (hereafter *Science Monthly*) 21 (September 1971): 48-53.
[12] The term 'technologist' refers to *Ke Ji Ren Cai*.

overall expenses on importing computers. Second, domestically-manufactured computers would display a country's overall technological achievements.

Hsieh, Tsay, graduate students, and faculty members at NCTU held periodic meetings to study computer infrastructure. According to Hsieh, the group read journal articles published by the Association for Computing Machinery (ACM) and the Institute of Electrical and Electronics Engineers (IEEE). They also read internal technical documents from companies such as AMD, IBM, and Bell Laboratories, acquired through informal personal connections. One of the books that Tsay remembered was *Computer-Circuitry Considerations*, from Philips's Electronic Tube Division, Industrial Components and Materials Division in the 1960s. Specially, informal personal connections meant that some alumni hired by these companies provided internal technical documents to minicomputer-building project members.[13] Tsay published an article on the design of the memory unit of minicomputers, and cited articles published in 1965 and 1966 from *Fairchild Application Bulletin* and *IEEE Transactions on Electronic Computers*.[14]

When it came to the stage of building a minicomputer, Hsieh discussed the project with some alumni, and obtained, notably, assistance from two foreign-invested companies in providing components.

[13] Oral-history interview with Ching-Chun Hsieh, June 5, 2009.
[14] Jong Chuang Tsay, "Design and Experimentation of a 4X4X2 Memory," Reprinted from a 1969 Research Report, Engineering Science Research Center, Taiwan, National Science Council, 595-608; "Jiao tong da xue shou zhi cheng gong wo guo di yi bu xiao xing dian zi ji suan ji jian jie [An Introduction to National Chiao-Tung University's First Domestically Electronic Digital Computer]," written in 1971, available online, accessed November 30, 2011, http://www.csie.nctu.edu.tw/~jctsay/

The first company was Philco-Ford, which employed Zai-Xing Qiu, who had obtained his Master's degree in Electronics from NCTU in 1966. Philco was a company founded in 1892 and acquired by Ford in 1961. When the Taiwanese government set up an Export Processing Zone in 1966, Philco-Ford was one of the first thirteen companies to establish factories there.[15] (Generally, the Export Processing Zone was a typical policy invention for so-called "developing" countries to increase foreign investment and domestic employment rates in the 1960s, as these countries could offer international companies better tax rates and discounted land leases in a particular area). At that time, Philco-Ford either manufactured or imported integrated-circuits for assembling its electronics products. Because of his exposure to the latest products at Philco-Ford's Taiwanese factory, Qiu was able to informally provide integrated-circuits for Hsieh's teaching at NCTU.[16] Because of this arrangement, the integrated-circuits (Diode-Transistor-Logic units) in the NCTU minicomputer were from Philco-Ford.

Qiu was precisely the kind of "talented youth" that Chien and Lee were trying to train and find jobs for (see chapter 2). When Qiu was studying at NCTU, he and a small number of NCTU students organized the Abnormal Club, the acronym of which was ABC, as opposed to the popular acronym for the American-Born Chinese. This club was organized precisely to celebrate those few NCTU students who chose to stay and contribute their talents to Taiwan, as opposed to the trend in which many college graduates tried every means to study and then move

[15] *United Daily News*, Gao xiong jia gong chu kuo qu jin ju xeng jian cheng dian li [Kaohsiung Exporting Processing Zone is Inaugurated Today], December 3, 1966, 2; Si-Yu Chen, "She Xia IC Ban Gong Ye Long Tou Quing Zhing Mei De Tan Suo—Qiu Zai Xing Xue Chang [Giving up ICs, Shifting to his Pursuit for Arts—Zai Xing Qiu]," *Jiao da jia zu ju le bu [NCTU Family]* 48 (December 2006), accessed November 30, 2011, http://140.113.39.126/13/2010-07-06/nctufamily.nctu.edu.tw/nctu_club/2006/12/p01.html

[16] Oral-history interview with Ching-Chun Hsieh, May 27, 2009. Jong-Chuang Tsay, "An Introduction to National Chiao-Tung University's First Domestically Electronic Digital Computer."

to the United States. As planned, Qiu chose to work for Philco-Ford immediately following his graduation, but did go to Philco-Ford's US headquarters for a six-month training course.[17]

The logic design of the minicomputer was begun by Hsieh and his students. Hsieh started Ph.D. studies in the graduate program in electronics at NCTU immediately upon obtaining his BA from the same program. When Hsieh left NCTU for MIT temporarily, to work on his dissertation in 1959, Tsay took over the leadership of the computer-building project, playing a particularly important role in the design and making of the memory units, relying, partially on assistance from the Taiwan branch of Wang laboratories.

Wang Laboratories had been making desktop electronic calculators for the US market since 1964.[18] An Wang, the founder of Wang Laboratories, was a Chinese American, who obtained his B.A. in electrical engineering from Chiao-Tung University, located in China, in 1940, and his Ph.D. in physics from Harvard University in 1948.[19] Wang Laboratories set up a factory in the Export Processing Zone in Taiwan in October 1967, with its Taiwan branch led by another Chinese American, Yuan-Quan Feng, who graduated from Purdue University and was fluent in Chinese.[20] Wang Laboratories began manufacturing parts in Taiwan in May of 1968, and planned to start assembling electronic digital computers by the end of the year. At that time, a news story referred to Wang Laboratories as "the first computer manufacturer in Taiwan." [21]

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[17] Si-Yu Chen, "Giving up ICs, Shifting to his Pursuit for Arts—Zai Xing Qiu."
[18] Armon Glenn, "Electronic Calculators," *Barron's National Business and Financial Weekly*, September 11, 1967, 37 and 47.
[19] An Wang and Eugene Linden, *Lessons, An Autobiography* (Reading: Addison-Wesley, 1986).
[20] *Economic News Daily*, "Mei guo wang shi shi yan suo lai tai she chang chan zhi dian zi ling jian feng yuan quan jin lai zu guo qia shang [Yuan-Quan Feng Visited Taiwan to Set up Factories for Wang Laboratories], June 1, 1967, 2.
[21] *Economic News Daily*, "Tai wan wang an dian nao ji ji kuo da chan xiao [Wang Laboratories' Taiwanese Factory Aims the Overseas Market]," May 23, 1968, 1.

While the precise date is unclear, shortly after the reading group began to meet, Feng was invited to its periodic meetings at NCTU. He offered his expertise and various types of assistance, and, eventually, provided the project with core-memory parts.

Having obtained parts from Feng, Tsay planned to construct a three-dimensional 12X13X4, 50 mil ferrite-core memory. In the beginning, Tsay wanted to manufacture the core memory on the NCTU campus, but it would involve several sophisticated tasks. Tsay and Hsieh pointed out that Tsay and other graduate students were unable to wire lines through magnetic cores, the diameter of which was one thousandth (10^{-3}) of an inch. Each of the 624 magnetic cores was supposed to be threaded by four lines and the scale of each magnetic core and line was too small to manipulate without factory facilities (see figure 2), such as those at Wang Laboratories, which then generously agreed to manufacture a magnetic core memory consisting of 1,248 bits for the project (see figure 3).[22]

One of the most daunting tasks in the project's final year was wiring. Tsay pointed out that, because of a lack of wiring experience, the connecting wires among the computer's parts were not organized enough for testing (debugging) and practical operation. Perhaps, there were too many wires to organize for Tsay, who had worked alone on wiring since 1970, since most participants were busy working on their own theses for graduation. For example, there were more than 100 output wires in the control unit, alone. These wires were not marked with numbers or codes, and some were soldered to other parts of the computer, making it difficult to identify problems when the computer did not function as it should. After months of testing and

[22] Jong-Chuang Tsay, "Design and Experimentation of a 4X4X2 Memory"; Tsay, "An Introduction to National Chiao-Tung University's First Domestically Electronic Digital Computer," ; Oral-history interview with Jong-Chuang Tsay, December 18, 2007; Oral-history interview with Ching-Chun Hsieh, May 27, 2009.

identifying problems, he decided to re-wire the entire computer, which took another three months.[23] In an article Tsay wrote about the computer-building project for *Science Monthly*, he provided four pictures to emphasize how complicated the wires included in the computer were (see figure 4).

In the same article, Tsay brought up twice that this project provided him and other group members opportunities to learn things that they could not have gotten from books. In detailing the process of organizing wires, he specified that the noisy signal and poor connection were the most difficult problems to identify, and that such problems could not be solved by looking up information in books. Furthermore, he pointed out that the project trained participants to a great extent, stating:

> Because of this project, participants have obtained practical knowledge and experiences which cannot be gained by merely reading books. The project has displayed its multiple effects. When UCLA Electrical Engineering professor Ernest S. Kuh visited last year, he commented that this project demonstrated the most practical and effective training method.[24] (Original in Chinese)

Tsay emphasized that the knowledge and practices which were not included in books constituted an important part of the training for the minicomputer-building project. This type of knowledge is what science and technology scholars have referred as tacit knowledge.[25] But, what

[23] Tsay, "An Introduction to National Chiao-Tung University's First Domestically Electronic Digital Computer," 3.
[24] Page 6 in Jong-Chuang Tsay, "An Introduction to National Chiao-Tung University's First Domestically Electronic Digital Computer."
[25] Harry M. Collins, "The TEA Laser," *Changing Order: Replication and Induction in Scientific Practice* (Chicago:

were the purposes for the training obtained from the process of building a computer? Similar to Chien and Lee's attention to training "talented youth," Tsay emphasized the necessity to nurture a greater number of native technologists during the process of carrying out research plans, as this project had already done, pointing out that:

> The logic design and circuit design of this computer was done by our citizens [*Guo-Ren*]. The process of building this computer has helped members at NCTU be confident about the manufacturing of computer hardware on our own. From now on, we should still continue to follow the spirits we had when our country started the study and development of expertise on electronic computers. We should embark on larger research plans to train more technologists for our country.[26] (Original in Chinese)

Soon after its completion, NCTU publicized the computer and the university's intention to manufacture computers on an industrial scale. On July 17, 1971, *Economic News Daily* published a news story on this first "domestically-manufactured" computer. The news story stated:

> After three years of research and design, the first domestically-manufactured computer is finally completed. This third-generation computer uses integrated circuits, as the IBM 1130 computer does. [27] (Original in Chinese)

University of Chicago, 1992, originally published in London; Beverly Hills: Sage, 1985).
[26] Tsay, "An Introduction to National Chiao-Tung University's First Domestically Electronic Digital Computer," 6.
[27] See *Economic News Daily*, "The First Domestically-manufactured Computer."

Although the NCTU computer did consist of integrated circuits, however, it was quite different from the IBM 1130 computer. For example, in terms of the memory unit, the minicomputer at NCTU had only 1,248 bits, making it much smaller than the IBM 1130 computer's memory capacity of 4,096 16-bit words.[28]

Overall, this news story indicates that Chu-Yi Chang (see chapter 2 and 3), a dean at NCTU, and the author of the story, was optimistic about expanding the manufacturing of the NCTU minicomputer to industrial-scale manufacturing. According to the article, several government agencies, including the National Science Council and the Ministries of Economic Affairs and Education, considered future collaboration with NCTU to develop a computer-manufacturing industry. Specifically, these agencies and the University planned "to mass manufacture different types of computers with reasonable prices for both domestic and international markets." According to the article:

> [Chu-Yi Chang] pointed out that the University has a certain extent of control over the techniques of the manufacturing of computers.
>
> Chu-Yi Chang said that he is proud to say that it took only $500,000 NT dollars ($12,500 US dollars) to make this first domestically-manufactured minicomputer, compared to $800,000 NT dollars ($20,000 US dollars) for importing a minicomputer [purchasing one from the market].

[28] IBM's Data Processing Division, "Technical Press Release," February 11, 1965, re-published online in the IBM Archives, accessed November 30, 2011, http://www-03.ibm.com/ibm/history/exhibits/1130/1130_technical.html

> Instructor Jong-Chuang Tsay, responsible for the design and the manufacturing of this computer, stated that this computer is mainly for computing mathematics problems, and the University should begin to work on the manufacturing of commercial minicomputers in the following years. [29] (Original in Chinese)

From the narratives of this news article, Chang and Tsay (and the journalist) seemed to agree on a promising potential for NCTU to mass manufacture digital electronic computers in the near future. But, their expectation was not realized. When I interviewed Tsay in 2007, he pointed out that he did not show potential investors enough "confidence in the vision of" the mass manufacturing of the NCTU minicomputer, because he knew that "advanced" computers such as the IBM 360 were already available on the market.[30] Moreover, if government officials had seriously evaluated the mass manufacturing of minicomputers, they would have realized that the integrated circuits and magnetic core memory of the NCTU minicomputer were from Philico-Ford and Wang laboratories, respectively. First, the facts about the sources for these parts could have made the minicomputer-project sound less impressive to these officials. Second, they would have had to think about how NCTU or a company would be able to make profit from the manufacturing of minicomputers when the company had to buy key parts from other suppliers.

