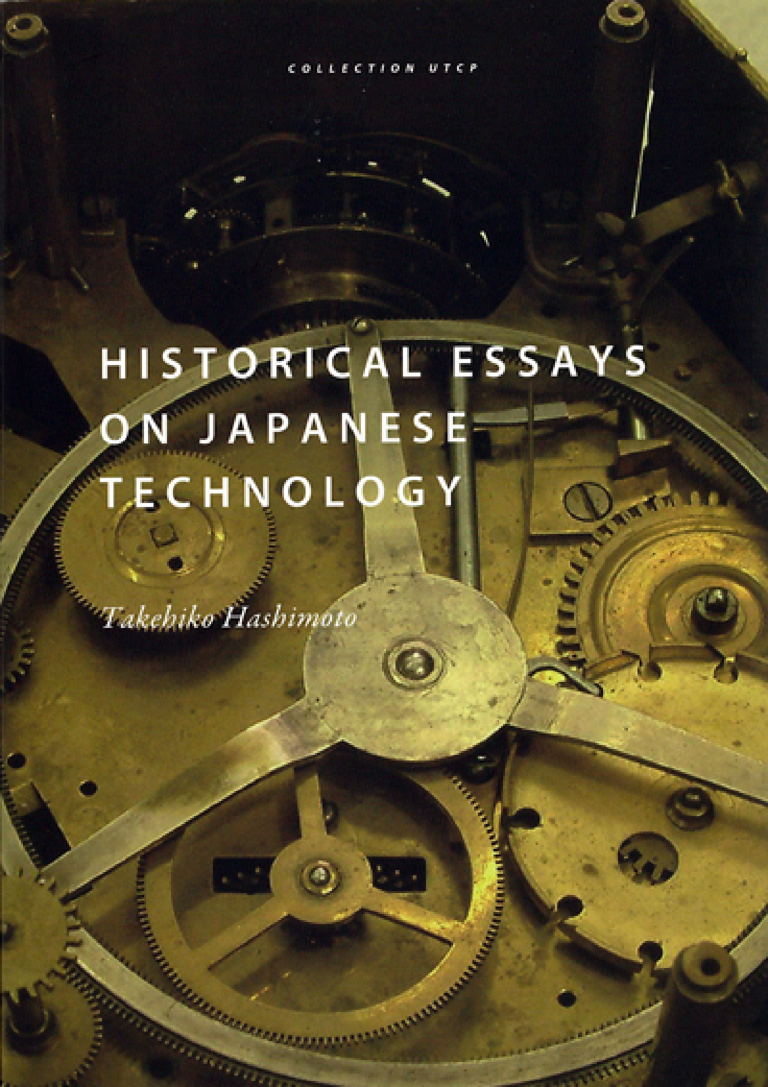

COLLECTION UTCP

HISTORICAL ESSAYS ON JAPANESE TECHNOLOGY

Takehiko Hashimoto

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Historical Essays on Japanese Technology

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Contents

Preface

Technology is a driving force in transforming society, which in turn shapes technology so that it is workable in a specific social circumstance in history. In the history of the modernization and postwar reconstruction of Japanese society, technology arriving from Western countries played a key role, interacting with already existing traditional techniques or previously imported technologies.

The steam engine attracted intense attention from leaders of Japan on the eve of the Meiji Restoration in 1868. Yet, as Chapter 6 of this volume shows, the more primitive water wheels continued to drive machines throughout Japan. They were used because the Japanese landscape was filled with slopes with running water, and because the constant operation of steam engines demanded the costly consumption of large amounts of coal. To minimize the cost of transportation of coal, steam engines were often used to pump water at coal mines, and to drive locomotives and ships which were easily accessible to the site where fuels were stored.

The introduction of modern technology and modern institutions required some basic changes and new foundations to keep them working in society. Modern technology needed a uniform standard system, including units of weights and measures. The safe and economic operation of modern technological systems, most notably railroads and factories, required modern work disciplines and rigorous punctuality, which was absent until the late 19th century. As Chapter 1 shows, the acquisition of punctuality, the requisite for the successful introduction of modern technologies and institutions, was a gradual process in modernizing Japan.

This volume is a collection of papers I published from 1992 to 2008 on a variety of topics about the history of Japanese technology. With the exception of Chapter 8 on postwar American history, all the topics contained in this volume are concerned with a certain facet of the history of technology in Japanese society, from the end of the Edo period to the present. The topics covered in this volume are diverse. Some are major themes in the history of Japanese technology; others are rather minor and hitherto unknown. However, the discussions in the following chapters touch on and disclose certain aspects of the nature of technology developed and used by Japanese engineers.

"Part 1: Mechanical Clocks and the Origin of Punctuality" covers time and clocks in modern and pre-modern societies. After the introduction of Western mechanical clocks by Jesuit missionaries in the sixteenth century, the mechanical clock created a unique engineering evolution in Edo society, so that its time-keeping and display function conformed to the seasonally variable time system in use at the time, according to which the length of hours changed, like the ancient and medieval time system in the West, from daytime to night and from season to season. With the introduction of the Western time and calendar system in 1873, Japanese society also introduced modern work discipline, which required strict punctuality in many quarters of society. Chapter 1 discusses the change in conception of time from the Edo to the Meiji period, and the historical evolution of modern Japanese society through observing how punctuality was accepted and consolidated in the society. Chapter 2 deals with the career of Hisashige Tanaka, a craftsman of the later Edo period known for his famous automata machines, and his masterpiece called the Myriad Year Clock, which was a complex time-keeping machine with a solar and lunar model on its top.

"Part 2: Roles and Visions of Foreign Engineers" deals with the work and thoughts of French and British engineers. Tokugawa and Meiji governments employed foreign engineers to build their various modern institutions—factories, dockyards, railroads, and engineering schools. Chapter 3 discusses the construction of the Yokosuka Dockyard, directed by the young French naval engineer François Verny. It describes the various facilities contained in the dockyard, including a school where basic instructions on science and engineering were given to selected young students. Chapter 4 explores how British engineers saw modernizing Japan, by surveying articles on Japan published in an English journal, *The Engineer.*

"Part 3: Forming Technological Foundations in Modern Japan" covers three different topics about technologies in modern Japan. Chapter 5 deals with the metrological standardization before and after the Meiji Restoration, especially the introduction of the metric system as a standard unit of weights and measures. The establishment of precise units of weights and measures was the fundamental premise for the operation of the modern technological system. In modern Japan, three systems—yard-and-pound, traditional shaku-and-kan, and the metric system—coexisted until after the Second World War. The chapter deals with the gradual process of acceptance and diffusion of the metric system in Japanese society. Chapter 6 outlines the evolution of power technology—water, steam, and electric powers—in pre-modern and modern Japan. This historical overview suggests the close relationship between the use and development of technology on the one hand, and the economic, social, geographical conditions in that period on the other. It shows, for instance, the continued use of water power long after the introduction of steam engines. Chapter 7 discusses the unsuccessful project of trans-Pacific flight in the 1920s and 1930s. Hidemasa Kimura, an aeronautical engineer at the Aeronautical Research Institute of Tokyo Imperial University, assisted on this project and dealt with the controversy over the aeronautical standards. The chapter shows his thoughts on reasonable standardization, and his later involvement with a project of long-distance record-setting flight.

"Part 4: University, Industry, and the Government in Postwar Society" deals with the relationship between these three sectors in the development of technologies in the United States and Japan. As an exception to this volume, Chapter 8 deals with the strong military involvement with R&D in postwar American society. During the Cold War, the United States government heavily subsidized industry, as well as universities, to develop advanced technologies related to nuclear weapons systems. The chapter surveys the recent historiographical debate over whether such military funding "distorted" postwar American science and technology. In contrast to the United States, Japanese industry concentrated on production for civilian markets, and the development of technologies for that purpose. The last three chapters investigate the less visible relationship between universities and industry in postwar Japanese society. Chapter 9 discusses this "hesitant" relationship between the two sectors in postwar Japan, which is contrasted with a more active relationship between the two in the prewar period. Chapter 10 examines the role of "Technological Research Associations" organized under the Ministry of International Trade and Industry (MITI) to serve as public forums for academic and corporate engineers, in order to facilitate their cooperation and the exchange of technical information. Chapter 11 discusses the "national innovation system" of Japan, and the role of the government in promoting and coordinating R&D activities in various sectors in the 1990s.

A few words on historical literature closely related to the articles collected in this volume, and the topics covered by them, are in order. Chapter 6, on the development and use of power technology in modernizing Japan, is a translation of a Japanese article originally published as a chapter in *The History of Industrial Technology*, a survey book on the history of industrial technology in Japan. The book, edited by the historians of technology Tetsuro Nakaoka, Jun Suzuki, and others, covers such topics as mining, steel, machinery, railroads, textile, chemicals, information, aside from power technology. A shorter version of the article is reprinted in the *Encyclopedia of the History of Industrial Technologies in Japan*, which comprehensively covers most important topics in the field, and is a good starting point for the study of the history of Japanese technology.

My interest in time and clocks originated from learning about the promotion of punctuality in the movement called "the Movement for the Improvement of Domestic Life," referred to in Chapter 5, on the introduction of the metric system, as well as in Chapter 1, on the origin of punctuality in modern Japan. After I learned about it, the technological historian Tetsuro Nakaoka drew my attention to the complaint prevalent among employed foreign engineers in the late Edo and early Meiji periods about the Japanese lack of punctuality. I then organized a collaborative and interdisciplinary research into the origin of punctuality at the International Research Center for Japanese Studies in Kyoto. The outcome of this collaborative research was published as a collection of papers from the participants as *Chikoku no Tanjō* (*The Birth of Tardiness*) from Sangensha in 2001.

My interest in time and work discipline led to the study of the history of the traditional Japanese clocks called *wadokei*. The research on wadokei was done as a part of a large research project, titled "Edo no Monozukuri (Inventions of the Edo Period)," supported by the Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science. The "Edo no Monozukuri" project produced numerous findings from a wide variety of archival investigations into mathematics, science, engineering, and medicine in the Edo period, whose results are now in gradual process of publication.

The last three chapters on the university-industry cooperation in postwar Japan resulted from my participation at a scholarly symposium on this theme. The symposium was organized by science-policy scholars Fumio Kodama and Lewis Branscomb, in collaboration with Japanese and American experts in economics and policy studies. As a historian, I contributed a paper on the history of the apparently inactive and non-existing collaborative relationship between academic and corporate engineers. I have subsequently pursued this historical problem, and tried to examine the important roles of less commercial relationships. But the papers contained in this last part are still exploratory in nature and by no means comprehensive in scope. Readers interested in the postwar Japanese science and technology should consult the more comprehensive work consisting of four volumes, *A Social History of Science and Technology in Contemporary Japan*, edited by the historians of science and technology Shigeru Nakayama, Kunio Goto, and Hitoshi Yoshioka; as well as the above-cited *Encyclopedia of the History of Industrial Technology in Japan* and *Sengo Nihon no Gijutsu Keisei: Mohō kara Sōzō e* (*The Formation of Technology in Postwar Japan: From Imitation to Creation*), edited by Tetsuro Nakaoka. The innovative and engineering activities of corporate engineers in postwar Japan were, however, not sufficiently covered in these volumes. More scholarly research needs to be done on this all-important theme in the history of technology in postwar Japan.

Lastly, it is noted that all the Japanese names cited throughout this volume are ordered as the personal name first, the family name second, contrary to the original order of Japanese names.

February 2009

Takehiko Hashimoto

Acknowledgments

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I. Mechanical Clocks and the Origin of Punctuality

1

Japanese Clocks and the Origin of Punctuality in Modern Japan

Reprint of "Japanese Clocks and the History of Punctuality in Modern Japan," *East Asian Science, Technology, and Society: An International Journal*, 2 (2008): 123–133.

In his *Machines as a Measure of Man*, Michael Adas discusses Westerners' encounters with non-Westerners since the modern period and how Westerners have viewed themselves and others through the historical process.[1] In following closely their encounters in Africa, India, and China, he makes an interesting reference to their puzzling experiences concerning the different sense of time between cultures. While Westerners were concerned with schedules, clocks and watches, non-Westerners seemed to Westerners to act as if they lacked a sense of punctuality, which gravely disrupted their schedules.

They had a similar experience when they came to Japan in the mid to late nineteenth century, when Japan started to negotiate with Western countries more substantially than before. This historical fact may puzzle many who know the punctual operation attained by Japanese social and technological systems such as home delivery service and super-express train, and the realization of this gap make them wonder about the origin of punctuality in modern Japanese history. In this chapter, I will first begin by discussing such an episode in late Edo Japan, will go on to discuss the historical implications of the change in Japanese attitudes towards punctuality through the process of its modernization, and will finally discuss how and when the Japanese have acquired and developed their concern with punctuality and speedy operation of social activities.

1. Michael Adas, *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance* (Ithaca: Cornell University Press, 1990), pp. 241–258.

1. The Frustrations of Employed Engineers

After arriving in 1857, as the Edo period was drawing to a close, Willem van Kattendyke, a Dutchman, spent two years at the naval training center in Nagasaki, where he taught young Japanese the principles of Western navigation and scientific technology. In his published memoir, Kattendyke cited a series of events to illustrate the frustrating slowness of the Japanese. For example, the supplies necessary to make repairs, which he had specifically ordered to be delivered at high tide, didn't arrive on time, one worker showed up just once and never returned, and a stableman spent two whole days going around to make his New Year's greetings. In his diary, Kattendyke lamented that while the Japanese were extraordinarily polite and modest, they had disappointed him in various respects, and he despaired that he would leave the country having accomplished much less than he had hoped.[2]

Kattendyke's frustrations were in fact shared by many foreign engineers in Japan in the latter half of the nineteenth century. They often found themselves vexed by the work habits of the Japanese, and the main reason for their vexation was the apparent lack of any sense of time. To these foreigners, the Japanese worked with an apparent indifference to the clock.

Despite Kattendyke's concerns, today in Japan trains depart and arrive punctually, factories economize their use of time and supplies to the absolute limits, and clocks that are precisely synchronized to the official time via radio signals are now sold. We now take it for granted that we and others act punctually, and we know this is the fundamental premise for the smooth and safe operation of modern society. But nothing like this common behavior existed in Meiji Japan. The fact of this lack of punctuality in nineteenth century Japan leads us to wonder: when and how did Japanese citizens come to acquire modern time discipline over the course of the past century and a half?