In the 1971 news article, Chu-Yi Chang's confidence in the mass manufacture of minicomputers was particularly intriguing, as it was based on his belief in the model of a pilot plant and the thriving future of the Taiwanese economy, both of which followed linear trajectories. He stated,

[29] *Economic News Daily*, "The First Domestically-manufactured Computer."
[30] Jong-Chuang Tsay, email communication, November 20, 2007

> [Chu-Yi Chang] stated that to build a computer industry, between the stage of successful research and the stage of "assembly line," researchers have to go through the stage of pilot plants. Now, National Chiao-Tung University can provide technical experts and personnel, and all we need for a pilot plant is a group of technicians that can work on the manufacturing process. It does not take too much private capital to invest in plants to manufacture computers, as one can try to rely on loans from financing institutions. As for uses, computers can be applied to a wide range of functions from the exploration of the moon and everyday life. There will be definitely a greater demand for computers. Our country, in particular, is transforming from an agricultural society to an industrial society, and our economy is thriving. In the near future, computers will be used for business management, quality control, and for solving complicated questions for enterprises." [31] (Original in Chinese)

First, Chang believed that the linear trajectory of building an industry included researching, setting up pilot plants, and establishing an assembly line. Chang's idea is similar to those of Chien and Lee in the 1964 proposal discussed above. While the 1964 proposal aimed to set up pilot plants for electron tubes and transistors, the 1971 article showed that Chang was interested in setting up pilot plants for minicomputers. Second, Chang believed that the economy in Taiwan was shifting from agricultural to industrial, and this shift would increase the demand for computers. In the early 1960s, as discussed in chapter 2, Chiao-Tung alumni, technocrats, and UN officials planned to utilize an electronics industry to speed up the transition from an agricultural society to an industrial society. In 1971, however, Chang considered this

[31] *Economic News Daily*, "The First Domestically-manufactured Computer."

transformation to have already happened, and felt that NCTU had to participate in the computer manufacturing industry.

Though the mass manufacturing of minicomputers did not occur in Taiwan, this minicomputer project serves as an interesting episode following NCTU's obtaining of digital electronic computers and the ending of the technical aid program established at NCTU in the mid-1960s. As discussed above, to Tsay, this minicomputer-building project was an extension of previous efforts in which NCTU members learned to understand and use their first two computers. As he believed that a country had to own a set of capacities—owning and knowing how to use and manufacture the technology, his minicomputer-building project fulfilled the pursuit of the capacity to manufacture digital electronic computers. As quoted above, he stated that "we should still continue to follow the spirits we had when our country started the study and development of the expertise on digital electronic computers." [32]

Furthermore, Tsay was interested in improving a country's capacity of designing, using, and manufacturing digital electronic computers. He did not treat this project as merely a university lab project. For example, as noted above, he emphasized that "the logic design and circuit design of this computer was done by our citizens [*Guo-Ren*]." [33] Nevertheless, intriguingly, a manager of Wang Laboratories and an engineer of Philco-Ford, two companies that were primarily owned by non-Taiwanese citizens, and set up in the Export Processing Zone, contributed critical components to build the NCTU minicomputer. This case is similar to Itty Abraham's analysis of the discourse of self-reliance and autonomy. Abraham has pointed out

[32] Tsay, "An Introduction to National Chiao-Tung University's First Domestically Electronic Digital Computer," 6.
[33] Ibid.

that self-reliance and autonomy were merely "watchwords" emerging at the time of nuclear development in India in the 1950s; but these watchwords were not precise at all, because the development of nuclear energy relied on "expertise and designs" from Britain, Canada, the United States, and France. [34]

Tsay became a professor at the Department of Computer Engineering at NCTU after returning from a two-year residency at the Center for Informatics Research at University of Florida in 1975.[35] Zai-Xing Qiu left Philco-Ford and began working for a company called Huan-Yu, owned by Taiwanese native textile-industry entrepreneurs.[36] Huan-Yu began to manufacture desktop calculators in the early 1970s, and was the first company that Stan Shih, the founder of Acer, worked for after graduating from NCTU. The 1970s witnessed the mushrooming of mass manufacture of integrated circuits and transistors for desktop calculators, electronics watches and clocks, and electronic toys in Taiwan.

[34] Itty Abraham, *The Making of the Indian Atomic Bomb*, 10.
[35] Shu-Xun Zhao,"Qie er bu she jian ku zhuo jue [An Interview with Jong-Chuang Tsay], " *The Voice of NCTU Alumni* 395 (2002): 46-50, accessed November 30, 2011, http://140.113.36.21/Alumni395/395-46-50.pdf
[36] Si-Yu Chen, "Giving up ICs, Shifting to his Pursuit for Arts—Zai Xing Qiu."

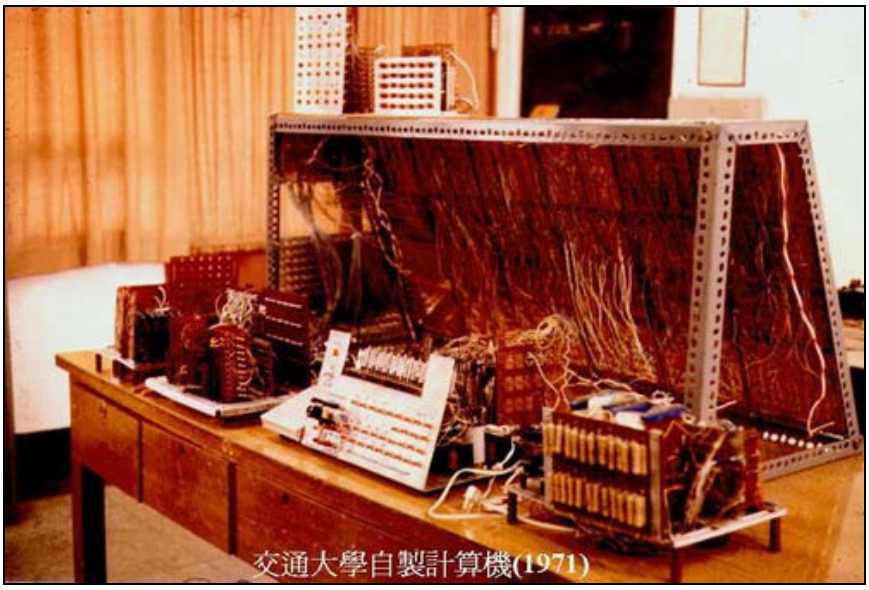

Figure 1: The NCTU minicomputer

Source: Reprinted, with permission, from Jong-Chuang Tsay and NCTU Museum. NCTU Museum's Website, Accessed November 30, 2011. http://www2.lib.nctu.edu.tw/museum/eng/cht/computer/computer.htm

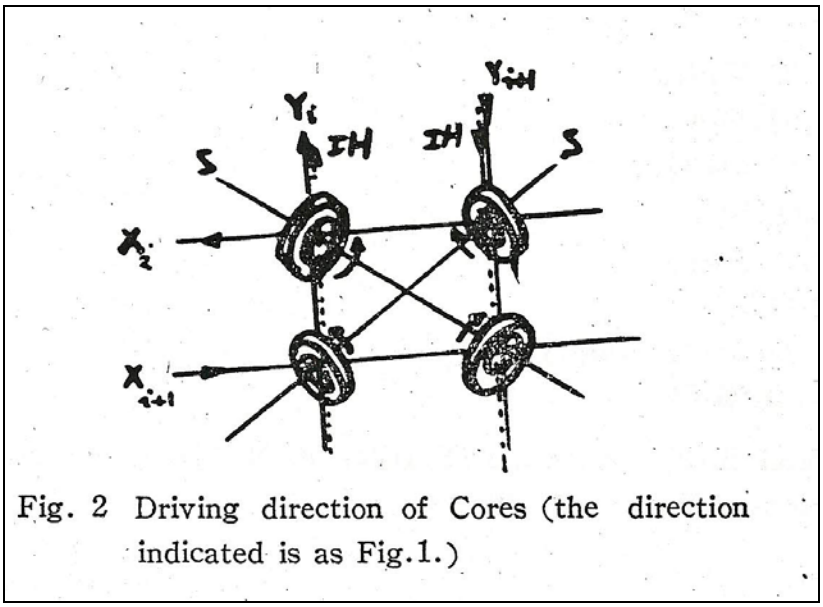

Fig. 2 Driving direction of Cores (the direction indicated is as Fig.1.)

Figure 2: Threaded Magnetic Cores

Source: Reprinted, with permission, from Jong-Chuang Tsay.
Jong-Chuang Tsay “Design and Experimentation of a 4X4X2 Memory,” Tsay reprinted from a 1969 Research Report he submitted to the National Science Council in Taiwan.

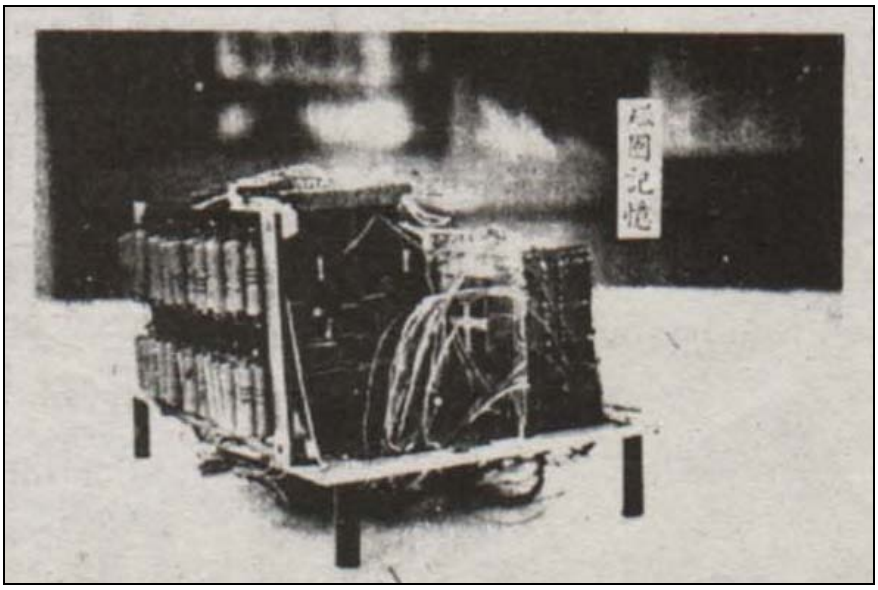

Figure 3: The Magnetic Core Memory of the NCTU minicomputer

Source: Reprinted, with permission, from *Science Monthly* and Jong-Chuang Tsay.
Jong-Chuang Tsay, "Wo guo di yi bu xiao xing dian zi ji suan ji jian jie jiao tong da xue shou zhi cheng gong [National Chiao-Tung University's Success in Building the First Domestically Electronic Digital Computer]," *Science Monthly* 21 (September 1971), 52.

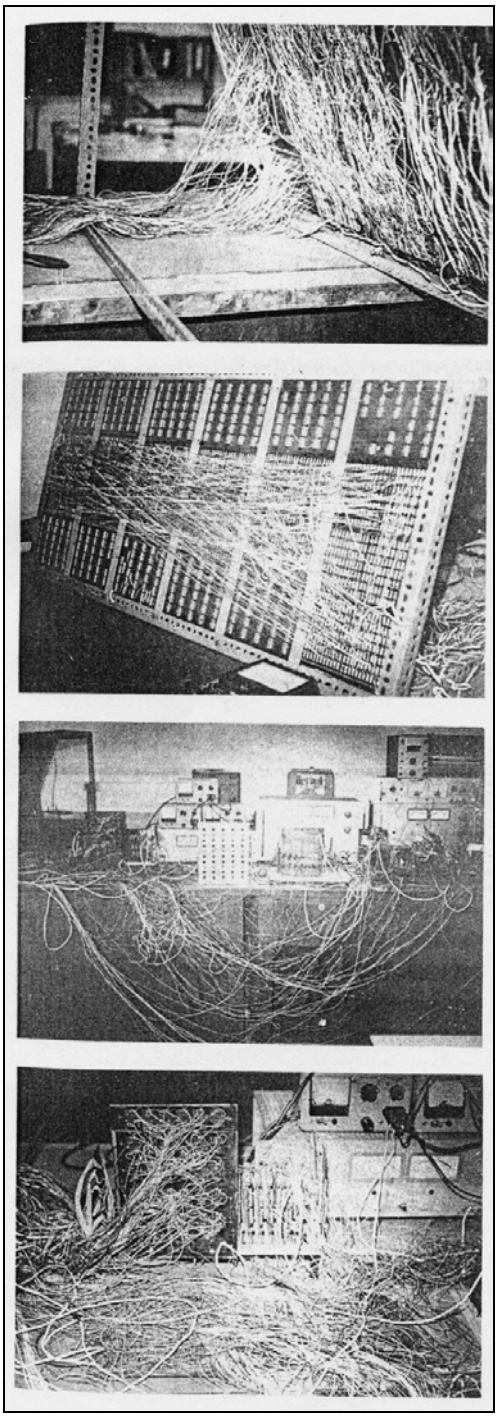

Figure 4: Wires of the NCTU Minicomputer

Source: Reprinted, with permission, from *Science Monthly* and Jong-Chuang Tsay.
Jong-Chuang Tsay, "Wo guo di yi bu xiao xing dian zi ji suan ji jian jie jiao tong da xue shou zhi cheng gong [National Chiao-Tung University's Success in Building the First Domestically Electronic Digital Computer]," *Science Monthly* 21 (September 1971): 53.

CHAPTER 6

THE CONTROVERSY OVER TINKERING WITH MICROCOMPUTERS IN TAIWAN, 1980-1984

Studies of hobbyists and amateurs have shown that actors outside the commercial production sector may powerfully revise or produce technological artifacts.[1] In particular, American computer-hobbyist communities exemplify users' modification and replication of computers. The commercial success of personal computers in the 1980s is partly attributable to hobbyists' interests in these new technological artifacts. US computer hobbyists in the 1970s were the pioneers in piecing together parts to make a working computer; their enthusiasm, despite evolving into other forms, facilitated the prevalence and the technical development of personal computers. Moreover, two of the early commercialized microcomputers, Altair 8800 and Mark-8, were advertised in magazines for electronics amateurs in 1974. Buying kits and assembling a computer was a common way to purchase a microcomputer in the United States in the late 1970s.[2]

This chapter discusses a robust and persistent practice of tinkering that was central in the proliferation, uses, and culture of microcomputers during the early 1980s in Taiwan. As I stated in the introduction, I define 'tinkering' as the practices of assembling and modifying computers, particularly of putting together parts to make a working computer and fixing it. The concept of

[1] ©2011 IEEE. Revised and reprinted, with permission, from Honghong Tinn, "From DIY Computers to Illegal Copies: The Controversy over Tinkering with Microcomputers in Taiwan, 1980-1984," *IEEE Annals of the History of Computing* 33, no. 2 (2011): 75-88.

[2] See Paul Ceruzzi, *A History of Modern Computing* (Cambridge: MIT Press, 1998); Martin Campbell-Kelly and William Aspray, *Computer: A History of the Information Machine* (Westview, the second edition, 2004; Basic Books, the first edition, 1996); Paul Freiberger and Michael Swaine, *Fire in the Valley* (Osborne/McGraw-Hill, 1984); and Lindsay, "From the Shadows: Users as Designers. Producers, Marketers, Distributors, and Technical Support."

tinkering emphasizes actors' modification of technological artifacts, informal production of technological artifacts, and the subsequent changes of the meanings of artifacts. During the early 1980s in Taiwan, tinkerers built their own computers the cost of which was slightly lower and the capacity of which was slightly greater than those of branded computers. In shops for computer parts, a customer might choose the brand and the model of the motherboard, ROM, RAM, case, and hard disk to build a computer. One might either put parts together to build a computer oneself or ask a shop to do so. The computers built by users or shops have been called "no-brand," "self-assembled," "assembled," or "Do-It-Yourself" computers. According to a survey, these self-assembled computers accounted for 36% of all computer sales in Taiwan in 1995.[3]

This chapter traces the origin and the development of their practices in the early 1980s. I demonstrate how tinkerers opened the black-boxed technology of microcomputers. In doing so, tinkerers who functioned as "technological mediators" fostered the material existence of the new technological system. The practice of tinkering was central to a diverse variety of social groups when they were pondering the policies of microcomputer manufacturers; in this sense, the practice of tinkering is critical to understanding the social meanings of microcomputers in early-1980s Taiwan. These social groups included computer scientists, engineers, manufacturers, users, hobbyists, and journalists. Compared to the previous chapters, this chapter includes emerging social groups such as hobbyists, manufacturers, computer-parts shops, and electronics-industry

[3] The statistics of the following several years are 43% in 1996, 50% in 1997, and 48% in 1998. No statistics are available for years prior to 1995. Nevertheless, one of my informants estimated that self-assembled computers accounted for at least 90% of all the computers during the early 1980s in Taiwan. He could be exaggerating, but the lack of the statistics of self-assembled computers offers a wonderful opportunity for this chapter to discuss the prevalence of the practice of building one's own computer during the early 1980s. For the statistics, see Institute for Information Industry, *An Analysis of the Market of Information Products* (Taipei: Institute for Information Industry, 1997), 21; and Wen-Bin Xie, *An Analysis of the Domestic Computer Market* (Taipei: Institute for Information Industry, 1999), 40.

journalists in Taiwan during the early 1980s. This chapter rests on oral-history interviews and a survey of computer magazines published in the 1980s in Taiwan.

In this chapter, I use the term 'tinkering' to refer to the practice of piecing together parts to make personal computers, regardless of whether the practice was carried out by individual users or small-scale shops; It is arbitrary to use one term to categorize the varied practices that rested on many different motivations and incentives. Yet users have never strictly distinguished user-built computers from shop-built computers. '*Zu-Zhuang* computers' refers to the computers built by both shops and users in Taiwan, and the literal translation is "assembled computers." By using one term to refer to the similar practices conducted by two different groups, I intend to emphasize two features. First, these computers consisted of parts of different brands. Second, in the debate which I will discuss in this chapter, protagonists considered these computers different from those branded computers, such as Apple computers.

It is difficult to propose a complete definition for the shops I have discussed so far, as the shops offered a wide range of service and differed in the business scale. Some shops hired staff to build computers for their customers, and, at the same time, provided with pre-assembled computers offered by computer manufacturers. Some shops could be owned by or obtained franchises from computer manufacturers. For the latter case, customers could still customize their computers by asking shop staff to build their computers.

Some of the tinkering-with-computers practices resulted in the assembling of illegal copies of Apple II computers in Taiwan. Unlike companies such as Acer (then Multitech) which

designed its own microcomputers and personal computers, a couple of computer manufacturers, shops, and individual users made copies of the software and firmware of Apple II computer to run their computers. This issue—on a more general plane—was controversial across the globe in the 1980s. In Taiwan, actors and institutions during the early 1980s had great difficulty trying to determine legal responsibility herein. In this regard, I use the phrases 'assembled computers', 'Apple II compatibles', or 'illegal copies of Apple II computers' interchangeably, depending on the context.

The Chinese-language verb used by these tinkerers was almost identical to 'to assemble'. In Chinese, there are at least three verbs that tinkerers used to refer to the practice of buying parts and of building up microcomputers and personal computers. The three verbs are *Zhuang-Pei* (裝配), *Zu* (組), and *Zu-Zhuang* (組裝). *Zhuang* means "to put parts together or to install"; *Pei* means "to allocate or to match"; *Zu* means "to organize parts and to put parts together." The three verbs refer to a set of similar actions and practices conducted by both electronics amateurs and the electronics industry in Taiwan. In the late 1980s, many magazines began referring to these self-assembled computers as "DIY computers" and using 'DIY' as a verb. 'DIY' stands for do-it-yourself in English. In addition to DIY computers, these computers are sometimes called "no-brand" and "mixed-brand" computers. People who can build personal computers are often called "people who can assemble computers," or "computer experts."

A Brief History of Tinkering with Computers in the Early 1980s

As early as 1980, microcomputer kits of various brands were available in Taiwan.[4] During the early 1980s, journalists for electronics magazines started to write introductions regarding what a microcomputer was and the functions it could have.[5] But there were few news articles about microcomputers in newspapers at this time.

The Taiwanese practice of assembling one's own computer mushroomed with Taiwan' importing of Apple II computers. In November 1980, Apple Computer granted a Taiwanese company the distribution franchise. At approximately the same time, readers of electronics magazines, such as *Electronics & Radio-TV Technical Monthly*, had already seen the circuit diagram of the Apple II computer.[6] Many of the people who were interested in assembling kits of radio or audio systems had been to the Chung-Hua Arcade or the Kuang-Hua Public Market to buy parts for building Apple II computers. In March 1982, it was estimated that there were tens of thousands of microcomputers, mostly Apple II compatibles, built by individual users and by shops on the retail market.[7] Many of my informants told me that they had never seen an authentic Apple II computer, though some of my informants were engineering or computer science majors in the early 1980s.[8] For example, Cheng Ku, one of my informants, told me that he first saw the circuit diagram of the Apple II computer in a magazine and that, later (in 1981),

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[4] See the advertisement of the TUP-80 microcomputer in *Electronics & Radio-TV Technical Monthly* 43, no. 6 (December 1980): 29.

[5] For example, Zhong-Yong He, "Wei dian nao ban yan de jiao se [The Roles of Microcomputers]," *Electronics & Radio-TV Technical Monthly* 44, no. 1 (January 1981): 39. Except for an article from *Wired*, all the news articles cited in this chapter were published in Chinese, and translated into English by the author.

[6] Cheng Ku, interviewed by the author on July 11, 2007.

[7] Mei-Bing Xu, "Dian dong wan ju jin zhi yi cheng ding ju [The Ban on Arcade Games Is Confirmed]," *United News Daily*, 28 March 1982, 3.
In comparison with this figure, only 17 domestic companies officially registered as manufacturers of microcomputers in 1981. The number of companies increased to 23 in 1982. See Institute for Information Industry, *Zhong hua min guo zi xun gong ye nian jian [Annual Book of Information Industry]* (Taipei: Institute for Information Industry, 1981), 38-39 and the 1982 volume, see page 41-43.

[8] For example, Iau-Sheng Wang had worked for a computer software magazine from 1986 to 1989. He estimated that computers built by shops or users accounted for at least 90% of all the computers during the early 1980s in Taiwan. The interview was conducted on June 17, 2007.

he saw the parts of Apple II compatibles in the Chung-Hua Arcade. He finally found that there were computers advertised as “Apple II” on the market, and came to understand that the so-called “Apple II” was a legally protected trademark and that those computers on the market were illegal copies.[9]

Cheng Ku pointed out that tinkering with microcomputers was an extension of the preceding practice of buying kits to make radios and audio systems. Many of the individual tinkerers of microcomputers were either amateurs of electronics kits or students majoring in computer science or related programs. Also, many computer-parts shops at this time were converted from selling electronics kits or audio-system parts to selling computer parts.

Parts, kits, and fully assembled Apple II compatibles were available in these shops in the Chung-Hua Arcade or the Kuang-Hua Public Market. Tinkerers could buy parts and build computers themselves. Or they could choose preferred-brand parts and ask the staff of the shops to build—for a fee—a computer with those parts. Or individual users could buy ready-to-use computers directly from shops or companies.

A news article in *Wired* in 1994 described the Kuang-Hua Public Market as follows:

> Across town, tucked beneath an overpass cutting through one of the city's busiest neighborhoods, is Taipei's KuangHua Market. Buddhist antique stores share space with tiny retail computer outlets. Incense wafts past young men and women hunched in concentration as they compare prices on cut-rate 486 chips. In the larger basement section across the street, crowds of Taiwanese nerds sift through bins of transistors and diodes,

[9] Oral- history Interview, July 11, 2007.

inspecting serial cables and math coprocessors, searching for that last part necessary to get their jerry-rigged clone up and running.[10] (Original in English)

Although written in 1994, the above description may still catch the atmosphere created by tinkerers and by vast basement markets in which several dozen 70-square-foot shops sit side by side.