This chapter cannot and will not, however, provide an analytical

2. Willem J.C.H. van Kattendyke, *Uittreksel uit het dagboek; gedurende zijn verblijf in Japan in 1857, 1858 en 1859* ('s Gravenhage: W.P. van Stockum, 1860), trans by Nobutoshi Mizuta, *Nagasaki Kaigun Denshujo no Hibi* (Tokyo: Heibonsha, 1964), chapter 8.

argument on this large question about Japanese history. It will rather provide a summary of the current scholarly arguments in addition to an opening footnote on the time system and clocks developed in the period prior to the Meiji Restoration.

2. **Wadokei** *and the Seasonal Time System in the Edo Period*

Until 1873, five years after the Meiji Restoration, daily life was framed by the variable hour system of seasonal time.[3] In contrast to the system of fixed hours, which follows the movements of the clock and divides the entire day into hours of equal length, seasonal time divides the day into day and night, and divides each of these separately into equal time units. In the Edo period, daytime and nighttime were divided into six partitions called koku, and each of these partitions was marked by the ringing of the official gong.[4]

Prior to the spread of mechanical clocks in the fifteenth century, seasonal time was also the standard in Europe. But the emergence of the mechanical clock in the fifteenth century gradually and radically changed European society and their fundamental attitude toward time. However, the introduction of the mechanical clock to Japan in the late sixteenth century did not lead to the same reorganization of its time system or the change of its society. On the contrary, the mechanical clock was adapted to the Japanese seasonal time system.

Known now as *wadokei*, or Japanese clock, the mechanical clock in the Edo period was ingeniously crafted to designate seasonal time.[5]

3. On calendar reform in Meiji Japan, see Yoshiro Okada, *Meiji Kaireki: "Toki" no Bunmei Kaika* (*The Meiji Reform of the Calendar: "Time" and the Movement for Civilization and Enlightenment*) (Tokyo: Taishukan Shoten, 1994).
4. On the history of systems of tracking time from ancient Japan to the present, see Manpei Hashimoto, *Nihon no Jikoku Seido* (*The Japanese System of Hours*) (Tokyo: Hanawa Shobō, 1966).
5. On Japanese clocks, see N.H.N. Mody, *A Collection of Japanese Clocks* (London: Kegan Paul, 1932); Ryuji Yamaguchi, *Nihon no Tokei* (*Clocks in Japan*) (Tokyo: Hyōronsha, 1950); Taizaburo Tsukada, *Wadokei* (*Japanese Clocks*) (Tokyo: Tohō Shoten, 1960); and, for a more recent scholarly article, M.P. Fernandez and P.C. Fernandez, "Precision Timekeepers of Tokugawa Japan and the Evolution of the Japanese Domestic Clock,"

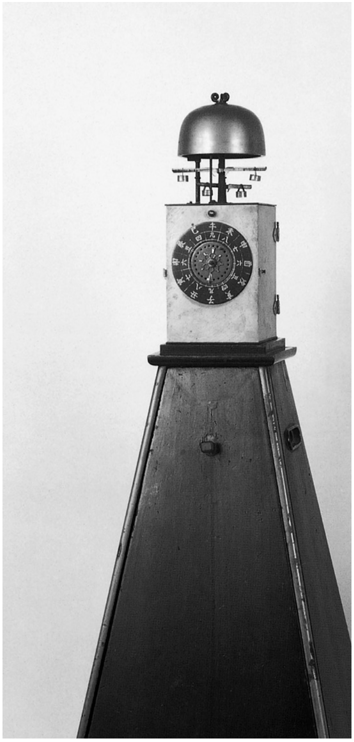

Figure 1.1
A Japanese clock of the type with two foliots (*nichō tempu type*). This is also called "yagura dokei (tower clock)," because of its tall trapezoidal stand encasing its descending weights to drive the clock mechanism.

There are several types of *wadokei* in existence today, of which I refer to the following three basic types: the first type with two variable foliots, the second with movable plates on the face, and the third with a graphical plate and a descending indicator. The first type has two oscillating foliots, or horizontal bars, on the top of the clock, each of which moves and stops alternately during the daytime and nighttime (See Figure 1.1). Pallets are hung in a position on the teeth of each foliot such that their oscillating period is tuned to the variable hour of the seasonal time system. The hand on the face of the clock rotates at different speeds in the daytime and the nighttime. The second type has a face with movable plates, and these movable plates are adjusted fortnightly to such that their positions indicate the seasonal time. In most clocks of this type, these plates are manually repositioned, although in a few exceptional cases they are automatically moved by an internal mechanism.[6] The third

Technology and Culture, 37(1996): 221–248.

6. The mechanism of a warikoma clock is quite simple and uses an eccentric circle and a comb-like sliding plate. See Katsuhiro Sasaki, et al., "Wadokei niokeru Futeijihō Jidō Hyojikikō (Automatic Mechanism to Indicate Seasonal Time in Japanese Clocks)" *Bulletin of the National Science Musuem*, Tokyo, series E, 28(2005): 31–47. Another type of automatic mechanism for the *warikoma* clock was devised by the famous inventor of

type is furnished with a replaceable plate of indicating lines showing the seasonal time. Its mechanism is simple and its price is generally much lower than other types, presumably several *ryō*, or several hundreds thousand yen. Most mechanical clocks were only available to the rich and powerful, but the emergence of the economical and less decorative type indicates that there was some demand for mechanical clocks in the general society, possibly by merchants for their practical use in knowing the precise time.

But even people possessing a mechanical clock which indicated seasonal time could have known only much less precise measure of time than contemporary Western citizens. Average citizens who reckoned time through hearing gongs every two hours had a still more crude sense of time. But as the systems of modern social organization were introduced during the Meiji period, this crude sense of time underwent radical change.

3. Enforcement of Punctuality at Modern Institutions

How, then, did the Japanese come to acquire a sharper sense of time over the past century and a half? How did they come to acquire and take for granted punctuality? How did they come to pursue efficiency and productivity? To investigate this broad problem, a collaborative and interdisciplinary study was organized for the academic year of 1999 and 2000 at the International Center for Japanese Studies in Kyoto. The study resulted in a collection of papers titled *Chikoku no Tanjō* (*the Birth of Tardiness*).[7]

Prior to the launch of this collaborative research project, the organizers had naturally assumed that several modern institutions introduced

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automata, Hisashige Tanaka, who is also known as "Karakuri Giemon."

7. Takehiko Hashimoto and Shigehisa Kuriyama, eds., *Chikoku no Tanjō: Kindai Nihon ni Okeru Jikan Ishiki no Keisei* (*The Birth of Tardiness: The Evolution of Time-Consciousness in Modern Japan*) (Tokyo: Sangensha, 2001). The book was translated by Shigehisa Kuriyama and James Baxter into English and published as a special issue of *Nichibunken Japan Review*, no. 14 (2002) with the title "The Birth of Tardiness: The Formation of Time Consciousness in Modern Japan."

from the West must have worked to facilitate the implementation of punctual and efficient behavior. Of them, three key institutions—schools, factories, and railroads—were investigated. Since the early Meiji period, punctuality has been strongly encouraged at these institutions. For new primary school students, for instance, the Ministry of Education issued the *Seito Kokoroe* (*Direction to Elementary School Children*) in 1873 with the following precepts:

> Make sure that you are at school ten minutes before the start of class every day.
> If you are late for school, do not enter the classroom without permission; explain the reason for your tardiness and wait for your teacher's instructions.[8]

These were explicit and fairly strict instructions for innocent children. They were issued at the time that Japan changed from its traditional calendar using seasonal time to the Western calendar using clock time; it is certainly doubtful that students actually followed the rule and attended school in time. Some episodes tell us that the reality was far from this ideal.[9] Even so, it can be conjectured that the emergence of the new school system officially emphasizing punctuality to students was highly significant in promoting punctuality in society through the creation of new generations of younger people who were at least conscious of the importance of punctuality.

Under the government's modernizing policy, the first railroad opened at the same time, and its lines were swiftly constructed with the assistance of British engineers. However, with the increase of railroad lines and complexity of their operation, the delay of trains became a problem. The following statement, made in 1901, vividly

8. Tokiomi Kaigo, ed. *Nihon Kyōkasho Taikei* (*The Collection of Japanese Textbooks*) (Tokyo: Kodansha, 1961), p. 561. The passage is cited in Ikuko Nishimoto, "Teaching Punctuality: Inside and Outside the Primary School," in *Birth of Tardiness*, op.cit., p. 123.

9. Nishimoto in her "Teaching Punctuality" cites an episode recollected by the poet Takuboku Ishikawa who had taught at a primary school in a local village of Iwate Prefecture. Ishikawa witnessed the clock in the teachers' room ran at least thirty minutes slower than the clock in the train station. Ibid., p. 129.

expresses the lamentable situation of the private railroad lines:

> Recently, trains belonging to privately owned railway companies depart or arrive late all the time. Almost all trains are behind schedule, with rare exceptions, and station staff who should give the first priority to maintaining time never seem concerned about delays, having given up on being punctual and acting as if delays were somehow inevitable. With some railways, almost no trains run on schedule, while others use timetables as a kind of hint indicating that trains will arrive behind schedule. Furthermore, delays are not a matter of a mere five or ten minutes, but rather it is unusual for them to extend up to thirty minutes or even an hour…. The cause of the delays is that Japanese, both those running the railroads and the passengers, are, owing to bad old customs, lacking the turn of mind that observes time strictly….[10]

To ameliorate the situation, railroad officials and engineers required stricter discipline from railroad workers. They constructed double-track lines, studied time and motion, and changed to the automatic coupling system throughout the entire railroad network, which was entirely new even compared with the railroad in the West.[11] And thanks to the engineer Okiie Yamashita, they succeeded in greatly reducing the time consumed for the inspection and repair of locomotives.

The factory, too, was a place where punctuality was strictly required. Punctuality has been demanded of all workers residing near the Yokosuka Arsenal since its foundation. A bird's eye view drawing of the arsenal in its early period shows a clock tower.[12] Workers living nearby knew the time from the ringing of the clock tower. Work at

10. "Hacchaku Jikan no Seisei," p. 4 in *Tetsudō Jihō* (*Railroad Journal*), no. 117(1901); Cited in Naofumi Nakamura, "Railway Systems and Time Consciousness in Modern Japan," in *The Birth of Tardiness*, op.cit., p. 30.

11. Of these modernizing systems, the introduction of the automatic coupling system is discussed in Tamio Takemura, "The Time Revolution of the Railways in the 1920s: The Impact of the Changeover to Automatic Couplers," in ibid.: 39–62.

12. Jun Suzuki, "Tokei (the Clock)" in idem, *Shin Gijutsu no Shakaishi* (*A Social History of New Technologies*) (Tokyo: Chuo Korona Shinsha, 1999).

the Arsenal started at 7 in the morning, except during the winter season, and all workers were expected to complete their preparations for work before that time.[13] Workers in factories of private corporations were also required to be punctual. In one episode, factory supervisors even delayed the clocks so that workers would work longer than the designated time.[14]

In attempting to introduce the techniques of scientific management to Japan, some experts became sharply aware that the establishment of punctuality was essential to further modernize the management of Japanese factory systems. In his effort to introduce Taylorism to a naval arsenal, Takuo Godō explicitly stated that punctuality was a premise for the introduction of more advanced scientific management, and his words implicitly indicated that Japanese workers were in reality still unfamiliar with punctual working attitudes and Japanese managers were not yet ready to introduce fully the method of Taylorism.[15] Godō, however, subsequently succeeded in introducing Taylorism to Japanese naval arsenals, as well as in introducing the technologies of the limit gauge system.

4. Punctuality and Efficiency in Ordinary Life

Through these efforts, time discipline and punctuality became well established at railroads as well as at arsenals and private factories in prewar Japan. However, while people began to act punctually in the official spaces of these modern institutions, they did not necessarily behave so in other public and private spaces. But there was an effort to do so. The movement to improve living conditions was organized and

13. Jun Suzuki, "Two Time Systems, Three Patterns of Working Hours," in *The Birth of Tardiness*, op.cit., p. 81.

14. The Ministry of Agriculture and Commerce, *Shokkō Jijō* (*Conditions of Craft Workers*) (Tokyo, 1903), revised edition (Tokyo: Iwnami Shoten, 1998), p. 237. Takehiko Hashimoto, "Punctuality and the Introduction of Scientific Management to Japan," in *The Birth of Tardiness*, op.cit., pp. 100–101; and Suzuki, *Shin Gijutsu no Shakaishi*, op.cit., p. 110.

15. Takuo Godō, "Kagakuteki Kanriho no Jissai (Scientific Management in Practice)," *Sangyo Noritsu* (*Industrial Efficiency*), 2 (1924), pp. 12–13.

promoted by the Association of the Improvement of Living Conditions, and one of its purposes was to promote punctuality and the efficient use of time.[16] The origin of this movement and this association was a series of educational exhibitions held at the Tokyo Educational Museum, the precursor of the present-day Science Museum. Exhibition topics included "The Prevention of Cholera," "The Great War (World War I) and Science," "Domestic Science," "Time," and "The Improvement of Domestic Life." They were all aimed at disseminating scientific knowledge among the wider public and emphasized the importance of precise measurement. At the same time, the promotion of the establishment of the metric system in Japan was occurring. At the exhibition of time, many posters were displayed showing how to measure the time consumed for daily activities and suggesting ways for spectators to economize their time. A poster showed, for instance, how long it took for school girls and ladies to fix up their hair; the time varied from five minutes of fixing a single plait to fifty five minutes of wearing the formal *shimada* style of hair dressing.

The exhibition also led the Association to appeal for the establishment of a Time Day to promote punctuality and efficiency. The Time Day was established on June 10, 1920, the day selected to commemorate the first use of a water clock by Emperor Tenchi in 671. The Association further published a pamphlet of moral maxims of time discipline such as "Work time and rest time must be clearly separated, and time must not be wasted."[17] The publication of such maxims indicates that a group of experts did desire to implement discipline among the general public, but it also suggests that many people behaved in the manner eschewed by the maxim; taking rests during work time and frequently being late for meetings. The pamphlet also stated, "A precise clock is the first requirement for enforcing strict punctuality," and also "A good way to set a clock precisely is by the midday cannon, or by going to the nearest telegraphy office or rail-

16. On the activity of this organization and its promotion of punctuality, see Hashimoto, op.cit., pp. 104–106.

17. Cited in The National Science Museum, ed., *Kokuritsu Kagaku Hakubutsukan Hyakunenshi* (*The Centennial History of the National Science Museum*) (Tokyo: Daiichi Hōki, 1977), p. 200.

way station."[18] Such was how clocks were adjusted in the 1920s.