In these computer-parts shops, tinkerers could buy suitable cases for Apple II compatibles.[11] The chips that could be used in the breadboards of Apple II compatibles were pre-programmed, ready to be assembled. Shop owners or microcomputer-kits manufacturers might have programmed some chips to sell. Power supplies could be found here too, because manufacturers of arcade-console power-supply and of audio-system parts had shifted their business to manufacturing power-supply for computers at this time.[12] As for keyboards, Cheng Ku told me that in 1981, he had bought a used item on the second floor of the Chung-Hua Arcade, where most of shops sold used—not new—electronics parts. He had made the purchase because no brand-new keyboard had yet become available on the retail market. The earliest advertisement of brand-new keyboards that I found in magazines was in the January 1982 issue of *0 & 1 Technology*, one of the most popular computer magazines in Taiwan at this time.[13] Ku

[10] Bob Johnstone and Andrew Leonard, "Me-Too Is Not My Style," *Wired* 2, no.9 (September 1994), Accessed November 30, 2011. http://www.wired.com/wired/archive/2.09/taiwan_pr.html
[11] Ting-Wen Kau, one of my informants, had purchased a case that was for amplifiers for his microcomputer. Kau was interviewed by the author on July 6, 2007.
[12] Chung-Er Liang, "Audio Systems and Computers," published on May 25, 2005 on Liang's personal website, accessed November 30, 2011, http://www.ac-dc.com.tw/dpage10.htm
[13] An advertisement for Wen-Mai Corporation, *0 & 1 Technology* 9 (January 1982): 163.

and Tsan-Sheng Hsu, two informants, told me that used chips were available on the retail market too.[14]

These self-assembled computers were less expensive than real Apple II computers, a fact that encouraged individual tinkerers to build their own computers. In most cases, a selection of parts cost less than 40 percent of the price of an authentic Apple II computer.[15] Equipping oneself with knowledge to *fix* one's own computer could save money too.[16] Beyond practical reasons, tinkerers built their own computers to explore the *contents* of computers. For example, Cheng Ku pointed out that the microcomputer was simply one product of a variety of electronics kits, a technological artifact to be explored, mastered, and assembled at home. Also, according to an article that a tinkerer submitted to a computer magazine, after he saw a microcomputer in the Chung-Hua arcade in 1983, he spent all his savings on a breadboard, chips, power supply, and keyboard, connected them to a TV set, and directly exposed the board of his Apple II compatible. He stated that the achievement of putting together a computer "temporarily satisfied my [his] curiosity and allowed me [him] to participate in the age of computers."[17]Another example concerns efforts to fix computers. When a journalist condemned the poor quality of some Apple II compatibles built by small-scale companies, he pointed out that the computers upset many

[14] Tsan-Sheng Hsu and Cheng Ku were interviewed by the author on June 27 and July 11, 2007, respectively. Sometimes, computer-parts shops might sell used items without identifying their second-hand status to customers. Individual buyers would have to be cautious of the computer parts they bought. The knowledge of distinguishing the new from the used and the ability to memorize model numbers of ICs were important for preventing fraud.
[15] The price of an Apple II ranged from approximately $1,490 to $1,700 US dollars in December 1982 in Taiwan. An Apple II compatible cost $250 US dollars on average, and the price could range from $150 to $750 US dollars. See Yong-Hu Zheng, "pin guo pai dian nao fang mao pin chong chi [The Illegal Copies Are Everywhere]," *Economic News Daily*, 16 December 1982, 10, and Qi-Ming Chen, "Fang pin guo er hao de bo xing yu mei luo [The Rise and Fall of Illegal Copies of Apple II Computers," *Economic News Daily*, February 22, 1983, 12.
[16] Xi-Long Jiang, "Te bie yan jiu ge ren dian nao xiu hu zhan [Fixing Your Own Computers: Apple II Computers and Compatibles]," *The Third Wave* 36 (August 1985): 55-68.
[17] Yong-Ji Lin, "Dian nao te bie yan jiu ge ren dian nao xiu hu zhan [Computers Changed My Life]," *The Third Wave* 30 (February 1985): 84-86.

customers but offered wonderful opportunities for tinkerers to marvel at how to fix them.[18] In this way, beyond programming, word-processing, and gaming, the act of *tinkering* with computer parts—fixing computers, and the process of selecting, purchasing, and assembling parts—was a notable *use* of computers. When commenting on these tinkerers' enthusiasm, a computer instructor pointed out, in 1982, that teenagers had replaced their previous interest in arcade games with an interest in computers. The instructor thought that computers rectified the social problems created by arcade games and helped to train teenagers to be potential contributors to the future information industry in Taiwan. [19]

The availability and circulation of computer parts in the Chung-Hua Arcade and the Kuang-Hua Public Market offered enthusiastic tinkerers an urban wonderland. Also, the two places provided a forum in which business people could sell Apple II compatibles. In the following section, I will discuss the business-scale manufacture of Apple II compatibles, which triggered a controversy over software copyright in Taiwanese society.

Burgeoning Apple II-compatible Manufacture

Before May 1982, rather than present articles on assembled computers, electronics and computer magazines only advertised them. During this period, journalists for magazines introduced microcomputers to the readership on the basis of the functions of microcomputers in general. The journalists had not started covering Apple II compatibles or where Taiwanese could

[18] Kun-Ming Lin, "Man tan ge ren yong dian nao ji xuan gou ji qiao [Tips for Purchasing Personal Computers]," *Information and Computers* 3, no. 7 (January 1983): 45-46.
[19] Zong-Ying Cai, "Jia yong dian nao bian hua wan qian qing shao nian wei zhi zhe mi pin guo bang ding qi ju hui yan jiu xing cheng xin wen hua [Teens Are Obsessed with Versatile Home Computers: Apple 'Gangs' Meet Periodically and Create New Cultures]," *United Daily News*, November 15, 1982, 3.

buy them. But readers would find advertisements of Apple II compatibles in *0 & 1 Technology* as early as November 1981. For example, two companies advertised their Apple compatibles in the January 1982 issue.[20] The first company was Focus Corporation, whose logo was an intact, unbitten apple. The advertisement read, "We also sell Apple computers." The second company was Rong-Kuan Corporation, which sold "Green Apple Computers" and claimed that "schools buy computers from us." In addition, Rong-Kuan Corporation advertised for a Sunday club where users could gather together and learn programming. In February 1982, the magazine *Electronics Information Magazine* placed an advertisement in *0 & 1 Technology*—the advertisement stating that readers would learn how to use Apple II to draw Donald Duck.[21] After March 1982, *0 & 1 Technology* had plenty of computer-parts advertisements, many of which explicitly advertised parts for Apple II compatibles or the ready-to-use Apple II compatibles.

The emergence of vast numbers of Apple II compatibles in Taiwan reflected a policy implemented in March 1982, when the Taiwanese government started strictly implementing its ban on arcade consoles showing up in unlicensed places. The ban was an effort to counter teenagers' loitering in allegedly inappropriate places. After the implementation of the policy, companies that had originally manufactured chips applicable to arcade consoles had to find new buyers. And companies that had been importing chips or that had been manufacturing arcade consoles had to find new applications for arcade-console parts. Because many arcade-console parts were applicable to microcomputers, some companies shifted their business from the manufacture of arcade consoles to the assembly of Apple II compatibles, without authorization from Apple Computer. Therefore, it turned out even easier for individual users or manufacturers

[20] Advertisements for Focus Corporation and Rong-Kuan Corporation, *0 & 1 Technology* 9 (1982): 25 and 31.
[21] An advertisement for *Electronics Information Magazine*, *0 & 1 Technology* 10 (1982): 199.

to access computer parts—after all, the surplus parts circulated heavily in the shops in the Chung-Hua Arcade and the Kuang-Hua Public Market. In the Taiwan of today, computer-industry workers, analysts, and my informants all have argued that the abovementioned ban contributed to the rise of Apple II compatible manufacturers and that the ban, in this way, merits an important page in the history of computer manufacture in Taiwan.[22]

It was easy for a business person planning to mass manufacture Apple II compatibles to find domestic plastic-product manufacturers that would manufacture cases for microprocessor computers, because plastic-product industry was a major industry in Taiwan at that time. Also, manufacturers could buy power supplies from existing domestic manufacturers, as mentioned earlier. The mass manufacture of breadboards was not an issue at all because the existing manufacturers of arcade consoles were able to do so.[23] A vast number of companies were importing diverse types of microprocessors too. It was estimated that Taiwan was home to at least 100 companies manufacturing Apple II compatibles in December 1982.[24]

An Apple II compatible needed the Autostart program and the Applesoft program to work in conjunction with an MOS 6502 chip. The first program, Autostart, was firmware and similar to what we nowadays call BIOS, a term used in relation to IBM PC systems. The second

[22] For articles published in 1982, see "Wei dian dong wan ju gong ye qing ming [Speak for the Arcade-console Industry: Please Save Our Information Industry]," *0 & 1 Technology* 13 (May 1982): 50-52 and "Lin lao shi fu xin xiang [Letter to Teacher Lin]," *0 & 1 Technology* 13 (May 1982): 217. For retrospective statements, see Institute for Information Industry, *An Analysis of Desktop Computers* (Taipei: Institute for Information Industry, 1994), 3; Commonwealth Magazine, Xing-Cheng Cao: *Liun Dian De Ba Ye Chuan Qi* [*Xing-Cheng Cao: UMC's Legend of Dominance]* (Taipei: Commonwealth Magazine Press, 1999), 125; Zheng-Xian Zhou, *Shi zhen rong de dian nao chuan qi [Stan Shih and the Computer Legend]* (Taipei: Linkingbooks, 1996), 81-82.

[23] It was difficult for me to find either owners of these shops or the manufacturers of Apple II compatibles and, consequently, to interview them. The details of the business of these shops and manufacturers were seldom explicitly introduced by the mass media or amateur magazines, partly because the legal status of the business was controversial at that time.

[24] Zheng, "The Illegal Copies Are Everywhere."

program was Applesoft, which was an operating system. Apple Computer later sued a few manufacturers for copyright infringement of the two programs in Taiwan, a topic that I will discuss later in this chapter. In order to make properly functioning Apple II compatibles, manufacturers had copied the two programs. Once able to buy chips from companies that imported chips or sold used ones, manufacturers could use EPROM programmers to copy programs to the new chips. EPROM programmers were perhaps available in Taiwan by the late 1970s because Taiwanese manufacturers of arcade consoles needed EPROM programmers to program chips. Also, computer magazines in 1982 featured many EPROM-programmer advertisements.[25] Anyone who had access to an EPROM programmer and a real Apple II computer could copy the two programs from the real Apple II computer to new chips.

The manufacturers of Apple II compatibles might have manufactured these computers while being fully aware that this manufacturing skirted copyright law. Or it is possible that the manufacturers were unknowingly engaged in questionable practices insofar as, prior to 1985, Taiwan's copyright law did not explicitly protect ROM-based computer programs. But, by the early 1980s, newspaper journalists had covered cases involving, for example, the illegal copy of arcade consoles. It is likely that these Apple II compatible manufacturers were already aware that making unauthorized copies of technological merchandise was a legal grey area.

In sum, the popularization of building one's own Apple II compatible stemmed from the availability of the existing industry's arcade-console parts and audio-system parts, as well as

[25] The earliest EPROM-programmer advertisement that I found was for Hui-Mao, an electronics retail company, see *Electronics & Radio-TV Technical Monthly* 43, no. 2 (August 1980): 209. In 1982, a reader wrote a letter to the editor of a column of *0 & 1 Technology* to ask how to use a newly purchased EPROM Programmer. See "Lin lao shi fu xin xiang [Letters to Teacher Lin]," *0 & 1 Technology* 9 (January 1982): 193.

from the preceding trend wherein hobbyists purchased electronics kits for self-assembly. Because the popularization of Apple II compatibles was synchronized with the early stage of the introduction of microcomputers to Taiwan, Taiwanese tinkerers were the early users of microcomputers; most of the early Taiwan-based users of microcomputers were users of Apple II compatibles. By tinkering with computer parts, individual tinkerers and shops appropriated the production role previously dominated by the manufacturer, Apple Computer.

After the legal controversy in 1983, which I will discuss later in this chapter, microcomputers acquired a new set of social meanings in Taiwan. *0 & 1 Technology* finally started covering the emergence of Apple II compatibles in May 1982 in a more or less condemnatory tone.[26] Taiwanese legal systems gradually outlawed the practice of piecing together parts to make Apple II compatibles in 1984. Also, tinkerers did not continue considering microcomputers similar to electronics kits. Instead, the microcomputer gradually evolved into an object, the manufacture of which embodied the development of Taiwan's technology industry.

Apple Computer's Legal Actions against Creators of Illegal Copies

In June 1982, Apple Computer registered its trademark and the copyright on the Autostart and Applesoft programs in Taiwan, although, up to 1985, the enactment of copyright law in Taiwan did not include computer software at all. A lawyer for Apple Computer came to Taiwan, acquired an Apple II compatible, and brought it back to the United States in July. Three months later, Apple Computer brought a case against two Taiwanese companies that manufactured

[26] Zhong-He Tai, "Wei dian nao gong ye de xin zang wei dian nao [The Heart of the Microcomputer Industry: Microprocessors]," *0 & 1 Technology* 13 (May 1982): 57-69.

illegal copies. Yet, because Apple Computer had not registered as a company in Taiwan, the Taiwanese courts declined (in February 1983) to hear the case. Probably owing to legal actions, more and more news articles about Apple II compatibles appeared in Taiwan's two main newspapers. After October 1982, one of Taiwan's two main newspaper companies started to call Apple II compatibles "Fake Apples." Eventually, Apple Computer registered as a company in Taiwan, and on these grounds, a prosecutor in August 1983 began the prosecution of six companies.[27] Concurrently, another two companies were prosecuted by another prosecutor.

The first trial of the August 1983 case immediately followed in September 1983. In this trial, the defense attorneys of the six companies questioned why Apple Computer had been able to obtain copyright on the firm's software if the enactment of copyright law in Taiwan did not cover computer software. Principally, the legal system in Taiwan rests on the model of continental law (or civil law), in which legislative enactment, rather than precedent, is binding in courts. The defense attorneys, thus, pleaded not guilty and requested that the Minister of Interior Affairs both testify and bring all relevant administrative documents, by which Apple obtained copyright on its software, to the court.[28]

On January 25, 1984, the Taipei District Court sided with Apple Computer and sentenced the owners of the six companies to imprisonment for eight months. The owners of the six companies appealed their case to a higher court. However, in December 1984, the High Court

[27] Chen, "The Rise and Fall of Illegal Copies of Apple II Computers," 12; *Economic Daily News*, "Mei shang kong wo fang zao pin guo liu jia gong si yi bei qi su [Six Company Owners Were Prosecuted for Selling Software]," August 14, 1983, 2.
[28] *United Daily News*, "Qin hai pin guo dian nao zhe zuo quan an zuo kai ting [Apple Software Infringement on Trial]," September 21, 1983, 2; *Economic News Daily*, "Pin guo guan si shang gong tang ruan ti su song da ying zhang [Apple Fights the Software Infringement Case]," September 21, 1983, 3.

sided, as well, with Apple Computer, and sentenced the six owners to imprisonment for six months but commuted this sentence to a fine. For the other case, in which two companies were prosecuted, the High Court also sided with Apple Computer in December 1984.[29]

Some journalists and law professors considered the rulings unusual insofar as there remained no pertinent legislative enactment, so the judges were attempting to establish a precedent in a continental law system. For the January 1984 verdict, a law professor, Chung-Sen Yang, pointed out that the jury should have followed the enactment, particularly because defendants' human rights are especially vulnerable in criminal law suits.[30]

A journalist, Mei-Bing Xu, wrote a news article about the January 1984 verdict on the following day. The editor sarcastically titled it "The Court Is 'Progressive' Enough While the Issue Remains Controversial Internationally" [emphasis in the original]. Xu cited an "expert" who hailed from the information industry and who suggested that domestic companies should collect information about the U.S. suits that Apple Computer had not yet won. The expert suggested that, during their testimony in court, the owners of the six companies emphasize the uncertain status of software copyright in the United States.[31]

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[29] *United Daily News*, "Fan mai fang mao pin guo dian nao liu bei gao pan xing ban nian [Selling Illegal Copies of Apple II, Defendants Face Six Months Sentences]," December 25, 1984, 7; Mei-Bing Xu, "Fang mao pin guo er hao dian nao bei pan wei fan zhe zuo quan fa [Making Illegal Copies of Apple II Computers Violates Copyright]," *United Daily News*, January 25, 1984, 3; *Economic News Daily*, "Dian nao ruan ti sui wei ming ding wei zhe zuo wu gao yuan yi ren ding zai bao hu zhi lie [Though Not Enacted into a Law, the Protection of Copyright on Computers Is Acknowledged by the High Court]," December 7, 1984, 2.

[30] *United Daily News*, "Fang mao dian nao pan chu tu xing jiao shou ren wei ying gai zhen zhuo [A Professor Disagreed with the Verdict of Computer Pirating]," January 26, 1984, 3; Shao-Long Guo and De-Yuan Weng, "Si fa ken ding dian nao zhe zuo quan sui ke xi dan yi ke yi [The Verdict on Copyright on Computers Was Agreeable but Also Controversial]," *Economic News Daily*, December 8, 1984, 2.

[31] Xu, "Making Illegal Copies of Apple II Computers Violates Copyright," 3.
"Progressive" in the context of this news article worked as a pun. The editor emphasized that (1) the Taiwanese courts had recognized the copyright on software earlier than other countries had, and (2) the quotation marks showed that the editor disagreed with the rulings. The original Chinese term was *Ling-Xian-Yi-Bu*, which connotes

Regarding these experts, I should note that, around this time, people who worked in the computer industry and in computer-science research institutes were called computer experts. Therefore, the classification of experts covered a wide range of occupations, including professors, researchers, engineers, entrepreneurs, and managers. It is difficult to generalize about the backgrounds of the experts.

Favorable Interpretations of Apple II Compatibles

Xu was not the first person who found the issue of software copyright contestable. After Apple started its legal actions, many social groups developed some favorable interpretations of Apple II compatibles—that is, of the illegal copies of Apple II computers. Obviously, these favorable interpretations stood in stark contrast to Apple Computer's perspectives. Now, I will discuss two kinds of interpretation that treated Apple II compatibles as generally beneficial to Taiwanese society. These interpretations came from people who were in the business of manufacturing Apple II compatibles and who ranged from journalists to engineers and "experts."

First, I discuss the debate that the aforementioned social groups held regarding software copyright. This will highlight both the meaning of 'tinkering-with-computers' and tinkering's relationship with the broader society. What I present here is a historically specific interpretation of computer-software copyright—after all, the copyright determined both *who* could legally manufacture microcomputers and *how* these manufacturers could legally undertake the practice. While the legal protection of software and firmware had not yet taken root in Taiwan, some

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'advanced', 'ahead', and 'progressive'.

social groups there argued that (1) making compatibles or illegal copies of Apple II was an unavoidable stage for a developing society, such as Taiwan, in relation to learning a new technology and (2) inexpensive Apple II compatibles contributed to the popularization of computers. At that time, Taiwan's discussion about software copyright was rather *open* or *different* in comparison to the current state of this discussion.

"Real or Fake Computers" Competition

In December 1982, two months after the term "Fake Apples" was coined, a competition entitled "Real or Fake Computers" took place in Taipei. The competition also followed Apple Computer's first attempt to sue two companies in Taiwan, a case that the nation's courts eventually declined to hear. The competition did not draw much attention in the media in December 1982, but signaled the beginning of a debate that lasted for two years.

According to a short news article, some domestic companies volunteered to participate in the competition in which they submitted computers that they had manufactured.[32] A group of loosely-named experts examined these computers and picked out better computers. The journalist did not specify the criteria used by the experts to judge which computer was superior. But it is likely that the experts examined the originality of the computer software and firmware, and the performance (i.e. the execution speed) of and the features (i.e. extra applications) of the computers. The participants in the competition's final convention included members of the Association of Business Administration, computer scientists, and people in the computer

[32] *China Times*, "Zhen jia dian nao bi hua jie xiao [Real or Fake Computers]," December 14, 1982, 3.

industry or the business of manufacturing Apple II compatibles.[33] An engineer who worked in a company that imported Apple computers attended the final convention but noted that he was not a representative sent by his company. It was estimated that more than 100 audience members witnessed the final convention.

Interpretations of Imitation

At the final convention, some participants in the business of manufacturing Apple compatibles or illegal copies of Apple II pointed out that "immature" industries in Taiwan had to face the challenges of survival, not just of growth. These participants argued that, if a developing country's immature industries were eventually to thrive, they had to go through, first, an unavoidable stage of imitation. [34]

To some extent, some experts at the convention agreed with this perspective. However, they had mixed feelings about Apple II compatibles. On the one hand, they emphasized that manufacturers of illegal copies should shoulder the involved legal responsibilities. On the other hand, some experts encouraged the business people in the Taiwanese computer industry to agree to tolerate a fledgling information industry's creation of illegal copies. According to the news article, these experts stated,

> At the same time, the business people in this field [the computer industry] should build a consensus regarding the computer culture [in a very broad sense, including the

[33] By 'convention', I mean that the competitors and the experts gathered together for the final tournament, in which they also discussed whether the Apple II compatibles were counted as illegal copies.
[34] *China Times*, "Real or Fake Computers," 3.

> manufacture of illegal copies]. We will have to tolerate the manufacture of illegal copies in the initial stage of a developing information industry.[35] (Original in Chinese)

It is likely that a consensus had existed among Taiwanese manufacturers of illegal copies. In February 1983, Qi-Ming Chen, a journalist for *Economic Daily News*, interviewed an engineer whom a firm had hired for the production of illegal copies. Overall, Chen's news story condemned the manufacturer of illegal copies. But the interviewed engineer engaged in a language similar to that of the aforementioned experts. The engineer pointed out that imitation is a necessary process for "technology-backward countries"—a category in which he placed contemporary Taiwan and 1960s-era Japan—that are trying to catch up to technology-advanced countries—a category in which he placed the United States and contemporary Japan. He considered Japan a good illustration of this rule. Chen cited comments from the engineer,

> A software engineer hired for the manufacture of illegal copies said that technology-backward countries might lose their direction while chasing after technology-advanced countries. He thinks that the imitation is a necessary process for technology-backward countries. He points out that Japan, years ago, was a relatively technology-backward country that, by imitating advanced countries, developed its own advanced industries.[36] (Original in Chinese)

What the engineer pointed out exactly reflected a prevailing idea of the 1970s and the 1980s in Taiwan, and perhaps elsewhere in the world. First, the engineer explained Japanese

[35] Ibid.
[36] Chen, "The Rise and Fall of Illegal Copies of Apple II Computers," 12.

economic success as a linear historical path, in which the Japanese had to imitate US technology. Second, the engineer developed nuanced and somewhat hypothetical thoughts about Taiwanese society's possible future trajectory. By seeing Taiwan as a developing economy that had to catch up to advanced economies in the 1980s, the engineer legitimized a developing country's efforts to develop technology industries and, thereby, to attain a foothold alongside or not far behind economic giants. In short, by legitimizing his categorization of developing countries and of advanced countries and his depiction of the linear historical relationship between the two kinds of countries, the engineer could legitimize imitation as a means by which developing countries could become advanced countries.

An article in the computer-software magazine *The Third Wave* reiterated similar arguments in January 1985. Hau Xuan, a freelancer at the magazine, argued that "making illegal copies is the beginning and the end." In the beginning, an industry makes illegal copies that will enable the industry to learn about the advanced technology. The news article identified Japan, again, as the best example of this model. "However," Xuan continued, "if people do not work on innovations, the industry will die. In this sense, making illegal copies kills the industry in a developing country."[37] Although his conclusion was one of disapproval of illegal copies, the freelancer concluded, as well, that imitation is a necessary process.

Similar interpretation, indicating that making illegal copies is the first step for a fledgling industry, existed before the emergence of the discussion of Apple II compatibles. For example, Taiwanese manufacturers of electronic toys acknowledged that the first step for manufacturers

[37] Hao Xuan, "Hua zi xun zhou tan zi xun [Information of the Information Exhibition Week]," *The Third Wave* 29 (January 1985): 57.

was to imitate the latest products. In this manner, they could study the latest products, but the second step should be to work on innovative designs in their products. Along a similar line, the abovementioned journalist, Qi-Ming Chen, wrote a news article describing an arcade-console manufacturer who advocated that the industry move forward from imitation to research and design. But the topic of imitation relative to these electronic products was sporadic and drew little attention from the media or the courts, compared to the topic of microcomputers. [38]

Computer retailers and manufacturers were probably the group most sensitive to the effects of allowing or banning imitation in the industry. For them, to close the gap between "technology-backward countries" and "technology-advanced countries" would require many strategies that would not subject the domestic markets of "technology-backward countries" to foreign companies.

In fact, soon after Apple Computer filed a suit against six Taiwanese companies in August 1983, more than 100 computer companies held a meeting in Taipei in September and proclaimed that a court ruling in favor of Apple Computer would devastate domestic companies and "make the domestic market a colony of US companies."[39] It is likely that some manufacturers of illegal copies simply found excuses to legitimize their economic activities. Nevertheless, their sophisticated interpretations of technology and of a given country's developmental status is worth further analyzing.

[38] Wen-Xi Zhu, "Ying he xiao shou dui xiang suo hao jia qiang zi wo chuang xin she ji [Studying the Target Consumer, Doing Innovative Design, and Expanding Sales Network Make Profits]," *Economic News Daily,* December 5, 1981, 12; Qi-Ming Chen, "Dian zi you le qi chan xiao qian cheng yuan da [The Bright Future of Arcade Console Industry]," *Economic News Daily,* March 26, 1982, 12.
[39] *United Daily News*, "Mei shang kong wo fang zao pin guo liu jia gong si yi bei qi su [US Company Sued Six Taiwanese Companies]," September 18, 1983, 3.

These Taiwanese actors' narratives show that their technological choices were embedded in their conceptions of their society's development status. The relationship between technological choices and conceptions of society is not an unusual theme in historical studies of technology. In fact, such an interplay of ideas about development and technology is quite common in postcolonial countries. For example, Suzanne Moon has shown that some Indonesian technologists' ideas about Indonesia's path toward a self-sufficient economy, rather than toward a "takeoff" economy, significantly shaped the technologists' views and choices regarding proper agricultural practices and machinery around 1960.[40] Moon, in her recent research on an Indonesian steel plant from 1950 to 1975, pointed out that Indonesian political figures, such as Suharto and Ibnu, identified Indonesia as a developing country to create a postcolonial desire for a stronger economy and social justice and invited citizens to share in that desire, thus legitimizing the state's investment in the steel plant.[41] Along similar lines, this chapter shows that "development" was an important framework in which Taiwanese actors would illustrate their ideas about the manufacture of technology. The legitimate ways in which Taiwanese companies could manufacture microcomputers were shaped by Taiwanese actors' perceptions of the status of a "developing" country and its relation to technology.