In spite of all these efforts by the Association of Improving Living Conditions, it is considered that punctuality and modern time discipline was not well established in the daily lives of ordinary citizens before the war. Sakae Tsunoyama, an economic historian who has studied on the social history of time in Japan and abroad, suggests a two-layer structure on the process of the assimilation of time discipline into Japanese society. Punctuality was established in these modern institutions early on, but it was not so at other social spaces. Just when punctuality was attained at other public and private spaces is not clear.

Tsunoyama himself suggests that the assimilation of punctuality into general society took place long after the war. He speculates that the wide circulation of cheap and precise watches due to the development of quartz time-keepers was a key event in spreading punctual behavior among Japanese people.[19] Ichiro Oda, who writes extensively on the history of time and clocks, argues in his *When Did the Japanese Become Impatient*, that people became punctual in their private lives after the Second World War through the comprehensive import of American social and cultural customs into Japanese society.[20] The Land Reform, he also speculates, may have made people sharply realize the significance of the idea that "time is money." Ikuko Nishimoto, another expert in social history of time, considers the emergence of Toyota's production system, which utilizes time with extreme efficiency, to be one of the key events in postwar history.[21]

5. Sazae-san and Accelerated Japan

Concerning the postwar evolution of people's conception of time, I would like to refer to some cartoons. It is "Sazae-san," a popular

18. Loc.cit.
19. Sakae Tsunoyama, *Jikan Kakumei* (*Revolution in Time*) (Tokyo: Shinshokan, 1998).
20. Ichiro Oda, *Nihonjin wa Itsukara Sekkachi ni Nattaka* (*Since When Did the Japanese Become Impatient?*) (Tokyo: PHP Research Institute, 1997).
21. Ikuko Nishimoto, "'Harmony' as Efficiency: Is 'Just-in-Time' a Product of Japanese Uniqueness?," *Time and Society*, 8 (1999): 119–140.

comic strip, which ran in the Asahi Newspaper for 25 years from 1949 to 1974. The cartoon was the continuing story of a family of elderly parents and three children, of whom the eldest sister, Sazae-san, lived with her husband and baby. Hasty and careless Sazae-san, mischievous Katsuo, innocent Wakame, and other family members formed a comic episode each day.

Of about five thousand episodes, I identified forty or fifty having to do with time, punctuality, and speed, and which are considered to reflect fairly well the ideas and perceptions of the day. Of them, I would like to discuss five strips that ran between 1952 and 1971. The first one, published in 1952, was about a new "speedy weaving machine" which Sazae-san's neighbor had just purchased.[22] Sazae-san was attracted to this new machine and visited the neighbor with her wool strings. But she spent the time idly talking with her friend and came back home with nothing done with her wool strings. A speedy machine was not usefully employed in a slow going society.

The next three strips were concerned with the introduction of electric appliances in the home. Of these three, the first piece, published in 1957, opened with Sazae-san's younger sister Wakame mistakenly saying that the family had purchased a vacuum cleaner, which intrigued their neighboring housewife.[23] But it turned out, to Sazae-san's shame, that they only had a hand-cleaner with a wiper. The next piece of interest, published in 1962, was about a neighboring couple who completed their collection of all the basic appliances by buying their final piece—an audio set.[24] The four neighbors, including Sazae-san, were all envious and imagined a worn-out husband, which turned out to be true. The third piece, published in 1966, showed that electric appliances were furnished at Sazae-san's home and consequently freed her from much of her household work.[25] With free time

22. Machiko Hasegawa, *Sazae-san*, vol. 10 (Tokyo: Asahi Shimbunsha, 1995), p. 72. The comic strips of *Sazae-san* were first reproduced and published from Shimaisha, and later republished as small pocket-sized version from Asahi Shimbunsha. I have used the version of Asahi Shimbunsha.

23. *Sazae-san*, vol. 17, p. 55.

24. *Sazae-san*, vol. 24, p. 57.

25. *Sazae-san*, vol. 34, p. 1.

on her hands, she decided to work as a maid at a wealthy home. In this strip, labor-saving machines were usefully employed, thus letting their user spend the saved time earning a supplementary income.

The fifth piece of interest was published in 1971 and showed a scene where Sazae-san's father Namihei and three other elderly persons gathered to form a Society of Slow Life, pasting on the wall their motto "Don't rush, Japanese!" The members heartily agreed on the policy, so they promptly volunteered for a job and ran away to get their job done.[26]

The connotations expressed by these comical stories clearly and decisively changed from 1952 to 1971. The contexts within which these stories were told shifted from a slow to a fast moving society. I encounter comics picturing the need for punctuality, a preference for the economical use of time, and a growing concern about speed and stress. The period from the late 1950s to the late 1960s was the time when many electric appliances—refrigerators, vacuum cleaners, and TV sets—were added to Japanese homes. This was also the time when the Japanese constructed highways and Shinkansen. Finally, this was the time when the government planned and achieved the doubling of the average income of its citizens. It would be reasonable to suppose that time meant money to the Japanese more than ever in this period, and that they were forced to be time conscious to increase their income.

In her recent book on the social history of time in modern Japan, Nishimoto also discusses the acceleration of social activities in the 1960s.[27] Her attention particularly focuses on the production as well as the use of automobiles. Toyota Automobile Company notably introduced its just-in-time system designed to minimize the stock of parts and maximize the economic efficiency of production. Images and words associated with high speed were used to make advertisements that attracted consumers. She reminds readers that the highway from Tokyo to Kobe was completed in 1969, and that scenes

26. *Sazae-san*, vol. 42, p. 51.

27. Ikuko Nishimoto, *Jikan Ishiki no Kindai: "Toki wa Kanenari" no Shakaishi* (*Modernity in Time Consciousness: A Social History of "Time is Money"*) (Tokyo: Hosei University Press, 2006), chapter 7.

of the highway in Tokyo were used in the 1972 Russian SF movie, "Solaris," to represent a futuristic city.

6. Conclusion

This chapter began with the attention to the puzzling problem of punctuality in Japanese history. Many foreigners in the Edo and early Meiji period complained about the Japanese people's apparent indifference to time as represented on the clock. But now in Japan, trains run and factories operate most punctually in the world. The observation of this radical difference from an early indifference to punctuality to the current strict adherence to it causes one to wonder about the origin of punctuality in Japanese history. As a possible explanatory answer to this question, I introduced the two-layer structure of the assimilation of modern time discipline into Japanese society. Punctuality and attentiveness to efficiency were well-established early on at such modern institutions as schools, factories, and railroads, but the daily lives of ordinary people were different until after the war. This explanation, however, will leave another question as to when and how people started to behave punctually in their daily lives in postwar Japan. As I have shown through the comic strip *Sazae-san*, we would be able to recognize the change of attitude towards time occurring from the late 1950s to the mid 1960s when the government implemented its double income policy. It may be interesting to see, from the standpoint of the social history of technology, how new engineering products transformed the perception of time among ordinary Japanese people in this age. Lastly, I would raise questions concerning similar and dissimilar situations in other countries in East and Southeast Asia. Although I referred to Adas' work at the opening of this chapter, works touching on the history of punctuality in Asia are very few, with a notable exception of an excellent work by the Taiwanese historian Liu Shaoli which discusses the history of punctuality in Taiwan during the time of Japanese occupation.[28] I believe the theme and

28. Liu Shaoli, *Shuiluo Xiangqi: Rizhi Shiji Taiwan Shehuide Shenghuo Zuoxi* (*Sound of*

related questions provide an interesting comparative perspective on the history of technology, culture, and society in Asian countries.

Steam Siren: Work and Leisure in Taiwan in the Period Occupied by Japan) (Taibei: Yuan Liu, 1998). It was translated in Japanese by Kōryū Kyōkai as *Jikan to Kiritsu: Nihon Tōchiki Taiwan ni okeru Kindaiteki Jikan Seido Dōnyū to Seikatsu Rizumu no Henyō* (*Time and Disciplone: The Introduction of Modern Time System and the Change of Rhythm of Life in Taiwan Occupied by Japan*) (Tokyo: Kōryū Kyōkai, 2006).

2

Hisashige Tanaka and His Myriad Year Clock

Reprint of "Mechanization of Time and Calendar: Tanaka Hisashige's Myriad Year Clock and Cosmological Model," *UTCP Bulletin*, 6 (2006): 47–55.

Hisashige Tanaka was a man who bridged two worlds: the world of traditional craftsmen during the Edo period and the world of modern Western engineers during the Meiji period. Well-known by his popular name, Karakuri Giemon, Tanaka invented amusing automata, the most famous of which was "yumiiri dōji," or the bow-shooting boy, who shoots arrows and smiles when they hit their target. Another famous invention was the cup-carrying doll, who carries a cup on a tray, serves it to a guest and returns to its original position. Tanaka made not only entertaining toys such as these primitive robots, but also various ingenious machines, precisely like Renaissance engineers in Europe, including a fire extinguisher, a self-pumping oil lamp and an intricate calendrical clock. Toward the end of the Edo period, the Nabeshima clan's feudal lord recruited him to construct various Western machines, including a steam engine; and he was seriously engaged in importing Western technologies before and after the Meiji Restoration.[1]

This chapter will focus on and explain one of this craftsman's masterpieces, the machine called the Myriad Year Clock (万年時計or 万歳

1. Of the several biographies published on Hisashige Tanaka's life, the most authoritative is Tanaka Ōmi Ou Ken'eikai, ed., *Tanaka Ōmi Taijō* (Tokyo, 1931), which the editorship of Kenji Imatsu has recently republished together with the additional bibliography on the literature concerning Hisashige Tanaka compiled by Imatsu. Imatsu also has written a concise but good biography of Tanaka: Kenji Imatsu, *Karakuri Giemon: Toshiba Sōritsusha Tanaka Hisashige to sono Jidai* (*The Ingenious Giemon: The Life and Times of Hisashige Tanaka, the founder of Toshiba*) (Tokyo: Daiyamondo, 1992).

自鳴鐘).[2] He built it in 1851, after he already had established his career by making various inventions, and just before he left for Saga to help introduce Western industrial and military technologies. I will explain below this clock's basic structure and mechanism, and present some findings on his inventing process based on an analysis performed by disassembling its parts. After that, I would like to explain two other models Tanaka constructed before and after this machine; they are astronomical models based on Buddhist cosmology. Before doing so, however, I first will describe briefly Tanaka's life and works, and the social milieu of his activities as an inventor. I also would like to provide a brief explanation of the Japanese time system during the Edo period, and of wadokei, the Japanese clocks devised to indicate time according to this Edo time system.

1. Life and Works of Hisashige Tanaka

Hisashige Tanaka was born in 1799 in Kurume, a clan whose area formed a part of the present Fukuoka Prefecture, as the eldest son of a craftsman of tortoise shell work who made daily and ornamental tools such as combs. His infant name was Giemon, thus he often was called Karakuri Giemon—Ingenious Giemon. After he established his fame, he was offered the official name from the Ōmi Shrine and, accordingly, was called Ōmi Taijō. He therefore is also called Tanaka Ōmi or Ōmi Taijō, as well as "Tanaka Hisashige"; all these names are used in the titles of his biographies. Several biographies, both authentic and somewhat fictitious, have been written; and they all cite episodes in his childhood testifying to his inventiveness from his early days. He surprised his friends by making a locking pen case. He helped a neighbor inventor to devise and construct a machine to weave a special type of cloth in the area he lived—*Kurume gasuri*. When he toyed around with these ingenious devices, he concentrated on making them even if it required him to stay up all night for several days straight. When he was 17, his father died. As the eldest son, he

2. See ibid., pp. 56–68.

was expected to assume his late father's position and duties, but he conceded this position to his younger brother and continued to work on mechanical various devices.

Tanaka's subsequent life as an inventor-craftsman can be conveniently divided according to his residential location. He started his career when he decided to become an inventor after his father's death. He stayed in Kurume and made various inventions. During this time, he made a grand tour making new devices, displaying entertaining toys, and learning new skills and knowledge. In 1834 he left his hometown and settled with his family in Osaka, and later in Fushimi. During this time, he opened his shop in the busy center of Kyoto, succeeded in making and selling his invented goods, and constructed the Myriad Year Clock. Immediately after its completion, the Saga clan's feudal lord invited him to visit in 1852. He then became an official engineer under Lord Nabeshima's patronage, and collaborated with other craftsmen and scholars to construct models of a steam ship and a steam locomotive, as well as artillery machines and weapons. After the Meiji Restoration, he went to Tokyo, established his own workshop, produced cutting-edge technological devices, and worked as an occasional engineering consultant for the government. A year after his death, his son-in-law opened a large factory, which became the origin of Toshiba, the present-day electronics company.

Tanaka's own biographical table notably recorded the festivals held at Gokoku Shrine five times from 1819 to 1830.[3] His frequent references to this shrine in his hometown meant that he performed shows there with the instruments he devised, and that he possibly earned money depending on how crowded these festivals were. This was probably his basic means of earning a living after he left home. He earned money by displaying his toys and machines, and entertaining the people who gathered at festivals. The shop he opened in Kyoto was prosperous. Tanaka made and sold many kinds of items—toys, tools and other useful goods. During his early period, Tanaka devised an air gun and a "mujintō," or "inextinguishable lamp," both of which contained a pump as one of their components and required a

3. *Tanaka Ōmi Taijō*, op.cit., p. 3.

technique for making an airtight structure. The air gun was popular among several engineers, and was known by rulers and scholars who were interested in Western military and production techniques, notably including the steam engine. The perpetual lamp was an oil lamp with a pump to push up rapeseed oil to be burned. Like Western oil lamps and unlike Japanese candles, it had a glass cover so that its fire and light would not fluctuate. The biographer Imatsu thinks that the fluctuation of light would have disturbed intellectual activities at night in Japan, and perceptively points out that the popularity of Tanaka's "inextinguishable lamp," which provided stable illumination brighter than previous oil or candle lights, reflected an increase in nighttime activities in Japan. Here Imatsu observes Tanaka's concern with rational and efficient use of time by Japanese people.[4] Tanaka's familiarity with pumping technology is important for his later involvement in understanding and constructing steam engines.

After 1847, Tanaka expanded his interests in astronomy and clock making. That year he started to learn the theory and practice of calendar making from the Tsuchimikado family, who were officially in charge of making calendars in Edo Japan. That same year, at a certain Buddhist monk's request, he initiated the design and construction of his own version of Shumisengi, which displayed a cosmological configuration to show celestial bodies' terrestrial structure and motion.