These Taiwanese social groups' perceptions or self-awareness in a developing country should be contextualized within the larger international structure. As Ravi Sundaram has argued, "pirate culture" and "pirate modernity" are ways in which the populations in India and

[40] Suzanne M. Moon, "Takeoff or Self-Sufficiency? Ideologies of Development in Indonesia, 1957-1961," *Technology and Culture* 39, no. 2 (1998): 187-212.
[41] Suzanne M. Moon, "Justice, Geography, and Steel: Technology and National Identity in Indonesian Industrialization," *Osiris* 24, no. 1 (2009): 253-77.

postcolonial countries bypass capitalist control.[42] Ivan da Costa Marques's analysis is especially insightful in this sense. Focusing on power relations between "the West and the Rest," North and South, and European and non-European, he studied the manufacturing of Macintosh clones, which were reverse-engineered by Brazilian company Unitron between 1987 and 1988 and banned by the Brazilian government. He has pointed out that facing the pressure of possible US restrictions on Brazilian exports and Apple Computer's powerful network in Brazil, the legal system in Brazil chose not to side with Unitron, even though Apple had not filed a patent in Brazil. The hierarchical relationship between a country exporting technology and a country importing technology, emphasized by da Costa Marques, may partially explain the rise of the aforementioned Taiwanese social groups' reasoning of imitation as a strategy to cope with the gap between countries.[43]

Still, ideas and actions against illegal copies gradually emerged in Taiwan in the mid-1980s. For example, some computer manufacturers were organized to counter illegal copies of Apple II computers or IBM computers in 1985.[44] Another example would be the comments made by the founder of Acer, Stan Shih, on the December 1984 verdict in favor of Apple. According to Shih, the verdict showed that Taiwanese society was making progress and that the public should consider copyright issues deeply.[45] By 'progress', he meant that the society institutionalized some degree of protection of copyright. A separate lengthy study would be necessary to delineate Shih's subsequent participation, as the leader of Acer and as a leader of

[42] Ravi Sundaram, *Pirate Modernity*: *Delhi's Media Urbanism* (New York: Routledge, 2010).
[43] Ivan da Costa Marques, "Cloning Computers: From Rights of Possession to Rights of Creation," *Science as Culture* 14, no. 2 (2005): 139-160. The notion of network used by da Costa Marques refers to that used by Bruno Latour, Michel Callon, and John Law. For example, see Bruno Latour, *Science in Action* (Cambridge: Harvard University Press, 1987).
[44] *Economic News Daily*, "Da ji fang mao gong hui gua shuai da gui mo cai zheng dian nao jie lian shou [The Association of Computer Manufacturers Fights Illegal Copies]," October 8, 1985, 3.
[45] Guo and Weng, "The Verdict on Copyright on Computers Was Agreeable but Also Controversial," 2.

Taiwanese computer manufacturers at that time, in tackling the software controversy between Taiwanese and US companies, including IBM. But Shih's comments strongly suggest that Taiwanese manufacturers such as Acer, which aimed to produce uniquely designed, export-oriented computers, would worry that other Taiwanese or foreign companies would make illegal copies of their own products.

Interpretations of Popularization

In the 1980s-era discussion on Apple II compatibles, sometimes critics, journalists, and engineers expressed their appreciation of the emergence of Apple II compatibles. They directly acknowledged that the mushrooming Apple II compatibles were the cause of the popularization of computers in Taiwan. These comments are consistent with my informants' related comments in interviews.

In February 1983, Qi-Ming Chen, the abovementioned journalist, interviewed an expert who, I think, was working in one of the national research institutes of computer science. The expert had conducted a short analysis of these compatibles' consequences for Taiwan. Chen wrote,

> Yet, this person [the expert] mentioned that a few business people have manufactured a great number of cheap computers that enable everyone throughout Taiwan to have a chance to experience computers. In particular, students in middle schools are getting interested in computers nowadays. The expert explicitly said that these computers should be given some credit for bringing about the nation-wide fervor for computers. The fervor

would not have surfaced if those expensive imported computers had dominated the domestic market.[46]

In January 1983, Kun-Ming Lin, a journalist at the magazine *Information and Computers* pointed out that Taiwan's early import of microcomputers did not constitute a sufficient condition for Taiwan's acceptance of new technology. The turning point was, instead, the local trend of making compatibles.[47]

In addition to the importance of imitation for a developing country, I have showed that experts, journalists, and my informants acknowledged the positive effect of assembled computers' lower price on the popularization of computers. While the interpretations regarding imitation emphasize the actions taken by manufacturers, the interpretations regarding popularization emphasize the actions taken by general users. Interestingly, both of the interpretations draw on a specific set of attitudes and beliefs relative to the notion of "developing country."

Conclusion

What I present here is a historically specific interpretation of one society's approach to the manufacture of microcomputers. The practice of tinkering with microcomputers yielded a variety of interpretations of what a microcomputer could be during the early 1980s in Taiwan. The practice of building one's own computer—tinkering—initiated the public's interpretations of these matters, including interpretations as to how much related government intervention should

[46] Chen, "The Rise and Fall of Illegal Copies of Apple II Computers," 12.
[47] Lin, "Tips for Purchasing Personal Computers," 45-46.

be permissible. Tinkerers' actions mediated various social groups' interpretations of microcomputers. Some critics, journalists, and computer scientists regarded tinkering as a back-and-forth movement between imitation and innovation. The discussion about the copyright of both software and firmware centered on the discussion about legitimate approaches to the manufacture of microcomputers. In this sense, the practice of tinkering was central in defining the social meanings of microcomputers in the Taiwan of that decade. The practice of tinkering can be a lens through which we can see the relationships between technological artifacts and societies.

I argue that the abovementioned social groups and tinkerers shaped the technology in two ways. First, tinkerers literally opened the black-boxed microcomputer and intervened in the manufacturing process. Beyond Apple's commercial development of microcomputers, Taiwanese tinkerers were able to manufacture their own microcomputers. Second, tinkerers negotiated with the gradually established ideas about copyright on software and firmware. In addition to tinkerers, the abovementioned social groups intended to divert the manufacture of computers away from a heavily restrictive copyright law, although eventually the Taiwanese government did not legalize the manufacture of copies of Apple II computers.

In contrast to the controversy ignited by the practice of tinkering, tinkerers created several widely recognized positive effects on expanding Taiwan's technological system of microcomputers. Some social groups have commented that inexpensive self-assembled computers helped Taiwanese gain access to computers. In addition to their created artifacts, tinkerers accounted for a big portion of microcomputer users: they were early adopters.

Constrained by the scope of this research, it would be hard to trace how the workforce or entrepreneurs of the late 1980s computer industry were trained or inspired by the fervor for tinkering with computers. Most assuredly, however, computer users and entrepreneurs of that era witnessed and were informed by the common practices of building one's own computer.

As da Costa Marquez's research has shown, producing Apple compatibles was not unusual in other societies in the 1980s. Some of the Taiwanese actors in my research thought that if immature technological industries were eventually to thrive, they had to go through, first, an unavoidable stage of imitation. This idea might have been shared by other social groups in other countries at the time. But, more case studies are needed to fully understand and analyze the law suits and social discussions of Apple II compatibles in a global realm.

This chapter raises an important question: is the statement that imitation was an unavoidable stage for a technological industry a valid statement concerning the information industry in 1980s Taiwan, as well as in other historical technology contexts? At least two aspects of this statement are questionable. First of all, is "unavoidable" a necessary adjective to be included in this statement? Second, did Taiwanese manufacturers and individual tinkerers merely imitate Apple II computers? To be specific, can one reasonably call it imitation when tinkerers used new applications, such as the Z-80 microprocessor, to make Apple compatibles process Chinese characters?[48] Was it imitation when tinkerers revised the Autostart and Applesoft program to make their compatibles operational? Was it merely imitation when some companies offered technical supports to Apple II compatibles?[49] I do not intend to discuss these questions by

[48] An advertisement for Jia Jia Corporation, *0 & 1 Technology* 13 (May 1982): 152.
[49] For example, a company called Bai-Sheng provided services for fixing authentic Apple computers and

referencing the legal definitions of 'pirating', 'patent', or 'copyright' as they apply to either the current society or the 1980s society. Instead, I would like to raise the question of how one could acquire the knowledge of a new technological artifact with or without imitation at cognitive or epistemological levels.

When Apple Computer began to lose its market share in Taiwan, some shops or individual tinkerers started making IBM compatibles. As for Taiwanese computer manufacturers, their responses to the rising IBM personal computers ranged from developing their own BIOS systems, continuing to copy IBM computers or branded compatibles, to outsourcing the manufacture of computers. In 1983, a Taiwanese government-funded research institute—the Electronics Research & Service Organization (ERSO), and five Taiwanese companies, including Acer (then Multitech), worked together to develop a BIOS system for IBM PC XT compatibles. After IBM acknowledged the legality of the ERSO's BIOS in 1984, IBM started to sue a couple of Taiwanese companies that neither used the ERSO's BIOS nor developed their unique BIOS.[50]

Despite frequent law suits, the ever-changing legal protection and authorization of BIOS systems and operating systems, and the endless updates of computer models in the decades that followed, the practice of tinkering-with-personal-computers has been a popular hobby in Taiwan for computer users from different backgrounds. Constrained by the scope of this research, it would be hard to evaluate the subtle changes of the number of tinkerers or of DIY computers from the 1980s to now. But, at least, from my personal experience of building my own computers since the mid-1990s, the practice of tinkering-with-computers has been robust and

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compatibles. See an advertisement for Bai-Sheng Corporation, *0 & 1 Technology* 13 (May 1982): 147.

[50] See "Gong ye ju pan qi ta chang shang xiang IBM zhu ce [ERSO Urges Companies to Obtain IBM's Approval]," *Information Biweekly* 4 (June 1984): 5.

persistent for years. The two commercial districts have functioned as a sacred space for decades where serious tinkerers and casual consumers could hang out to keep informed of the latest computers and electronics.[51]

[51] Because of an urban-planning project of building underground railway, the Chung-Hua Arcade closed in 1992 and many computer-parts shops moved to the Kuang-Hua Public Market. In 2008, the Kuang-Hua Public Market moved to a nearby newly-constructed building, the design of which is much similar to a contemporary trendy department store. The move was caused by another urban-planning project, in which the overpass above the Market was torn down. The re-organization of the space for selling cutting-edge computers and electronics in Taipei reflects the changes of the social meaning ascribed to these technological artifacts, which deserves another research project to fully explore.

CHAPTER 7

CONCLUSION

This dissertation explores digital electronic computing in Taiwan during the Cold War. Specifically, the dissertation uses a developing country's appropriation of mainframe computers, minicomputers, and microcomputers as a lens for understanding the historical relationships among the development discourse, the technology underlying the Cold War, and the international exchanges of scientific and technical expertise in the context of the Cold War. I argue that Taiwanese technocrats, engineers, scientists, and ordinary computer users' interpretations of the developmental status of their country shaped their perceptions of the importance of possessing, using, and manufacturing computers. Although the aforementioned social groups' knowledge of digital electronic computing rested partly on their interactions with US experts or US-based companies, the Taiwanese individuals did not simply engage in wholesale copying of US sources. Instead, they modeled their own practices after the existing successful practices related to mainframe computers and later started to build and tinker with minicomputers and microcomputers.

By presenting a history of non-inventors of digital electronic computing in a so-called developing country, this dissertation contributes to two streams of scholarship: (1) the history of digital electronic computing, and (2) technology-user studies in the fields of science and technology studies and of the history of technology. First, while historians of computing have emphasized that the Cold War functioned as a type of discourse and created cultures and institutions profoundly shaping the contingencies of technological choices in this time period, this dissertation focuses on a social setting in which development discourse, prevailing during

the Cold War and a product of the Cold War, was critical in shaping Taiwan's digital electronic computing in the historical periods examined. Rather than focus on the origins of digital electronic computing technology, this dissertation addresses Taiwanese engineers, technocrats, scientists, and computer users' local interpretations and practices of introducing mainframe computers, minicomputers, and microcomputers to Taiwan. Taiwanese historical actors examined in this dissertation were enthusiastic about owning, mastering, using, and manufacturing digital electronic computers. Furthermore, I emphasize that Taiwanese historical actors' enthusiasm did not emerge autonomously: it flowed from development discourse and Cold War-related politics. Second, I propose the concept of tinkering to describe the interventions of a wide range of social groups in and modification of digital electronic computing technology. The concept of tinkering proposed by this dissertation expands the field of user studies in science and technology studies. By emphasizing users' strategies for bypassing the typical innovation process (i.e., strategies of revising, re-producing, and engaging with technology), this dissertation addresses under-explored themes about re-production or modification in the lifespan of a technology.

Development Discourse and Technological Practices

The Cold War's military and ideological confrontations, as the historical context of the emergence of digital electronic computing, contributed to the construction in both the United States and the Soviet Union of their respective digital electronic computing practices, political discourses, and societal changes. For places in which people desired digital electronic computers, such as Taiwan, development discourse, another product of the Cold War, also shaped the technological practices related to digital electronic computing practices.

This dissertation lays out the development discourse that was constructed by the following factors: but: United Nations technical-aid programs; the widely circulated classificatory system identifying developed, developing, and underdeveloped countries; computer-assisted economic-knowledge production; and Taiwanese computer users' self-identity concerning Taiwan as a developing country. In each chapter, the relationships between development discourses and Taiwanese technological practices work slightly differently.

In chapters 2 and 3, I describe a group of Taiwanese technocrats, engineers, and scientists who, in the mid-1950s, operated on the belief that introducing Taiwan to cutting-edge expertise in "electronics science" and digital electronic computers would help develop Taiwan's industrial sector, which would then supersede the agricultural sector, ultimately transforming Taiwan, then categorized as a developing country, into a developed country. Central to the industrial sector was the country's capacity of nurturing an electronics-manufacturing industry. These social groups successfully applied for a UN technical-aid program that helped NCTU come into possession of two IBM computers, invite US professors to teach programming, and become the hub of digital electronic computing in Taiwan from 1962 to 1964. As I discuss at greater length in chapter 2, the historical actors S. M. Lee (the director of the graduate program of electronics at NCTU), C. C. Wang (a Sperry Rand engineer), Tsen-Cha Tsao (a researcher at Columbia University), and Gisson Chi-Chen Chien (the head of the Bureau of Telecommunications in Taiwan) were not experts in digital electronic computing and grasped merely the potential of digital electronic computing; nevertheless, they set up the UN-NCTU technical-aid program to facilitate the academic learning and the practical uses surrounding digital electronic computers in Taiwan.

In chapter 3, which delineates the UN-NCTU technical-aid program, neither visiting US professors (namely, Dean Arden and W. W. Peterson) nor NCTU instructors (namely, Henry Y. H. Chuang, Chi-Chang Lee, and Tseng-Yu Lee) directly discussed the necessity of developing Taiwan. Nevertheless, Arden, Peterson, Chuang, Chi-Chang Lee, and Tseng-Yu Lee directly participated in helping engineers from Taiwan Power Company and Chinese Petroleum Corporation carry out industrial or infrastructural development projects in Taiwan; their participation in establishing NCTU's computing center provided the necessary material and intellectual support for Ta-Chung Liu and the CIECD's work in producing inter-industry input-output analyses of Taiwanese industries (see chapter 4). Conversely, the inter-industry input-output analyses of Taiwanese industries reinforced the development discourse because the analyses were supposed to prove that Taiwan's economy was better than communist economies.

As discussed in chapter 4, the mainframe-assisted economic-planning project demonstrates that the historical relationship between digital electronic computers and the development discourse in Taiwan were multi-layered. Chapters 2 and 3 describe the derivation of Taiwan's digital electronic computing from development discourse, and chapters 3 and 4 argue that the development discourse supported a series of practices involved in the development of Taiwan. Chapter 4 reveals that the IBM 1620 computer helped Liu and the CIECD produce econometric knowledge for the pursuit of improved economic performance of Taiwan. The materiality of digital electronic computers supported the production of econometric knowledge, which is part of development discourse.

Whereas chapters 3 and 4 address the introduction of mainframe computers to Taiwan, chapters 5 and 6 address the introduction of minicomputers and microcomputers to Taiwan. In particular, during the time period extending from 1962 to 1968 (covered in chapters 3 and 4), Taiwanese computer users aimed to emulate successful practices of digital electronic computing. The cases discussed in chapters 5 and 6 concern Taiwanese computer users who went from emulating to building and tinkering with computers.

Chapters 5 and 6 show that Taiwanese engineers, scientists, and ordinary computer users' perceptions of the developmental status of their country shaped their perceptions of the importance of manufacturing computers. These social groups acknowledged that an electronics-manufacturing industry was central to the process of transforming Taiwan from a developing country into a developed country. When Taiwanese companies or individuals would be able to manufacture electronics products, the national economy would register significant improvements through exports of domestically manufactured merchandise or at least through decreases in the overall expense of importing merchandise: Taiwan's industrial sector and economic performance would grow stronger. To facilitate the establishment of an electronics-manufacturing industry, Taiwanese scientists at NCTU experimented in building a minicomputer from scratch and then evaluated the possibility of mass manufacturing it. They ended up building a calculator instead of a minicomputer, and the completion of the technological artifact partially depended upon two US-related electronics-manufacturing factories located in the Export Processing Zone. Export Processing Zones derived from the import-substitution policy adopted by the so-called developing countries at that time.

Chapter 6 shows that, although some Taiwanese microcomputer users and companies built microcomputers from scratch, some of the practices of some of these users resulted in the assembling of illegal copies of Apple II computers in Taiwan and initiated a series of debates about whether legal institutions had allowed Taiwanese individuals and companies to make Apple II compatibles. The protagonists legitimized or delegitimized one's building of one's own computer by mobilizing a development discourse, insofar as they believed that the success of Taiwan's electronics industry would place Taiwan on a track leading to the camp of developed countries.

In contrast to Taiwanese engineers, scientists, and technocrats' emphasis on the communism-and-capitalism struggle in the late 1950s and 1960s, NCTU instructors (such as Jong-Chuang Tsay and Chu-Yi Chang, in chapter 5), journalists, engineers, and ordinary microcomputer users in the 1970s and the early 1980sseemed to indicate that while they were concerned about expanding the industrial sector of Taiwan's economy, they were less interested in connecting the digital electronic computer to the communism-and-capitalism struggle involving the United States, Taiwan, and China. Without mentioning communists, both Tsay's and Chang's writings in 1971 as well as journalists, engineers, and ordinary microcomputer users' discussions in the early 1980s addressed possible approaches to improving Taiwan's trailing status in terms of technological achievements. Nevertheless, from researching news articles around 1971 and around the early 1980s, I find the communism-and-capitalism struggle frequently discussed in the editorial pages and op-eds. The development discourse of the late 1950s and the 1960s, which addressed the effects of expanding Taiwan's industrial sector on the economic competition between 'democratic China' and 'communist China' differs slightly from

the development discourse of the 1970s and 1980s, which emphasized the effects of creating a computer-manufacturing industry in Taiwan on its developmental status.

Building Chinese/ Taiwanese Computers

The possible electronics industry considered by Taiwanese historical actors in the 1960s included a wide range of electronics manufacturing. For example, S. M. Lee ambitiously proposed that NCTU might be able to manufacture digital electronic computers in the early 1960s; C. C. Wang seemed to be more practical, as he advocated that NCTU should start to experiment with vacuum-tube manufacturing.

In 1959, S. M. Lee stated that "the graduate program will purchase parts to design and manufacture small-scale computing devices to meet researchers' demands."[1] In 1961, after discovering that the United Nations had approved the UN-NCTU technical-aid program, he told journalists that "three years from now, Chinese scientists will be able to use computers we manufacture ourselves."[2] Lee expected to see domestically manufactured computers or a type of "Chinese" computer, both of which would represent the capability of Free China's technological achievements and contribute to Free China's economy.

Three years later, Lee's prediction had not yet come to pass, though the technical-aid program had successfully trained a group of capable users in universities and in state-owned enterprises. When NCTU hired Chin-Chi Kao to be the principal maintenance engineer for the

[1] S. M. Lee, "Dian Zi Yan Jiu suo jiao xue fang zhen yu jin hou fa zhan [The Directions and Development of the Graduate Program in Electronics]," *The Voice of NCTU Alumni* 82 (September 1959): 11-14.
[2] "Dian zi ji suan yi jiao da dian zi yan jiu suo ji hua yu shi yue zhuang zhi [NCTU Will Set Up an Electronic Computer in October]," *The Voice of NCTU Alumni* 104 (August 1961): 23.

IBM 1620 computer, he opened the black-boxed mainframe computer and was able to replace components of it. But the black-boxe opening at that time did not encourage him or other NCTU users to plan for the manufacture of a digital electronic computer. NCTU administrators and Peterson decided to simply replace IBM-computer maintenance service with an in-house Taiwanese technician.

Lee's predictions partially came true when Tsay completed a calculator domestically in 1971. By "partially," I mean that Tsay and NCTU members were not able to mass manufacture a minicomputer or a calculator and that they relied on parts from Wang laboratories and a Ford-funded Taiwanese integrated-circuit manufacturer. Nevertheless, Tsay and other NCTU members came up with a calculator on the basis of their own design of logic units and magnetic-core memory units. In particular, it took Tsay a long time to wire each component together. Tsay and his colleagues tinkered with the architecture of digital electronic computers at this time, though eventually the computer they built had a relatively limited capacity.

Lee's expectations regarding the domestic manufacture of computers finally became a reality, to some extent, after Taiwanese microcomputer users started to build their own microcomputers from scratch. By "to some extent," I mean that neither Taiwanese microcomputer users nor Taiwanese companies relied on parts manufactured in Taiwan in the early 1980s. It was difficult to find a computer in which every single component was domestically manufactured in Taiwan, and there was no common standard for examining whether a computer was 'Chinese' or 'Taiwanese'; these microcomputers should not be categorized as 'American' either. Nevertheless, if Lee had been alive in the 1990s, he might have

been satisfied with the accomplishments of ‘Taiwanese’ companies such as Acer, which sold their own brand of personal computers to other countries.

I recognize that diverse Taiwanese social groups were enthusiastic about building computers domestically throughout these time periods, but their practices of mainframe computing in the early 1960s, their completion of the NCTU minicomputer in 1971, and their building of microcomputers in the early 1980s were not purely Taiwanese, Chinese, or American. I argue that these computers and related practices constituted a juncture at which several different social forces converged: development discourses, Taiwanese social groups’ participation in development discourses, and science and technology exchanges prevailing during the Cold War.

To build a computer is to infuse into the building project a large amount of diverse knowledge. Part of this diverse knowledge is how to adapt, modify, and re-assemble computers in an innovative manner, that is, to tinker with computers. Taiwanese computer users’ building of computers and tinkering with computers worked in tandem with each other. The users’ tinkering was part of the result of their decision to build computers. Conversely, their tinkering practices helped them to complete the building of computers.

Tinkering with Computers

What determined how much a computer user could successfully tinker with a computer? On the one hand, mainframe computers from that era seem bulky, complicated, and black-boxed in contrast to the personal computers we use nowadays. Following this logic, one might conclude

that Taiwanese users would have had greater difficulty tinkering with mainframe computers than with minicomputers and microcomputers. Yet the extent to which a computer is black-boxed can be analyzed from another viewpoint: vacuum-tube computers give the impression of being containers of components that one might arrange in the way car users who open a hood to fix a car might arrange the parts in the engine. But integrated circuits of microcomputers involve sealed layers and layers of circuits, all in a small device, so it could be difficult for users to modify settings inscribed in a chip.

But, past users of mainframe computers and minicomputers may still feel that it is easier to fix mainframe computers and minicomputers than contemporary personal computers. In general, users familiar with a certain technology may think that the technology is a translucent box. A 'translucent box' or a box's 'opacity' are terms used by Cyrus Mody in his research on microscope users, researchers, manufacturers, and other relevant communities. He has pointed out that different communities hold different viewpoints on the extent to which an instrument is black-boxed.[3] In other words, the extent to which a technology is black-boxed is relatively defined, depending on which social group attempts to assess the extent to which a technology is black-boxed.

Beyond the actors' perceptions of the extent to which an instrument is black-boxed, I would like to propose a couple of factors that were central to the materiality of Taiwan's early computers and that played a role in determining how much a Taiwanese user was able to tinker with a computer. These factors include the availability of computer parts, different architectures

[3] Cyrus Mody, "*Crafting the Tools of Knowledge: The Invention, Spread, and Commercialization of Probe Microscopy, 1960-2000*," PhD Diss. Cornell Univ., 2004. See page 311.

of computers, the institutionalization of digital-electronic-computing education in Taiwan, and the restrictions set up by manufacturers.

First, the availability of computer parts constitutes a significant difference among the histories of NCTU's IBM 650 and IBM 1620 computers, of the NCTU minicomputer-building project, and of the microcomputer-tinkering practices in Taiwan. In the early 1980s, microcomputer users built their own computers by putting together parts widely available on the market, especially the two commercial districts described in chapter 6. These parts were not merely available, but also modularized for kits or for manufacturers, in a way similar to the modularization of parts for homebrew acoustic systems at that time. However, in 1971, Tsay and NCTU members built their small-scale calculator with parts specially acquired from Wang laboratories and from a Ford-funded Taiwanese integrated-circuit manufacturer. Tsay and NCTU members obtained the parts through personal connections, not through purchases of computer parts at a shopping mall's computer store. If Wang laboratories and Ford had not invested in Taiwan, Tsay and NCTU members might have faced more difficulties.

As for the mainframe computer case, a comparison between the IBM 650 and the IBM 1620 indicates that the availability of parts, combined with the architectures of computers, played a role in discouraging NCTU users to tinker with computers. While the reliability of vacuum-tube computers is intrinsically poorer than transistorized computers (discussed in chapter 3), it was equally difficult for NCTU users to obtain parts to modify their IBM 650 and 1620 computers. Vacuum tubes 6350, 5965, 6211, 5687, 5726, 12AY7, 2D21, and 6AL5 were

used for the arithmetic unit and the circuit elements of the IBM 650 computer.[4] In particular, the 6350, 5965, and 6211 were tubes, the typical application of which was for digital electronic computers. It is not clear whether IBM manufactured its tubes in its own factories at that time, but it is clear that some of these vacuum tubes were manufactured by RCA and Raytheon in the United States.[5] One might be able to obtain these vacuum tubes in the United States, but in Taiwan, vacuum tubes in the early 1960s were imported mainly for the manufacture of radio sets. Therefore, outside their reliance on IBM, Taiwanese users could not obtain spare tubes to fix their IBM 650 computer.