He then engaged in constructing the Myriad Year Clock, which, of course, he did not intend to move for 10,000 years. He expected it to remain in motion for several months, which was much longer than the duration of ordinary Japanese clocks at that time, a single day. This clock was a complex system that represented time and calendar through its six faces. It represented the Western time system, the Japanese time system, the days according to both solar and weekly calendars, the year counted by the Chinese system, and the day of the lunar calendar showing the moon's shape. Atop the clock sat an astronomical model with the sun and the moon rotating above and below a map of Japan. A set of two strong and heavy springs provided the clock's driving force, and the other set of two springs drove gears to

4. Imatsu, op.cit., pp. 45–47.

chime the bell. The timekeeping piece for the whole system was a French-made watch, which was connected to the other mechanical systems. But the system's most intricate part was the block, which designated the Japanese time system.[5]

2. Clocks and Seasonal Time System in Edo Japan

The time system used during the Edo period was the so-called seasonal time system.[6] In contrast to the clock time system, which divides each day into 24 hours of equal length, the seasonal time system divides daytime and nighttime separately into hours of equal length. Japanese seasonal time divided daytime and nighttime into six units of time, called "*koku* (刻)." Each *koku* was named after one of the 12 horary animals, from rat (子) to boar (亥). Each *koku* also was numbered in a rather unusual manner. Midnight, or the time of the rat, was numbered nine; the next *koku* was eight; the next was seven; the time of dawn was six; down to five, four and three, which was the last *koku* before noon. Noon was numbered nine, just like midnight; and the same numbering proceeded through the afternoon and evening. The crucial times in this seasonal time system were the times of boundary between daytime and nighttime. These boundary points in time, at dawn and dusk, were pragmatically defined as the times when three lines on a human hand became visible or invisible. Astronomers and calendrical experts precisely defined these chronometrical points as 36 minutes, or 1/40 of a day, before sunrise and after sunset. These experts used their own unit of time, which was also called a "*koku*," but which differed from the previously and ordinarily used *koku*. They divided 24 hours into 100 units; 36 minutes equaled 1/40 of a day, or 2.5 *koku*.

5. On the Myriad Year Clock, see Tei-ichi Asahina and Sachiko Oda, "'Myriad Year Clock' Made by G.H. Tanaka 100 Years Ago in Japan," *Kokuritsu Kagaku Hakubutsukan Kenkyū Hōkoku*, no. 35 (1954). The paper is a report of their investigation of the clock in 1969.
6. On the traditional timekeeping system in Japan, see Manpei Hashimoto, *Nihon no Jikoku Seido* (*Time System of Japan*) (Tokyo: Hanawa Shobō, 1994).

Japanese astronomers and calendrical experts further refined this definition at the end of the 18th century. At that time, they attempted to introduce Western astronomical theories to improve present calendars and, as a result, they proposed and adopted a new calendar called "Kansei reki (寛政暦)." This calendar defined the beginning and end of daytime, or "akemutsu (明六)" and "kuremutsu (暮六)," respectively, as the times when the sun was positioned 7 degrees, 21 minutes and 36 seconds below the horizon. Alterations of the definition arose because of astronomical considerations; the sun's angle and rate of descent differ from season to season. The astronomers deduced this fragmented number for the sun's position from the sun's position at equinoctical time and Kyoto's latitude. The new definition more precisely corresponded to the brightness of the twilight sky than the previous definition, but required calculations that were considerably complex for ordinary people.[7]

On a calendar, these defining points changed only 24 times each year, at the time of the turning of seasonal points called *sekki* (節気), or at the beginning and middle of each lunar month. The table attached in the Appendix shows the length of daytime counted by the astronomical unit, *koku*, according to three calendars: 1777, 1800 and 1844.[8]

How, then, can the clock be adjusted to this seasonal time system? Clockmakers devised several different types of clocks for this purpose during the Edo period.[9] The most notable methods were the "tempu" and "warikoma" methods. The first used two oscillating foliots, or horizontal bars, on the top of the clock, each of which moved and

7. On the definition of akemutsu and kuremutsu, see Takehiko Hshimoto, "Kanseireki to Wadokei: Yoake no Teigi o Megutte (Kansei Calendar and Japanese Clocks: Concerning the Definition of Twilight)," *Tenmon Geppo*, 98(2005): 373–379.

8. I have consulted the calendars of each year from those preserved at Seiko Tokei Shiryōkan (Seiko Institute of Horology) in Mukōjima, Tokyo.

9. On the history of Japanese traditional clocks, see Ryuji Yamaguchi, *Nihon no Tokei* (*Clocks in Japan*) (Tokyo: Nihon Hyoronsha, 1950), whose second version was published in 1942; Taizaburo Tsukada, *Wadokei* (*Japanese Clocks*) (Tokyo: Toho Shoin, 1960); Sachiko Oda, ed., *Seiko Tokei Shiryōkan Zō Wadokei Zuroku* (*A Pictorial Record of Japanese Clocks Preserved at the Seiko Institute of Horology*) (Tokyo: Seiko Institute of Horology, 1986), which visually and textually explains various different types of *wadokei.*

stopped alternately in the daytime and nighttime. The pallets were hung in a position on the foliot's teeth so that their oscillation period would be tuned to the varying hours of the seasonal time system, and this position changed bimonthly when *sekki* changed. The hands on the clock's face rotated at different speeds during the daytime and nighttime.

The second, or "warikoma," type had a face with movable plates, which were also repositioned by users or clock makers bimonthly so that they would indicate the seasonal time. Almost all these *warikoma*-type clocks were manually adjusted. An exception has been discovered recently in the storage area of the Takekawa family, located near Matsuzaka, south of Nagoya, which was in the former area of Kishū. The clock has a mechanism that could automatically adjust these movable plates to designate seasonal time. This mechanism has turned out to be fairly simple, using an eccentric circle and a comb-like sliding plate; but it has no similarity with any mechanism used in clocks or other machines.[10]

3. The Japanese Clock of the Myriad Year Clock

Another exception is Tanaka's Myriad Year Clock (Figure 2.1). It had a face of the *wadokei* or *warikoma* type which has an automatically movable mechanism. The mechanism differed significantly from the one discovered recently. Curators of the National Science Museum had investigated the mechanical details of this clock twice, in 1949 and 1969. In 2004, a new project was organized to disassemble and make a replica of this clock. The work of disassembling the machine and measuring its parts' sizes was done by scholars at the National Science Museum and former clock-making engineers of Seiko Company. These examinations have clarified its basic mechanism more precisely than the previous investigations. Like the

10. Katsuhiro Sasaki, Takehiko Hashimoto, Hideo Tsuchiya, Katsuyuki Kondo, and Kazuo Okada, "The Mechanism of Automatic Display for the Temporal Hour in the Japanese Clocks," *Bulletin of the National Science Museum*, ser. E, vol. 28 (2005): 31–47.

Figure 2.1 Hisashige Tanaka's Myriad Year Clock
(Photo by the author)

It has six faces on its side, including the Western clock and the Japanese *warikoma* type clock as seen on the photo, and a solar and lunar model on its top. The Japanese clock has a mechanism inside to move automatically *warikomas* on its face.

Takekawa family's clock, Tanaka's clock's own internal mechanism automatically slid its movable plates to their proper positions; but the mechanism is significantly more intricate than the Takekawa clock's. Making the plates move required the conversion of daily or hourly

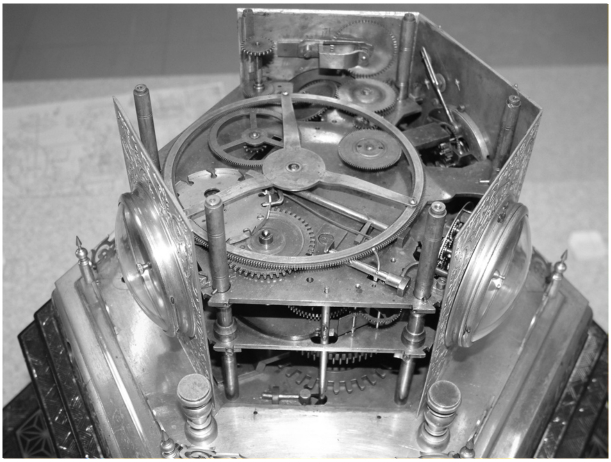

Figure 2.2 Complex mechanism inside the Myriad Year Clock (Photo by the author)

The conspicuous silver large wheel has 365 teeth to produce annual rotation. The three arms to support the wheel are slightly bent, apparently because its center had to be finely adjusted after it had been made. The lower right face displays the Japanese clock in front, and holds intricate encased mechanism behind.

rotational motion to annually oscillating motion. Tanaka used 10 tiny sun-and-planet wheels, an insect-shaped cog and special gears with teeth on only one of their sides. The last two elements converted rotational movement into oscillating, semicircular rotations; and the first ones converted these semicircular oscillations into linear oscillations.

Close analysis achieved by disassembling the Myriad Year Clock's parts at the skilled hands of former Seiko engineers has disclosed the hidden characteristics of its mechanical construction: certain errors in gear ratio, redundant holes pierced in the *warikoma* clock's base plate, and traces of hand grinding the small teeth on a sub-millimeter scale. Although many of Tanaka's notebooks have been lost, one of his surviving sketchbooks shows three shaded figures, each precisely delineating the crucial comb-shaped component found in Takekawa's *warikoma* clock.[11] No other related components such as spokes or rails are drawn in the sketchbook. We conjecture that the remaining redundant holes and the shaded figures of crucial parts of the automatic warikoma clock suggest that Tanaka might have considered the use of a mechanism such as the one used in Takekawa's clock, with the comb-shaped plate; but eventually gave up on the idea to employ a far more complicated, but fragile, mechanism.

Observers of the disassembled components of the Myriad Year Clock would be amazed by the extraordinary complexity of the whole mechanism and the very finely manufactured gears (Figure 2.2). The components numbered just over 1,000, far superior to and far more complex than ordinary Japanese clocks. Tanaka's ability to design this whole complex system in a limited space, surpassed any other craftsmen in Japan. They would also be impressed with the precise processing of the fine gear teeth. All these gears, small and large, were constructed by hand. However, we are totally uncertain about the tools used by Japanese clockmakers, including Tanaka. Obviously, he must have used a file thin and fine enough to process a brass tooth a millimeter wide; and he must have noticed the great limitations of hand processing and the need for a machine tool for such precision manufacturing. Indeed, he introduced foreign-made machine tools for constructing mechanical parts such as screws.

How precisely did this clock designate time according to the seasonal time system used during the Edo period? As mentioned above, the beginning and the end of the daytime, *akemutsu* and *kuremutsu*, were defined as the times when the sun was 7 degrees and 22 minutes or so below the horizon; and this point in time corresponded, on the equinoxes, to 36 minutes (2.5 *koku*) before and after the sun passed the horizon. This length of time (1/40 of a day) corresponds to an angle of nine degrees (1/40 of 360 degrees). The inner mechanism of the Myriad Year Clock's *wadokei*, however, designates an angle slightly larger than this (10–11°, which corresponds to 3 *koku* instead of 2.5 *koku*) for the position of both the *akemutsu* and *kuremutsu*. Memos

11. *Tanaka Ōmi Taijō,* op. cit. contains the list of archival sources of Hisashige Tanaka, but many of them were destroyed by the Great Kanto Earthquake in 1923. The Edo Tokyo Museum presently preserves several remaining sources of Hisashige Tanaka.

from the previous disassembling investigation of the Myriad Year Clock also indicate that scholars were concerned with this specific value and recognized its discrepancy from the theoretical value.

This small discrepancy, however, had good reasons behind it. Tanaka stated in his advertisement for this clock that the daytime of summer solstice lasted for 66 *koku*, which was rounded up from the length designated by the calendar, a little more than 65 1/2 *koku*. The daytime on the winter solstice lasted for 46 *koku*, and therefore the value halfway between the two solstices is 56 *koku*. This value of 56 *koku* means that 3 *koku* are additional twilight during the morning and evening. Why does the mean value between the two solstices differ from the value according to the original definition of twilight's duration on the referential seasonal days of the year? This is because precise equinoxes are not exactly between the two solstices, but are a few days closer to summer solstices than to winter solstices in the northern hemisphere. In fact, equinoxes on Japanese calendars were not designated as true equinoxes until the calendric reformation of the Tempo years at the end of the Edo period. Tanaka's clock, therefore, quite accurately indicated Japanese time. In fact, it indicated seasonal time more accurately than calendars did, because its mechanical device changes the length of daytime continuously throughout the year; whereas calendars were officially designed to change it only bimonthly, at the time of each *sekki*.

What happened to the Myriad Year Clock after its completion? It was intricate and far more complicated than other Japanese clocks. He tried to sell it to a feudal lord or a wealthy merchant, but nobody dared to purchase it. It is said that a lord wanted to get it, but his men persuaded him not to because it appeared to be extraordinarily expensive. Tanaka intended to make and sell more than one Myriad Year Clock, but he could make only one. After the Saga clan recruited him, he geared his ingenuity toward industrial engineering to construct tools, instruments and machines for useful purposes, rather than entertaining aims. After the Meiji Restoration, he came to Tokyo to set up a new factory to construct and sell telegraphic devices and other modern machines.

4. Tanaka's Astronomical and Cosmological Models

Tanaka's Myriad Year Clock has a model above the clock system to represent solar and lunar motions. This astronomical model defined the beginning and end of daytime as the points in time when the sun was a specific angle below the horizon. The model consists of a rotating sun and moon, and a hemisphere that represented the earth, whose circular top face depicted a Japanese map. The sun and moon rotated to go below the earth, moving between this earth-representing hemisphere and the outer hemispherical bowl, which had a ring located 7 degrees and 22 minutes below the horizon represented by the inner hemisphere's plane. In his advertisement to this clock's potential users, Tanaka explicitly said that this ring represented the twilight boundary between daytime and nighttime (晨昏際), which meant that when the sun passed this point on the east side, daytime begins, and on the west side, daytime ends. The model clearly indicates that Tanaka learned the definition of twilight from the Kansei Calendar, and therefore probably also learned about the astronomical mechanism and structure behind the basic astronomical phenomena of daily solar and lunar motions.

Before he constructed the Myriad Year Clock, Tanaka was asked by a monk to make a clock-working Buddhist cosmological model, which was called "shumisengi (須弥山儀)."[12] The model represented a flat earth with a large central mountain and two astronomical bodies circling above the mountain. The mountain, shumisen, was supposed to be located at the center of the earth, and our world was located at the eastern quarter of this mountainous geographic square representing the earth. Outside the earth are seas with bits of small islands, and beyond the seas is a golden ring representing "konrinzai (金輪際)." The Buddhist monk Kanchū (環中), who was a disciple of the noted monk Entsū (円通), asked Tanaka to make this machine. Entsū had his own *Shumisengi* and walked around Japan teaching Buddhist cosmology and refuting the heliocentric cosmology recently introduced

12. See Kazuhiko Miyajima, "Shumisengi to Shaku Entsū no Uchūkan (The Cosmology of Shumisengi and Shaku Entsū"), *Wadokei,* nos. 7–9 (1988).

from the West. When Kanchū approached Tanaka and asked him to construct a pedagogical model to explain Buddhist cosmology, Tanaka apparently promptly accepted the monk's request. Tanaka indeed subsequently constructed several such models to represent Buddhist cosmology, some of which were replicas of the first model, and others were compact versions.

After the Meiji Restoration, another Buddhist asked Tanaka to construct a different version of a mechanical model that he intended to represent not only Buddhist cosmology, but also an epistemological theory to defend that cosmology. Unlike other cosmological models, it does not explain its cosmological structure to its viewers. It had a conspicuous helical spiral tapering down toward the main disk. On the main disk's plane are four spheres, each of which represents one of the four worlds corresponding to the four continents. The top of the spiral was a ring to guide the daily motions of the sun and the moon, and the ring was supported by a 40 cm high pole erected at the center of the disk.

The man who ordered this model was Kaisuke Sada, who wrote the booklet, "Description of the Model to Represent the Equivalency of the Visual and the Real (視実等象儀記)."[13]In it, he explained the model's structure and the philosophical reasons behind this unusual structure. He first stated that visual appearance did not represent nature's real structure. The daily rotation of the sun, moon and stars seemed to suggest their rotation around our world and our world's spherical structure. But another entirely different structure, which this model represents, would also reproduce the same astronomical appearance that our eyes see when we are standing on the earth. The sun and the moon were rotating high above the earthly ground, not around the earthly globe; and to our eyes, the rotation around the stellar ring above us should seem to appear as rotary motion around a smaller sphere on the continental ground. His explanation of this perceptual mechanism is, however, unintelligible to us. It is hard to understand what he argued about the visual equivalency of the stellar objects around the ring above and around the small sphere below, on the

13. Kaisuke Sada, *Shijitsu Tōshō Giki* (Tokyo, 1877).

ground.

Setting aside this basic problem, readers might wonder how the argument about these two systems' visual equivalency leads to an argument for the plausibility of one over the other. Sada cited here the recent news about the exploration to the north pole to refute the cosmological model and assume the earth as a spherical globe. It took explorers starting from a high latitude much longer than they expected to get to the north pole. Sada calculated from the time they took to arrive at their destination that the distance from this geographical point to the north pole was much longer than indicated by the simple assumption that the earth was a sphere, and used this calculation as evidence to assume that the earth was, in fact, a vast plane. He subsequently cited, rather anachronistically, ancient Chinese cosmology, "Gaitianshuo(蓋天説)," which presupposed the flatness of the earth and the celestial hemisphere over it.

We do not know how Tanaka considered this Buddhist cosmology and Sada's epistemological reasoning. He was a close friend of a Dutch-educated Japanese scholar, Genkyō Hirose, and knew Western science and technology well. It is therefore safe to assume that he accepted Western cosmology, based on which Westerners developed all the science and technologies that enabled them to make their world-wide commercial and military activities. Philosophical arguments that criticize the epistemological basis of the scientific theories developed in Sada's treatise might have not been a concern for Tanaka the technologist, whose interest more and more focused on modern Western technology such as steam engines, weapons and telegraphy.

Appendix

The table of the length of daylight in 24 seasonal periods according to the three calendars published in 1777, 1800 and 1844.

明け六つ 〜暮れ六つの時間	1777 年 （文政 2 年）	1800 年 （寛政 12 年）	1844 年 （天保 15 年）
1 月		48.75	48.75
1 月中	49.5	50.75	50.5
2 月	52.5	53	52.75
2 月中	55	55.25	55
3 月	57.5	57.75	57.5
3 月中	60.5	60	59.75
4 月	62.5	62.25	62
4 月中	63.5	64	64
5 月	64.5	65.25	65.25
5 月中	65	65.75	65.75
6 月	64.5	65.25	65.25
6 月中	63.5	64	64
7 月	62.5	62.25	62
7 月中	60.5	60	59.75
8 月	57.5	57.75	57.5
8 月中	55	55.25	55
9 月	52.5	53	52.75
9 月中	49.5	50.75	50.5
10 月	47.5	48.75	48.75
10 月中	46.5	47.25	47
11 月	45.5	46	46
11 月中	45	45.75	45.75
12 月	45.5	46	46
12 月中	46.5	47.25	47

The unit of the numbers in the table is the astronomical *koku*, 1/100 of a day. On calendars, the length of daylight between akemutsu and kuremutsu is rounded: The fraction of half was designated by *amari* (余) on calendars, and is conveniently expressed as 0.25 in the table above. On the oldest calendar, mid-February (2月中) represented the spring equinox, and the three calendars designated the length of daytime as 55, 55.25 and 55 *koku*, respectively. These numbers' difference from the number 50, half length of the day, signified twice the twilight's duration, 2 × 2.5, in the morning and evening. The calendar from 1800, which was the Kansei Calendar, adopted the equal division method (平気法), dividing a year into 24 equal lengths. This method, however, set the day of the two equinoxes somewhat nearer to the summer solstice than to the true equinox because of the sun's elliptical orbit, which caused the additional fraction of 0.25. The following 1844 calendar, which was the Tempo Calendar, changed again to a round number, because it adopted the fixed division method (定気法), which divided the year according to the sun's position in relation to the zodiac.

II. Roles and Visions of Foreign Engineers

3

Introducing a French Technological System
The Origin and Early History of the Yokosuka Dockyard

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When we discuss the all-important question of technology in the modernization of Japan, reference to the Dutch or the British connection is usually in order.[1] Before Japan opened its doors to the outside world at the end of the Edo period, contact with the West was mainly through the Dutch at Nagasaki. It was primarily via this connection that Western writings, including military and industrial treatises, entered the country. After the Meiji Restoration in 1868, attention shifted from the Dutch to the more "advanced" British. Indeed, the new government relied primarily on British engineering to build a modern infrastructure. Central to this effort was *Kōbushō*, the Ministry of Public Works, which hired several hundred British engineers, some of whom served in the newly established Imperial College of Engineering, the precursor of the present School of Engineering of the University of Tokyo, where they taught—in English—a variety of engineering subjects and supervised senior theses written in English.[2]

But there was also a French connection in modern Japan, though on a more limited scale. One of the most important engineering links between France and Japan was found at Yokosuka, a city located 60 kilometers south of Tokyo and now well known as the site of a United States Naval Base. Before and during the Pacific War, the Yokosuka

1. On the modernization of Japan, see Tessa Morris-Suzuki, *The Technological Transformation of Japan* (Cambridge: Cambridge University Press, 1994).
2. Some of these senior theses are preserved at the libraries of the engineering departments of the University of Tokyo. The library of the Electrical Engineering Department, for instance, contains a complete set of senior theses, from the beginning to the present.

base housed a large arsenal as well as being the technological center of the Imperial Japanese Navy.[3] The origin of the arsenal extends back to the Yokosuka Dockyard, founded at the end of the Tokugawa era and designed and constructed by French naval engineers.

The planning, construction, and early management of the Yokosuka Dockyard were all conducted under the directorship of a young French naval engineer, François-Léonce Verny. What Verny achieved in Japan was not only the construction of a dockyard and related manufacturing facilities but also the establishment of the whole technological complex necessary for the operation of a shipbuilding enterprise—the establishment of supply networks, iron foundries, an engineering school, and so on. In other words, Verny introduced and implemented an entire technological system of naval construction, and he did so, albeit on a small scale compared with the burgeoning development after the Meiji Restoration, several years before British engineers arrived on the scene.

An important feature of the dockyard in its early history was the existence of a school, where prospective engineers were instructed in basic mathematics and science as well as engineering subjects. Graduates from this school went on to form an important group of naval engineers who were instrumental in the development of the Imperial Japanese Navy as it prepared for war against China and Russia at the turn of the twentieth century.

Before turning to the history of the dockyard, a few words should be addressed about the name of this institution. The word *seitetsusho* 製鉄所 as in *Yokosuka Seitetsusho*, the original name of the dockyard, now means an ironworks, but it then had a broader meaning, implying a factory producing machines made of iron and other materials.[4] Although the *Yokosuka Seitetsusho* had such a factory with machine tools, its obvious and primary purpose was to build and maintain modern ships. In 1871 its name was changed to the more suitable

3. On the technological significance of the Yokosuka Arsenal, see Kōzō Yamamura, "Success Ill-gotten?: The Role of Meiji Militarism in Japan's Technological Progress," *Journal of Economic History,* 37 (1977): 113–135.

4. Jun Suzuki, *Meiji no Kikai Kōgyō* (*The Machine industry in the Meiji Era*) (Kyoto: Minerva Shobō, 1996), p. 50.

Yokosuka Zōsenjo (Yokosuka Dockyard) and, in 1903, to *Yokosuka Kaigun Kōshō* (Yokosuka Naval Arsenal).[5] However, throughout this chapter, I will refer to it as the Yokosuka Dockyard.

The Origin of the Yokosuka Dockyard

The introduction of Western technology to Japan mainly revolved around military exigencies. After the news reached Japan of China's defeat at the hands of the British in the Opium War, the Tokugawa government and powerful clans grasped the implications of what had happened, and attempted to introduce advanced Western military technologies and related knowledge and techniques.[6] The Saga, Satsuma, and Mito clans in particular led the scramble to construct and operate furnaces to cast iron and factories to produce machinery of various kinds.

The appearance of the fleet of United States Commodore Matthew Perry off the coast of Uraga in 1853 accelerated the pace of these modernizing efforts. After Perry's arrival, the Tokugawa government became more serious about Western military-related technology, and in this connection it lifted the two-centuries old ban on building sea-going vessels, and even went so far as to encourage powerful clans like the Satsuma—which were its potential rivals—to build Western-style ships. Two hundred years earlier, the Tokugawa government had forbidden local clans to build sea-going vessels having a deck and more than one mast. For two centuries thereafter, with only a few exceptions, sea-going vessels were not built in Japan.[7]

5. More precisely, the *Yokosuka Zōsenjo* was renamed *Yokosuka Chinjufu Zōsenbu* in 1889 and *Yokosuka Kaigun Zōsenjo* in 1897.

6.A remarkable figure who had studied Western artillery was Takashima Shūhan. Takashima had learned Western artillery from the German-born Philip Franz B. von Siebold, and continued to study it when he heard the news of the Opium War. He urged the government to introduce Western military technology, and was assigned the role of using Western guns. See Seiho Arima, *Takashima Shūhan* (Tokyo: Yoshikawa Kōbunkan, 1858).

7. There are many works on the history of shipbuilding in pre-modern Japan. See, among others, Kanji Ishii, *Wasen* (*Japanese Ships*) (Tokyo: Hosei University Press, 1995) and

Within a few years after Perry's arrival, several Western-style ships were built by the Satsuma, Mito, and other clans, but all turned out unsuccessful. Their failure, according to the official history of the Yokosuka Dockyard, was partly due to Japan's lack of tools and parts, even those as simple as screw nails.[8] Unable to produce screw nails, nuts and bolts, Japanese shipwrights constructed Western-style ships with ordinary nails, which caused their wooden structure to work loose and ultimately to leak in rough seas. The Tokugawa government began to negotiate and consult with the Dutch government on this matter. It first purchased two ships from them, and then in 1857 decided to set up a shipbuilding school, staffed by Dutch instructors, and a dockyard in Nagasaki.[9] Although the school was soon closed down, the dockyard continued to develop into a large factory-dockyard complex, later to be owned by the Mitsubishi Shipbuilding Company.[10]

The purchase of ships and the construction of a dockyard entailed, of course, an extraordinary large expenditure for the already ailing Tokugawa government. To compete with, and in some instances to fight against, enemy clans inside Japan, the government decided that it needed a dockyard in a place much nearer than Nagasaki. Space around the existing Ishikawajima Dockyard at the mouth of the Sumida River proved to be too constricted to permit expansion. The authorities thus launched a plan to build another dockyard in Edo Bay. To search

Hiroyuki Adachi, *Iyō no Fune: Yōshikisen Dōnyū to Sakoku Taisei* (*Extraordinary Ships: The Introduction of Western Ships and the Closed Country System*) (Tokyo: Heibonsha, 1987).

8. "The Japanese did not know of the spiral nail for industrial use, and built ships with ordinary nails. As a result, [the structure of] some ships reportedly loosened because of this." *Yokosuka Kaigun Senshōshi* (*The History of the Yokosuka Naval Dockyard*) (Yokosuka: Yokosuka Arsenal, 1915), vol. 1, p. 3.
9. On the school at Nagasaki, see Tetsuhiro Fujii, *Nagasaki Kaigun Denshūjo: Jūkyū Seiki Tōzai Bunka no Setten* (*The Nagasaki Naval Training School: A Contact Point between Eastern and western Cultures in the Nineteenth Century*) (Tokyo: Chūō Kōronsha, 1991).
10. The origin and the evolution of this dockyard, which can be contrasted with the Yokosuka Dockyard, has been analyzed in detail by Nakanishi Hiroshi, *Nihon Kindaika no Kiso Katei: Nagasaki Zōsenjo to Sono Rōshi Kankei, 1855–1899 (The Basic Process of Japanese Modernization: The Nagasaki Dockyard and Its Labor-Capital Relations, 1855–1899*), 3 vols. (Tokyo: University of Tokyo Press, 1982–2003).

for a suitable site, they sought the aid of France. Their decision to turn to France mainly arose from a connection with the new French ambassador, which was based on a cordial relationship between the secretary of the French Embassy and Jōun Kurimoto, a subordinate of Tadamasa Oguri, chief treasurer of the Tokugawa government.