Furthermore, IBM vacuum-tube computers used an "eight-tube pluggable unit" that might complicate Taiwanese computer users' efforts to replace the vacuum tubes of the IBM 650 for repairs.[6] While one might have been able to obtain vacuum tubes from RCA or Raytheon, another issue entirely might have been efforts to manufacture tubes compatible with IBM's eight-tube pluggable unit. For transistorized computers, IBM manufactured its own transistors, so NCTU had to obtain spare parts from IBM. Obviously, NCTU members (and most US IBM customers) only fixed—never modified—their IBM 1620 computer.

To clarify the differences between the Taiwanese actors who tinkered with computers (see chapters 5 and 6) and the Taiwanese actors who did not (see chapters 3 and 4), I would like to emphasize that the institutionalization of digital electronic computing education in Taiwan may

[4] See page 370 in Martin H. Weik, *A Third Survey of Domestic Electronic Digital Computing Systems* (*The BRL Report 1961*), Report No. 1115, published by Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, March 1961, available at the Computer History Museum Center website, accessed November 30, 2011, http://ed-thelen.org/comp-hist/BRL61.html

[5] An online electron tube catalog database, accessed November 30, 2011, http://www.wps.com/archives/tube-datasheets/

[6] Charles J. Bashe, Lyle R. Johnson, John H. Palmer, and Emerson W. Pugh, *IBM's Early Computers* (Cambridge: MIT Press, 1985), see page 150.

partially explains the differences. (I did not use the terms 'confidence' and 'capacity' because they suggest either a collective psychological status called confidence for a country or a measurable collective ability for a country.) At the surface level, the passage of time seems to have been associated with an increased possibility that Taiwanese users would intervene in or modify computers. But time is not the main factor here. The increased degree of intervention was due in large part to the institutionalization of digital-electronic-computing education in Taiwan. As noted in chapter 5, Tsay and NCTU members in 1968 started to build a minicomputer; at that time, they were enrolled in or affiliated with the NCTU's graduate programs. It is important to note that the UN-NCTU technical-aid program had been successfully completed just three years earlier. Chapter 6 addresses a segment of microcomputer tinkerers who were computer-science majors and makes clear that, in general, mainframe computers and minicomputers were much more visible in the 1980s than in the 1960s and the 1970s.

Technology manufacturers often set up restrictions to prevent users of the technology from disassembling and tinkering with it. After all, manufacturers sell products for profits, not for the pleasure of sharpening customers' technological literacy. Many manufacturers void their promised warranties when customers modify the product in question. This practice of voiding warranties has a long history: for example, US automobile manufacturers adopted this policy in the early twentieth century.[7] As there were merely two digital electronic computers available in Taiwan in the early 1960s, and as NCTU members still planned to use the two computers for various types of calculations, it would have made no sense for NCTU members to dismantle the computers for the purposes of modification. Modifying the IBM 650 and 1620 computers was

[7] Ronald R. Kline and Trevor J. Pinch, "Users as Agents of Technological Change: The Social Construction of the Automobile in the Rural United States," *Technology and Culture* 37, no.4 (1996): 763-95.

risky because in the worst-case scenario where NCTU would lose their access to digital electronic computers. The risk of losing a technological artifact through acts of tinkering can be extended to a discussion of the risks associated with tinkering, in general. How much risk do users shoulder when tinkering with technology? In contrast to other Cold War technologies, such as nuclear energy or atomic bombs, building and tinkering with minicomputers rarely posed any direct threat to anyone.

Tinkering, Emulation, and Mimicry

For historians of technology, historical actors' minor modifications of technological artifacts, though not necessarily patentable, are extremely important to historians' efforts to identify the life spans of technology. Brooke Hindle would have used the term 'emulation' to identify Taiwanese users' (1) modeling of successful mainframe-computing practices, (2) building of minicomputers and microcomputers, (2) tinkering of minicomputers and microcomputers. He has pointed out that American inventors and their mechanics, by emulating European machines and by modifying the designs of these European machines, eventually led to two major technological breakthroughs in the United States: Samuel Morse's telegraph system and Robert Fulton's steam boats. Hindle emphasizes American's agency and autonomy by highlighting the technological modifications undertaken by American inventors. Nevertheless, postcolonial-studies scholars may view the agency and autonomy differently, as they could argue that American inventors' emulation of European designs exemplifies the theoretical concept of mimicry in which a less 'modern', more 'traditional', and also 'postcolonial' society is trying to transform itself by copying a more 'modern' society. I should note, however, that the 'ideal type' of mimicry is the historical colonial settings in which elite members of colonial Indian were

almost—but not quite—the same as members of the British colonizer population: the quintessence of most Western colonialism was to create dichotomized categories between the colonizer and the colonized. Postcolonial scholars may consider Morse's telegraph system and Robert Fulton's steam boats both hybrid objects. Historians of technology and postcolonial scholars differ from one another when weighing the overall importance of precisely these two factors: the agency that people exhibit when facilitating technological change and the practices that people exhibit when modifying technological artifacts. This dissertation describes Taiwanese actors' agency in the context of development discourse. This dissertation treats Taiwanese computer users' minor modification of technological artifacts as both an act of creativity and a product of a complicated web of events under the auspices of development discourse (e.g., Taiwanese historical actors' enthusiasm for a stronger industrial sector, and the intimate academic and technological connections between Taiwan and the United States during the Cold War).

Was this so-called developing country's mimicry of developed countries inevitable? Some of the Taiwanese actors in the early 1980s thought that if a technological industry in Taiwan were eventually to thrive, the industry would first have to undergo an unavoidable stage of imitation. According to one of the news stories discussed in chapter 6,

> A software engineer hired for the manufacture of illegal copies said that technology-backward countries might lose their direction while chasing after technology-advanced countries. He thinks that the imitation is a necessary process for technology-backward countries. He points out that Japan, years ago, was a relatively technology-backward

country that, by imitating advanced countries, developed its own advanced industries.[8] (Original in Chinese)

Mimicry appears to be the best and most convenient strategy by which a so-called developing country might adopt when they intend to significantly enhance its developed status. This dissertation describes how Taiwanese historical actors, by continuously referencing the technological artifacts in the United States, conceptualized strategies for their country's electronics industry. These strategies involved variously the introduction of mainframe computing to Taiwan through technical-aid programs, Taiwan's mass-manufacture of existing minicomputers, and Taiwanese users' enthusiasm for owning and tinkering with newly emerging microcomputers.

Development discourse, though sometimes functioning as a type of hegemony, includes contradictory ideas and generates unintended consequences. While delineating how Taiwanese engineers, technocrats, scientists, and ordinary computer users participated in Taiwan's development discourse, this dissertation also traces the development discourse's contributions to inconsistent, incongruent, and unintended circumstances. For example, chapter 2 notes the expectation, held by some UN-affiliated officials, that the UN-NCTU technical-aid program would help the NCTU-based training center's students join the workforce and help students collaborate with employed engineers. After the training center's kick-off, NCTU concentrated its recruitment on state-owned enterprise engineers and was more interested in having the university conduct research for industry than in facilitating collaborations the university and on-site

[8] Qi-Ming Chen, "Fang pin guo er hao de bo xing yu mei luo [The Rise and Fall of Illegal Copies of Apple II Computers," *Economic News Daily*, February 22, 1983, 12.

engineers. Chapter 3the limited funding period of the UN-NCTU technical-aid program accidentally encouraged NCTU members and Taiwanese technocrats to purchase the 1620 computer and to have it maintained by an in-house engineer, rather than rent the computer from IBM and rely on the company's own maintenance service. In chapter 4, the interdependence between digital electronic computing and the inter-industry input-output analysis indicates that Taiwan was the site of socially constructed development-related econometric knowledge. Taiwanese analysts' work on economic models was contingent on the capacity of available computing devices.

The history discussed in this dissertation, concerning the introduction of digital electronic computing to Taiwan during the Cold War, demonstrates that the technological practices and choices of Taiwanese technocrats, engineers, scientists, and computer users were intertwined with their ideas about the societal, political, and economic aspects of Taiwanese society. This study sheds light on the roles that digital electronic computing technologies played in different social settings, such as a technical-aid program, government-related policy planning, a university lab, and a popular hobby which prompted a controversy. This dissertation emphasizes not only diverse social groups that shaped technologies but also diverse types of computers that constituted the social settings. Herein, this dissertation demonstrates that technological artifacts and practices are helpful lenses for understanding societies. Throughout this dissertation, Taiwanese technocrats, engineers, scientists, and computer users focused on mainframes, minicomputers, and microcomputers' potential for Taiwan's economic development. Conversely, these computers were central to a series of development-related attempts in Taiwan.

APPENDIX A

LIST OF ORAL-HISTORY INTERVIEWS

1. Iau-Sheng Wang, June 17, 2007.
2. Tsan-Sheng Hsu, June 27, 2007
3. Samuel Chen, July 1, 2007.
4. Edward Liau, July 3, 2007
5. Ting-Wen Kau, July 6, 2007.
6. Cheng Ku, July 11, 2007.
7. Zai-Xing Qiu, August 6, 2007.
8. Jong-Chuang Tsay, November, 20 and December 18, 2007.
9. Dean N. Arden, October 4, 2008 and November 10 and 11, 2008.
10. G. Conrad Dalman, October 24, 31, 2008; December 4, 2009; February 8, April 28, 2010.
11. Chi-Chang Lee, January 7, 14, and February 11, 2009.
12. Tseng-Yu Lee, January 7, 2009.
13. Pin-Yen Lin, Feb 5, 15, and 25, 2009
14. Yun-Tzong Chen, May 24, 2009.
15. Ching-Chun Hsieh, May 27 and June 5, 2009.
16. Yuan-Kuan Chen, June 2 and 10, 2009.
17. Chin-Chi Kao, June 2, June 17, June 20, July 5, 2009.
18. Henry Y. H. Chuang, June 7, 2009.
19. Chiong-Yuan Han, June 15 and 22, 2009
20. Chin-Long Chen, July 1 and 8, 2009.
21. Chiang-Chang Huang, August 22, 2009.

APPENDIX B

ARCHIVES AND OTHER COLLECTIONS

Archives:

Charles Babbage Institute, University of Minnesota, Minneapolis.

Computer Product Manuals Collection (CBI 60)
James W. Cortada Papers (CBI 185)

National Archives at College Park, College Park, MD, USA

Research Group 469: Records of U.S. Foreign Assistance Agencies, 1942-1961, MLR UD 409: China (Taiwan) subject files of the office of the deputy director 1948-59, Box 252, 227, 263

United Nations Archives and Records Management Section, United Nations, NYC, USA.
S-0132 Technical Assistance Projects Files- Asia and Pacific Branch

Ministry of Foreign Affairs Files (MFA Files), Institute of Modern History, Academia Sinica, Taiwan.

635.31 0200
635.31 0201
635.31 0202
635.31 0208

CIECD (the Council for International Economic Cooperation and Development) Central Files, Institute of Modern History, Academia Sinica, Taiwan.

36-10-011-026
36-01-002-027

University Records, National Chiao-Tung University Museum, Taiwan
University Records, National Taiwan University, Taiwan

A List of Periodicals, Trade Journals, and Newspapers Consulted:

China Times
Computer Research Quarterly
Cornell Daily Sun
Economic Daily News
Electronics & Radio-TV Technical Monthly

Information and Computers
Ithaca Journal
Monthly Journal of Taipower's Engineering
Petroleum Geology of Taiwan
Science Bulletin National Chiao-Tung University
Science Monthly
Taiwan Engineering
Telecommunication Journal
The Third Wave
The Voice of NCTU Alumni
United Daily News
0 & 1 Technology

Institutional Reports and Yearbooks:

NCTU Publications:

The Yearbook of the Training Course of Electronic Computers, February-June, 1963
The Yearbook of the Institute of Electronics at NCTU, 1964
The 11th Yearbook of Training Courses of Electronic Computers, November-December 1964

The United Nations' Publications and Reports:

Yearbook of the United Nations 1948-49. 1950.
Yearbook of the United Nations 1950. 1951.
Yearbook of the United Nations 1958. 1959
Training and Research Centre for Telecommunications and Electronics, Republic of China: Report. 1968.
The Priorities of Progress. 1961.

Publications and Reports from the Institute for Information Industry, Taiwan:

Zhong hua min guo zi xun gong ye nian jian [Annual Book of Information Industry], 1981.
Zhong hua min guo zi xun gong ye nian jian [Annual Book of Information Industry], 1982.
An Analysis of Desktop Computers, 1994.
An Analysis of the Market of Information Products, 1997.
An Analysis of the Domestic Computer Market, authored by Wen-Bin Xie, 1999.

Others:

Chinese Institute of Engineers, *Yi nian lai de gong cheng jian she gai kuang [The Previous Year's Engineering Accomplishments]*. Taipei: Zhing guo gong cheng shi xie hui [Chinese Institute of Engineers], 1970.

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