In his dealings with the Tokugawa government, the French ambassador Léon Roches displayed consummate diplomatic skill.[11] By the time he arrived in Japan in April 1864, the Western Powers were well aware of the increasing weakness of the Tokugawa regime, yet they agreed to recognize it as the legitimate government of Japan while at the same time remaining neutral in the conflict between the central government and the rival clans. When Roches stepped ashore in Japan, four Western countries—Britain, France, the Netherlands, and the United States—were about to go to war against one of the powerful clans, the Chōshū. This war, which continued for only a few days, was prosecuted under the initiative of the British ambassador, Rutherford Alcock. Roches considered it undesirable to let Britain take the initiative in negotiating an end to the hostilities, and thus around this time he began to make friendly overtures to the Tokugawa government. The government responded by asking the French diplomat to arrange for the repair of one of its Western-style ships that frequently gave trouble. Roches was happy to oblige and promptly had the vessel made ship shape. Oguri, impressed with the results, became convinced of the need of a dockyard near Edo. According to Kurimoto's recollection, Oguri selected France because its representatives were "courteous and reliable," whereas those of other countries were sometimes "arrogant and avaricious," and also because he considered that even if the Tokugawa regime were to fall, cooperation with the French could leave "a house for sale with godown."[12] He thus officially asked

11. On Roches's activities as ambassador to Japan, see Naruiwa Sōzō, *Bakumatsu Nippon to Furansu Gaikō* (*Japan at the End of the Edo Period and Its Diplomatic Relations with France*) (Tokyo: Sōgensha, 1998).

12. Jōun Kurimoto, *Kurimoto Jōun Ikō* (*Posthumous Manuscripts of Jōun Kurimoto*), cited in Nihon Kagakushi Gakkai (History of Science Society of Japan), ed., *Nihon Kagaku Gijutsushi Taikei* (*A Comprehensive History of Japanese Science and Technology*) (Tokyo: Daiichi Hōki, 1964–70), vol. 17, p. 47.

Roches about the possibility of constructing a dockyard near Edo. Roches and his staff reconnoitered around Edo Bay and discovered a spot—Yokosuka—that immediately appealed because of its topographical similarity to Toulon, France. It was here that Roches proposed the dockyard be built.

Behind this French move one may detect an economic motivation: France was anxious to import Japanese silk for its own textile industry at a time when almost ninety percent of Japan's silk exports went to Britain. This French economic interest was apparent in Roches's advice to the Tokugawa government on the question of payment. He urged them to export their silk, but at the same time advised that they choose their markets carefully. Underlying this generous advice was an imperialist agenda. In a letter to the French foreign minister, Roches set forth his plan to develop trade with Japan, being explicit on the question of economic motivation: "Japan will become for France what China became for Britain; in other words she will be our market."[13] All these arrangements for the construction of the Yokosuka Dockyard were carried out before the new British ambassador, Harry Parkes, arrived at Yokohama in July 1865.

Aside from the construction of a large dockyard, Roches also agreed to provide assistance in training the Japanese army. The Tokugawa government had also asked for assistance with naval training, but Roches declined in view of the delicate diplomatic relationship between France and Britain. Although he diligently cultivated the Japanese government, Roches was careful not to offend the British. He duly advised the Japanese that for naval training they should seek British personnel. Aware of the inconvenience that would arise from having two foreign countries assist with the construction of the new Japanese navy, Roches suggested the possibility of a quick and temporary training of naval officers at the Yokosuka dockyard.[14] It was thus decided that the dockyard would be constructed by French engineers, while the Japanese Navy as a whole would be built up with the help

13. Quoted in Naruiwa, op.cit.(note 11), p. 74.

14. Hiroshi Shinohara, *Kaigun Sōsetsushi: Igirisu Gunji Komondan no Kage* (*A History of the Establishment of the Navy: The Shadow of the British Naval Consultants*) (Tokyo: Libroport, 1986), pp. 131–137.

of British naval officers.[15]

2. Construction of the Dockyard

For the post of director of construction and management of the dockyard, the French side proposed a young naval engineer, François-Léonce Verny, who was just finishing up a shipbuilding project at the dockyard in Ningbo, China, and was about to return to France. Verny had graduated from the École Polytechnique in 1858 and the École du Génie Maritime, which was then located in Paris, in 1860.[16] As a fledging naval engineer, Verny first went to the dockyard at Brest and then was sent to China in 1862. After working in Ningbo and Shanghai for two years, he was picked for the important job of building a dockyard in Japan. Upon his arrival in Japan in 1865 at the age of twenty-seven, Verny consulted Japanese and French officials and then set to drawing up a plan and schedule for the Yokosuka project.[17]

Verny's proposal began with a plan to construct first a smaller factory complex for ship repair in Yokohama, which was to be called the Yokohama Ironworks (*Yokohama Seitetsusho* 横浜製鉄所). It then laid out procedures for the actual construction of the dockyard at Yokosuka. In his proposal, Verny emphasized that the Yokosuka project would be Japan's first complex built and operated according to Western technological know-how. All matters, Verny insisted, should be subject to the direction of French naval officers. Although a hundred Japanese artisans would be recruited to build and man the dockyard, in technical matters these artisans would be required to follow the orders of French engineers. Furthermore, French mechanics and technicians would also be recruited, and all machinery would be purchased in Japan and France. The plan also specified the financial

15. On the role of foreign advisers in the development of the Japanese navy, see ibid and idem, *Nihon Kaigun Oyatoi Gaijin* (*Foreigners Employed by the Japanese Navy*) (Tokyo: Chūō Kōronsha).

16. For biographical information on Verny, see Georges Balay, *Léonce Verny* (Les Vans: G. Balay, 1990).

17. *Senshōshi,* op.cit., vol. 1, pp. 5–18.

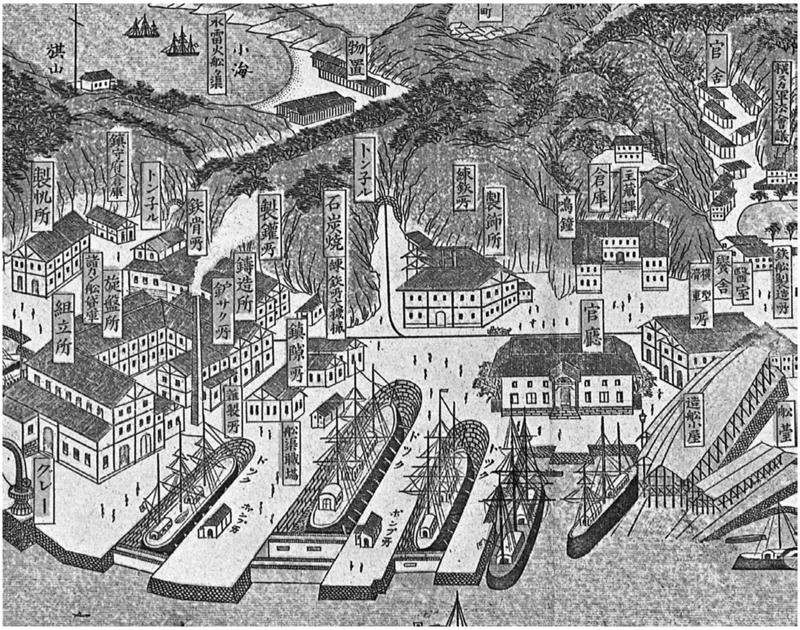
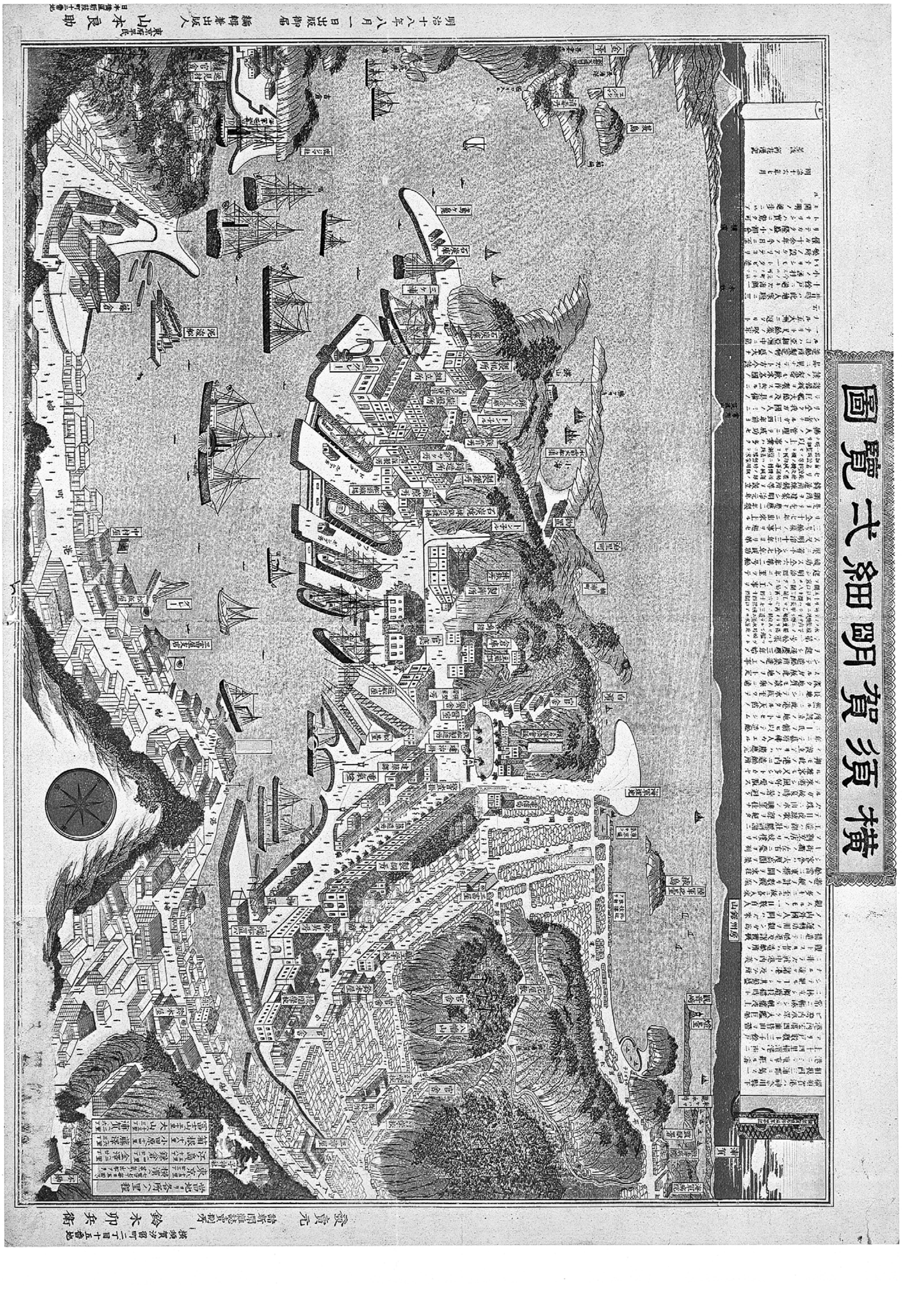


Fig. 3.1 A bird's-eye view of the Yokosuka Dockyard in 1883 (oppsite page) and a detail of its part (above)

NOTE: There were three main docks (*dokku* ドック) at the Yokosuka Dockyard. To the left of these docks were a number of factories. The largest, the C-shaped building with a tall smokestack, contained machining (*senbansho* 旋盤所), drilling (*rosakusho* 鑪サク所), and assembling works (*kumitatesho* 組立所). Adjacent to this C-shaped building were factories for caulking (*tengekisho* 鎮隙所). The larger building at the left end of the complex was a canvas-making factory (*seihansho* 製帆所). In the cental open area was the main office building (*kanchō* 官廳); behind it were factories for decoration making (*seishokusho* 製飾所) and for puddling (*rentetsusho* 練鉄所) and a warehouse (*sōko* 倉庫); and to the right was a plant that constructed models and pulleys (*mokei-kasshajo* 模型滑車所). Behind this plant was a hospital (*ishitsu* 医室) and a school for engineers (*kōsha* 黌舎). The conspicuously long building at the right of the dockyard site housed a rope-making factory (*seikōsho* 製綱所), reminding us that this dockyard constructed sailing ships as well as steamers. Behind the rope-making factory and across the street was the school for technicians (*shokkō gakkō* 職工学校).

SOURCE: Kanagawaken Kikakuchōsabu Kenshihenshūshitsu, ed., *Kanagawaken Shi* (*The History of Kanagawa Prefecture*), *Shiryō Hen* (*Sources*) (Yokohama: Kanagawa Prefecture, 1970), vol. 17, appendix. (Courtesy of Kanagawa Prefecture.)


横須賀明細一覧圖

procedures, which were to be under the control of a French accountant: even purchases by Japanese officials were subject to the scrutiny of the French accountant and the director. A month after arriving in Japan Verny made a trip back to France, and soon thereafter a Japanese mission visited France to purchase machine tools and, under Verny's guidance, to recruit French mechanics and engineers. Most of those selected were from French dockyards: Cherbourg, Brest, Lorient, and Toulon. In 1867, the first dock at Yokosuka was completed. It was finally furnished with three docks and other engineering and logistic facilities. Figure 3.1 shows the bird's-eye view of Yokosuka Dockyard surrounded by its vicinity town and hills in 1883.

Tables 3.1 and 3.2 list the French staff at the Yokohama Ironworks and the Yokosuka Dockyard, respectively, recruited on the eve of the Meiji Restoration. At Yokohama, 16 French staff members were recruited, and at Yokosuka, 43. Of 16 working at Yokohama, 7 men, including its new director (Ferdinand N. Gautrin, who originally was to have been the Director of Machinists at Yokosuka), had originally been sent to Yokosuka and then transferred to Yokohama.

Among the dozens of French mechanics and professionals, there was a physician, Paul A.-L. Savatier, who was employed on Verny's insistence that a Western doctor was needed to care for the French staff. Because of his mastery in botanical knowledge, Savatier was also assigned the task of inspecting the quality of timbers for ship construction and of investigating Japan's flora.[18] Soon after his arrival, Savatier was sent to Fukagawa to select timbers suitable for small ships to be used in the construction of the dockyard. The area at the mouth of the river (that is, Fukagawa) was chosen on the advice of the director of the Yokohama Dockyard that timbers be stocked where fresh water and sea water met. As for the collection of timbers,

18. Hiroshi Tomita and Akira Nishibori, *Yokosuka Seitetsusho no Hitobito: Hanahiraku Furansu Bunka* (*People at the Yokosuka Ironworks: The Blooming of French Culture*) (Yokohama: Yūrindō, 1983), pp. 45–48. Aside from discussing Savatier and Verny, Tomita and Nishibori also touch on the activities and fate of three French engineers: the canvass-maker Antoine Licchione (killed in a naval accident), the architect Edmond August Bastien (who constructed a textile mill in Tomioka), and the architect Louis Félix Florent (who constructed a lighthouse on a cape near Yokosuka).

Position	Monthly Solary US $	Position	Monthly Salary US $
Director (sent from Yokosuka)	400	Technician 3	75
Chief Engineer 1	150	id 4	75
id 2 (sent from Yokosuka)	150	id 5 (sent from Yokosuka)	75
id 3 (sent from Yokosuka)	150	id 6 (sent from Yokosuka)	75
id 4 (sent from Yokosuka)	145	id 7 (sent from Yokosuka)	75
id 5	75	id 8	70
Technician 1	80	id 9	60
id 2	75	id 10	60

Table 3.1 French Staff at the Yokohama Ironworks, 1886
Note: Salaries are in U.S. dollars, valued of 1866.
Source: *Senshōshi* 1915, vol. 1, p. 78.

Position	Monthly Salary US $	Position	Monthly Salary US $
Director	833	Boilermaker 3	75
Physician	417	id 4	75
Architectural Director	400	id 5	75
Machinery Director	400	Chief Hydraulist	75
Accounting Manager	270	Chief Mason	75
Chief Draftsman	225	Decorator	75
Chief Boilermaker	150	Drawer	75
Chief Founder	150	Drawer & Shipbuild-er	75
Chief Puddler	150	Founder 1	75
Chief Hydraulist	145	id 2	75
Chief Mechanic	130	Mechanic 1	75
Draftsman for Architect	130	id 2	75
Chief Shipbuilder	120	id 3	75

Table 3.2 French Staff at the Yokosuka Dockyard, 1866
Note: Salaries are in U.S. dollars, valued of 1866.
Source: *Senshōshi* 1915, vol. 1, pp. 75–77.

Verny suggested to the government that it set up an office for forestry management in order to assure the availability of shipbuilding timber, pointing out that the cypress and oak that abounded in the area around what is now Shizuoka might be suitable, something which could be determined by an actual inspection by French experts.[19] Later, Adolph E.-F. Dupont, then in charge of timber supply, made several tours to inspect trees and plants all over middle and western Japan.[20]

Verny also proposed that the Japanese government foster the cultivation of trees which contained resin for waterproofing, essential for shipbuilding. In answer to this proposal, Oguri sent one of his subordinates, Tarokurō Masuda, to Yokosuka to learn how to manufacture waterproofing from vegetable bitumen. A few years earlier, a Russian ship had been wrecked off the coast of Izu Peninsula, and the Japanese government had agreed to replace it with a schooner to be built, with the assistance of Russian engineers who had been on board, in the town of Heda. Masuda had a hand in building this schooner—which was named *Heda* after the town—and had learned some shipbuilding skills from the Russians.[21] Because of this experience, he was easily able to master the manufacturing of waterproofing. Impressed with the results, Oguri decided to launch the domestic production of bitumen. In a letter of appreciation to Verny, Oguri gave the Frenchman full credit for this success.[22]

Minerals, too, were needed. At an early stage of the project, volcanic ash from Ōshima Island was sent to Yokosuka for examination.[23] Verny later ordered a search for good-quality limestone in the more immediate area, and planned to send calcined lime down the Tama River to Edo Bay. The plan was not realized, however, simply because

19. *Senshōshi*, op.cit., vol. 1, p. 84.

20. *Senshōshi*, op.cit., vol. 2, pp. 19–25.

21. *Senshōshi*, op.cit., vol. 1., p. 86. On the construction of the Heda, see Heda Mura Bunkazai Senmon Iinkai (Heda Village Cultural Assests Special Committee), ed., *Hedagō no Kenzō* (*The Construction of the* Heda) (Heda: Heda Mura Kyoiku Iinnkai, 1979). See also Kiyoshi Yamamoto, *Nihon niokeru Shokuba no Gijutsu-rōdōshi, 1854 nen–1990 nen* (*The Technological and Labor History of the Workplace in Japan, 1854–1990*) (Tokyo: University of Tokyo Press, 1994)

22. *Senshōshi*, op.cit., vol. 1., p. 86.

23. Ibid., p. 31.

moving raw material down the Tama River proved too difficult.[24] Metal ores were also searched out. The dockyard employed a French chemist named Boel who was ordered to analyze metal ores produced throughout Japan.[25] He found clay from Izu suitable for brickmaking, and successfully manufactured bricks used at the dockyard.[26]

The same Boel was ordered to make a pictorial record of the construction of the dockyard. He was directed to photograph the excavation of hills, the reclaiming of coastline, and the construction of buildings. All this was done quite openly. The French asked the Japanese authorities for permission to make a photographic record, and the Japanese agreed on the condition that the photographs be duplicated and preserved both in Japan and France.[27] Yet in the desire of the French to photograph the project and in certain statements in the official history of the dockyard, we see hints of the French perspective on Yokosuka as a part of their larger East Asian strategy. As we have noted, immediately before being sent to Yokosuka, Verny had worked at the important project at Ningbo and at Shanghai. France was involved in still another large naval project in China, at Fuzhou. At the beginning of 1868, it was proposed through Verny that an architect working at Yokosuka be given three months' leave so that he could be sent to work at the dockyard under construction in Fuzhou, which was to become one of China's largest modern factory-and-dockyard complexes.[28]

In the midst of all this development the Meiji Restoration took place. The new rulers basically agreed to proceed with the inherited project at Yokosuka, but they also raised several important objections. They were most critical of the way money had been freely spent at a time of military and financial crisis. The official history of the dockyard is filled with reports of occasions when, upon Verny's decision,

24. Ibid., pp. 82–83.
25. Ibid., p. 72.
26. Ibid., p. 84.
27. Ibid., p. 72.
28. Ibid., p. 91. In 1871, the director of construction at the Fuzhou dockyard visited Verny in Yokosuka. In a letter home, Verny enviously noted that the budget in Fuzhou was three times greater than his own. Balay, *Verny,* op.cit., p. 167.

the salaries of the French employees had been increased or they had been paid bonuses. For instance, Boel had received a bonus of 200 francs when he set up the brickmaking operation. The new government also complained about the cost of employing the doctor, Savatier, given the availability of a Western hospital in Yokohama which could also serve the French employees in Yokosuka, the two places being only about 15 kilometers apart. Verny insisted on the need for Savatier and in the end persuaded the new authorities to let him stay.[29] This proved to be a pyrrhic victory. On the all important question of decision-making, the Meiji government sought, and obtained, a crucial change in procedure: henceforth accounting was to be under joint control, and Verny was required to consult with Japanese officials before purchasing any goods, foreign or domestic.[30] As a result, expenses were reduced, although not without grumbling from the French staff, some of whom resigned, claiming that under the new regime they had become underpaid.[31]

The officials of the new government also clashed with the French staff over technical procedures. After the Restoration, the Yokosuka Dockyard was put under the Ministry of Public Works, but within four years it was transferred to the newly created Ministry of the Navy, which had been clamoring for a dockyard of its own.[32] After this transfer, the naval bureau in charge of the dockyard complained to its parent ministry about work procedures under Verny's French staff. The bureau pointed out that some Japanese skilled craftsmen refused to permit every detail of their work be directed by French engineers.[33] Verny's plan, as we have noted, stipulated that "[Japanese] craftsmen should totally follow all the directions given by the officer and the head of construction, and should learn techniques from French engineers. They should never state their own opinions or fol-

29. *Senshōshi,* op.cit., vol. 1, pp. 113–114.

30. Ibid., pp. 107–108.

31. Balay, *Verny*, op.cit., p. 183.

32. See Nakanishi, op.cit., vol. 2, pp. 322–323. The Ministry of Public Works retained control of the Nagasaki Dockyard until its disposal (to Mitsubishi) in 1884.

33. Kaigun Shō (Ministry of Navy), ed., *Kaigun Seido Enkaku* (*The Institutional Origins of the Navy*) vol. 3, no. 1, repr ed. (Tokyo: Hara Shobō, 1971), pp. 292–293.

low the directions of anyone else."[34] Evidently, some of the Japanese craftsmen found this requirement sufficiently frustrating or humiliating that they left the dockyard. The conflict over work procedures was closely related to the question of finances. At that time, the dockyard employed more than thirty French technical experts. The Japanese bureaucrats in the bureau considered such a number excessive and believed that five or six foreign engineers would be sufficient. The Ministry of Navy found the bureau's complaints persuasive and thereafter tried to fire French craftsmen and engineers whenever possible. Finally, by 1876, it had discharged the entire French staff, including Verny.

3. The French School

Both sides recognized from the outset that at some point the Japanese would assume full control over the dockyard. Verny's proposed plan envisioned that when a trained Japanese staff was in place, it would replace the French experts. To this end, Verny proposed that a school be established in the dockyard where future engineers and technicians would be educated. For the training of engineers, Verny's plan went on to state that young students be selected from the samurai class and taught French and engineering with the aid of the head interpreter. As for the education of technicians, the students—on whose class origins the plan was silent—were to work at the dockyard factories in the morning and study drafting and other relevant subjects in the afternoon. Finally, the plan declared that the rules of the school were to be modeled after those of French naval school.[35]

In a letter to Roches, Verny laid out the details of the engineering curriculum. As educational historian Fumiya Iida has pointed out, the subjects to be taught and the number of sessions reflect the curriculum of the École Polytechnique, where Verny had been educated about ten years earlier, although the content and the level of the cur-

34. *Senshōshi*, op.cit., vol. 1, p. 13.

35. Ibid., pp. 13–14.

riculum at the two schools may have differed greatly.[36] According to Verny's plan, engineering students (who were to be between the ages of 17 and 21) were to study mathematics, sciences, drawing, and French literature in the first two years, and then, in the third year, engineering subjects on materials, machinery, ships, and architecture. Verny expected that graduates of the Yokosuka school would be sent to France for further education at the school for naval engineers at Cherbourg. In this sense, the engineering school at Yokosuka differed from the later Imperial College of Engineering planned and launched by British engineers. While the former aimed at providing basic scientific knowledge, the Imperial College intended to provide both scientific knowledge and technical on-site training.[37]

In practice, the selection of engineering and technical students at Yokosuka closely followed Verny's plan. Many of the engineering students were transferred from the Language School in Yokohama and from Kaiseijo, the national college which later became a part of the University of Tokyo, and all technical students were selected from children of local residents.[38] However, no graduates of the engineering course in this early period became naval engineers; most became French interpreters or took managerial positions at the Yokosuka

36. Verny's plan for the engineering course at Yokosuka is analyzed in Fumiya Iida, "Bakumatsu-ishi-ki ni okeru Futsugo-kei Gunji Kōgaku Jinzai no Keifu (A Genealogical Study of the Japanese Naval Architects Trained in the French Language in the Second Half of the Nineteenth Century)," *Nihon no Kyōiku Shigaku* (*Studies in the History of Education in Japan*), 37 (1994): 4–19; idem, "Nihon ni okeru Ekōru-Poritekuniku shisō no juyō to henyō: F.L. Verny no gijuutsu kyōiku kōsō no igi (The Acceptance and Modification of the Idea of Ecole Polytechnique in Japan: The Significance of F.-L. Verny's Plan of Engineering Education)," *Nichifutsu Kyōiku Gakkai Nenpō* (*Annales de la Société franco-japonaise des Sciences de l'Education*), 23 (1994): 4–19; and idem, "Meiji-ki Taishō-ki ni okeru Yokosuka Kaigun Kōshō no 'Gite' Kyōiku Karikyuramu no Hensen ni Kansuru Kenkyu (A Historical Study of the Curriculum for the Engineering Assistant in the Yokosuka Naval Arsenal in the Meiji and Taishō Eras)," *Bulletin of Fukuoka University of Education Part 4, Education and Psychology*, no. 44 (1995): 1–8.

37. On the Imperial College of Engineering, see Nobuhiro Miyoshi, *Nihon Kōgyō Kyōiku Seiristushi no Kenkyū* (*Research on the History of the Establishment of Engineering Education in Japan*) (Tokyo: Hara Shobō, 1979); and idem, *Meiji no Enjinia Kyōiku* (*Engineering Education in the Meiji Era*) (Tokyo: Chūō Kōronsha, 1983).

38. The official history tells us that there were only nine applicants for the first class.

Dockyard.[39]

Soon after the Meiji Restoration, the new rulers closed down the Yokosuka Dockyard School as a cost-cutting measure. But the influential political figures Hirobumi Ito and Shigenobu Okuma decried this step and insisted on the need for an engineering school. In 1870 the government relented and reopened the school, intending to teach basic scientific and engineering subjects in order to turn out naval engineers rather than technicians. New students were to be between 13 and 20 years of age, but exceptional applicants outside that range were also to be admitted.[40] They were first to study French and basic mathematics and then to go on to study various advanced subjects in mathematics, sciences, and naval engineering. Before 1873, instructors were drawn from the dockyard engineers, who added teaching to their other duties. In that year, however, it was decided to employ a new, full-time instructor, the mechanical engineer Paul Sarda, a graduate of the École Centrale de Arts et Manufactures in Paris. At Yokosuka, Sarda taught mathematics, physics and chemistry.

We know what Sarda taught at Yokosuka from the lecture notes taken by one of his students, Hajime Tatsumi.[41] Tatsumi's notebooks, preserved at the University of Tokyo, cover the years from 1875 to 1877 and number several thousand pages—an unusual, but valuable historical resource.[42] In 1870, Tatsumi (who was then only 13 years old) and four others were admitted to *Kōsha,* the Yokosuka Dockyard School. (According to Tatsumi's recollection, two of his classmates

39. See Iida, "A Genealogical Study," op.cit., pp. 5–6, and the biographical sketches of Hiroyoshi Tanaka, Saikichi Nakajima, Nobutsura Yamadaka, and Tadanosuke Kawashima in Tomita and Nishibori, *Yokosuka Seitetsusho*, op.cit.

40. *Senshōshi*, op.cit., vol. 1, p. 155.

41. The collection of Hajime Tatsumi, consisting of a large number of lecture notes as well as technical treatises and design plans and specifications, was kept by his descendant and is now preserved at the Center for Modern Japanese Legal and Political Documents, the Graduate Schools for Law and Politics, the University of Tokyo.

42. Judging from the neat handwriting and from a comparison with other lecture notes taken in this period, these are not directly transcribed notes but fair copies later written by Tatsumi. On lecture notes in this period and the pedagogical policy of note taking at the Ecole Centrale de Arts et Manufactures, see Takehiko Hashimoto, "Gijutsusha to Kōgi Nōto (Engineers and Lecture Notes)," *Daigakushi Kenkyū* (*Historical Studies on Higher Education*), 13 (1998): 30–44.

were quickly dismissed because they were over the age limit and replaced by students from the University of Tokyo.)[43] The new students first tackled French, and then turned to mathematical, scientific, and engineering subjects taught by Sarda through lectures on basic mathematics: geometry, descriptive geometry, algebra, analysis, calculus, and analytical geometry. It seems that under Sarda's tutelage, the teenaged Tatsumi mastered mathematical tools so that he was subsequently able to handle engineering problems in the design and construction of ships. When Tatsumi and his classmates completed their course of study at the Yokosuka school in 1877, they were sent to the École du Génie Maritime at Cherbourg to complete their education in naval engineering.

In 1876, the contract with Sarda ended and was not renewed. After Sarda departed, no appropriate teacher of middle-level subjects remained at the dockyard. Before his departure, the school had been divided into preparatory and regular courses. It was then decided that students at the preparatory level be sent to the University of Tokyo under the sponsorship of the navy and that only those in the regular courses be taught at Yokosuka. At that time, the physics department at the university's School of Science taught in English, French, and German, though the medium of instruction would soon be unified to English only. The plan was to send naval students to the "French physics class." The arrangement was accepted by the Ministry of Education, and five students enrolled at the University of Tokyo.[44] Sarda himself came to teach this physics class at the University of Tokyo for a short period.[45] The students who were educated both at Yokosuka and Tokyo form the third generation of engineering students from

43. Tatsumi was born in 1857, the only son of a samurai family of Kanazawa. In 1868, he entered the Dōseikan, the official school of his clan, where he learned arithmetic and foreign languages. Two years later, he was selected to attend the Yokosuka Dockyard School. See Tatsumi's autobiographical note in the Tatsumi Collection at the Center for Modern Japanese Legal and Political Documents.

44. *Senshōshi*, op.cit., vol. 2, pp. 77, 82–83, 85.

45. Tokyo Daigaku Hyakunenshi Henshū Iinkai (The Editorial Committee of the Centennial History of the University of Tokyo), ed., *Tokyo Daigaku Hyakunenshi* (*The Centennial History of the University of Tokyo*), *Bukyokushi* (*The History of Divisions*), vol. 2 (Tokyo: University of Tokyo Press, 1987), p. 337.

Yokosuka, and they too became important naval engineers.

In 1875, the dockyard naval engineering school, then still managed and instructed by an entirely French faculty, was officially, and aptly, named for the 1875 World's Fair exposition as the "French School."[46] But the next year, when Verny left Yokosuka, the school stopped teaching French to students in the technicians' course and began to use translated textbooks only.[47] In his concluding report Verny expressed his regret that the school was not as successful as he had expected, a disappointment he attributed to the frequent institutional changes.[48]

In 1878, the Yokosuka Dockyard School announced that it was abandoning its French roots in favor of the British system. The school's official history declares:

> This dockyard adopted the French system because it was originally founded with the assistance of French engineers. But our navy has generally relied on the British system, and this dockyard also should adopt that system. However, a total and immediate switch of systems would be difficult, and thus this goal should be realized gradually. As a first step, the teaching of the English language is to be started. It was therefore requested of the Ministry of Navy on the eighteenth day of this month that one English teacher be employed, and this request has been accepted.[49]

These words concluded the early history of the French connection at the Yokosuka Dockyard. From then on, the dockyard hired an increasing number of British engineers. One of these, Francis Elgar, was employed to advise the Ministry of Navy on a number of engineering subjects. Noting the problems inherent in using the French (i.e., metric) system of measurement at the Yokosuka Dockyard while other Japanese naval facilities used the British system of measurement, he recommended the adoption of a single, unified system. The dock-

46. *Senshōshi*, op.cit., vol. 2, p. 20.

47. Ibid., p. 98.

48. Ibid., p. 49.

49. Ibid., pp. 111–12.

yard decided to continue its use of the metric system because of its convenience in calculation. The adoption of the international metric system, it seems, remained the only visible evidence of the French tradition. In 1882, the school stopped accepting new students and only the course—using translated textbooks—for technicians continued. This institution was reorganized in 1889 as the Naval School of Shipbuilding, and produced an important group of engineers.

Conclusion

In the late nineteenth century, foreigners flocked to Japan, bringing with them Western knowledge and techniques demanded by a modernizing state. Most foreign experts recruited and invited by the Tokugawa and the Meiji governments were Dutch and British, but the French also played a key role because of the close connection between the French and the Tokugawa government forged toward the end of the old regime. The Yokosuka Dockyard was one of the fruits of this close relationship.

The job of François-Léonce Verny, who was chosen to direct the construction of this project, was to establish a large factory and dockyard complex, an institutional network for supplying material resources for the dockyard, and a school to train technical workers and naval engineers. Verny recognized that building such a complex in a country only recently opened to the outside world necessitated introducing a total technological system. With this in mind, he insisted that all Japanese workers, whether skilled or unskilled, follow the orders and procedures of the French staff. As one might have expected, this led to conflict with Japanese skilled workers. As a Polytechnicien, Verny was thorough and methodical in implementing his notion of a Western technological system, but perhaps lacked the pragmatic flexibility of the British, whose railroad engineers, for example, evaluated the level and condition of Japanese civil engineering and relied to some extent on Japanese craftsmen, following Japanese procedures.

Although the majority of the officers of the Imperial Japanese Navy were trained and educated after the British style, those who had studied at the Yokosuka school formed an important group of naval engineers. After finishing the polytechnical education at Yokosuka, some of the graduates were sent to the naval engineering school at Cherbourg;[50] after their return, this select group played an important role in the development of the Imperial Navy.

The above mentioned Tatsumi, for instance, briefly taught at Yokosuka after his return from France in 1881, and then worked as a naval architect and engineer at Kure, Yokosuka, and Sasebo until his retirement in1903. During his career, he was sent again to France to supervise the construction of battleships for the Japanese navy designed by his teacher and the French leading naval engineer, Louis Emile Bertin.[51] Ten years after the Yokosuka Dockyard had laid off the last of its French staff, the Japanese navy invited Bertin to Japan, where he proceeded to design a number of important ships for the Japanese navy.[52] Of the three battleships he designed, Bertin himself supervised the construction of the third, at Toulon. The Yokosuka group of French-trained naval engineers served as indispensable assistants to Bertin, although during the Sino-Japanese war of 1894 the tactical effectiveness of Bertin's three battleships proved to be very limited.

Despite the dominance of the British in the formation of the modern Japanese navy, the influence of French engineers should not be underestimated. Through the construction and operation of the Yokosuka Dockyard, Verny and his staff instilled the skills and knowledge needed for an entire shipbuilding operation. In addition, the dockyard school produced those who would eventually replace the French engineers. Comparison of this French naval tradition with the British tradition as well evaluation of its historical significance in the

50. On one occasion, two students underwent an oral examination by a French engineer, who judged both to be capable, in a year, of following the course of the Ecole Centrale, and one capable of following the course of the Ecole d'Applications, an advanced school of engineering. See Balay, *Verny*, op.cit., p. 184.

51. See Bertin's curriculum vitae in the Tatsumi Collection; see also Tomita and Nishibori, op.cit., pp. 103–108.

52. For a biographical account of Bertin, see Christian Dedet, *Les fleurs d'acier du Mikado* (Paris: Flammarion, 1993), and a review of this book by Larrie Ferreiro, in *Naval Engineers Journal* (May 1998): 105–106.

formation of the modern Japanese navy are subjects that await further research.

4

Views from England

Technological Conditions of Meiji Japan in The Engineer

Reprint of translation of "Eikoku karano Shisen: Enjinia shi ni miru Meiji Nihon no Gijutsu Jijō," in Jun Suzuki, ed., *Kōbushō to Sono Jidai* (Tokyo: Yamakawa Shuppansha, 2002): 83–94.

After the Meiji Restoration in 1868, the Japanese government attempted to introduce methodically and massively the technology of Western civilization. The Meiji government invited, in particular, numerous British engineers for the construction and operation of modern factories and railroads as well as for the instruction of young Japanese engineering students at its Imperial College of Engineering. This attempt prompts the following questions for discussion: How was Japan's introduction of Western technologies viewed by Western engineers? And how were these educational activities for Japanese engineering students viewed by engineers of their own country?

The present chapter would look at such Western visions of Meiji modernization through the pages of an English engineering journal, *The Engineer*. Following articles on events taking place in Japan, I would attempt to see how they viewed Japanese engineering activities. *The Engineer* was a weekly journal established in 1856 addressed to industrial engineers rather than academic scholars. With numerous technical illustrations, it informed its readers about state-of-art of engineering and social conditions surrounding engineering activities, addressing craftsmen, engineers, and industrialists in various industries. The content was not limited to engineering activities in Britain and Western countries, but also covered those in India, China, and other Asian countries, including Japan. News of events in these countries, most probably, interested those British engineers who may have had a chance to get work there. In contrast to the visions of invited engineers employed by the Japanese government, these visions and opinions expressed in the pages of *The Engineer* reflect the more realistic view of those residing in Britain.

1. Curiosity about Traditional Craftwork

Articles on Japan at the end of its Tokugawa period were mostly concerned with the introduction of the Japanese country and its exoticism, with curiosity towards the unknown, mysterious country. The 1863 article on "Japanese" opened with the statement that "They are bold, courageous, proud, and eager after every kind of knowledge", and went on to admire the Japanese deftness of a small copper-made working-model of a steamer based only on a Dutch textbook on naval engineering.[1] It also narrated the story of a craftsman who copied precisely a lock made by the famous English lock maker, Bramer, and another man who wove a shirt exactly the same as one given to him. These and other episodes provided readers the impression that the Japanese were deft and skilled at copying.

The article also paid attention to natural resources in Japan, especially its woods and coal, their qualities and potential quantity. It referred to the good quality of coal produced in the Iwanai region of Hokkaido, and mentioned the abundant wood resources found in this unexploited northern island of Japan. On mining methods, it referred to the present method as primitive and "unscientific," entirely relying on manual labor, but expected the Meiji government to soon realize the effectiveness of the "scientific" method by relying on various machines.[2]

On ceramics, one of the traditional craft products well-known to Westerners, the article provided an admiring but slightly inaccurate account. Craftsmen in Seto, it reported, had been manufacturing porcelain products with their methods unaltered for over a thousand years, and the kaolin and clay used for their production was of good quality and abundant. The observation of this manufacturing process

1. *The Engineer,* 20 November 1863, vol. 16, p. 299.
2. *The Engineer,* 16 March 1866, vol. 21, p. 203; 20 September 1867, vol. 24, p. 250.

led the reporter to recall an ancient Egyptian illustration of a similar process of making ceramics and the Hebrew proverb "as clay in the hands of ceramic craftsmen."[3]

2. A Proposal for the Nakasendo Railroad Line

The construction of the railroads in Japan was major news in *The Engineer* after the establishment of the Meiji government. *Kōbushō*, or the Ministry of Public Works, was established on the advice of Edmund Morel who had been invited by the Meiji government to supervise the construction of the railroads in Japan. The primary function of the proposed ministry was to construct a modern infrastructure, largely relying on British engineers and craftsmen, of which the most important and expensive project was the construction of the railroad. A report in 1870 compared the conditions of transportation in China and Japan. Whereas networks of canals and rivers were well developed in China, there was no such well-developed water transportation system in Japan. It took one month to reach a distant place by walking on unpaved routes and two weeks to commute between Tokyo and Kyoto using the most popular and important route.[4] Here was a country which needed a railroad, it concluded.

The route from Tokyo to Kyoto first suggested by a British engineer was a line along the Nakasendo route. (Fig. 4.1) The Nakasendo was one of the five major roads connecting major cities in Edo Japan. The Tokaido as well as the Nakasendo connected Tokyo and Kyoto. While the Tokaido went along the Pacific Ocean, the Nakasendo went across the middle of Honshu island. Modern Japanese readers would wonder why the Nakasendo going across mountainous areas, rather than the Tokaido, was conceived by British railroad experts as the first candidate for the route. R. Vickers Boyle who was engaged in the design and construction of the Japanese railroad explained in his article in *The Engineer* that this choice was mainly due to consider-

3. *The Engineer*, 22 September 1876, vol. 42, p. 216.
4. *The Engineer*, 27 August 1870, vol. 29, p. 397.

ation of the development of domestic industries inside the Japanese island and the transporting communication between the well-opened cities on the Pacific side and ports of the Japanese Sea. As he stated:

> The main trunk line from Tokio to Kioto would pass through the silk districts of the S[outh] part of Kodzuke and the N[orth] portions of Shinano. The line to Niigata would traverse the rice districts of Yechigo, and therefore, with increased facilities of transport, the production and export of those articles and of tea might be expected to increase from many parts of the interior. As main arteries through the heart of Japan, to and from which numerous feeders and branches by improved roads would bring the outlying districts within easy communication of the chief seaports, these lines, if gradually constructed, could not fail to aid in developing the agricultural and mineral wealth of the country, to benefit trade generally, and to advance alike the convenience and interests of the Government and of the people.[5]

British readers of *The Engineer*, having seen the map with the planned Nakasendo rail route without contour lines to designate geographical altitudes on the area where it was crossing, would have taken Boyle's planning of the route and his explanation as natural and reasonable. They would have thought that the southern route along the Pacific Ocean was entirely unattractive from the viewpoint of transportation of inland goods and produce. Takasaki, on the route about a hundred kilometres north of Tokyo, was a regional center of transportation, connecting the routes of Nakasendo and Joetsudo, crossing a mountain and leading to Niigata, as well as being located near Maebashi and Kiryu, the areas that produced silk. The route would be able to carry products like rice, tea, and silk from inland farmlands to ports on the coasts of the Pacific or possibly the Japanese Sea in the future. After all, the plan to construct the Nakasendo line was given up and was only realized long after the publication of

5. *The Engineer,* 25 May 1877, vol. 43, pp. 362–363, on p. 363. The career of Boyle is briefly explained in Naomasa Yamada, *Oyatoi Gaikokujin* (*Employed Foreigners*), vol. 4 "Kōtsū (Transportation)" (Tokyo: Kashima Shuppankai, 1968), pp. 172–174.

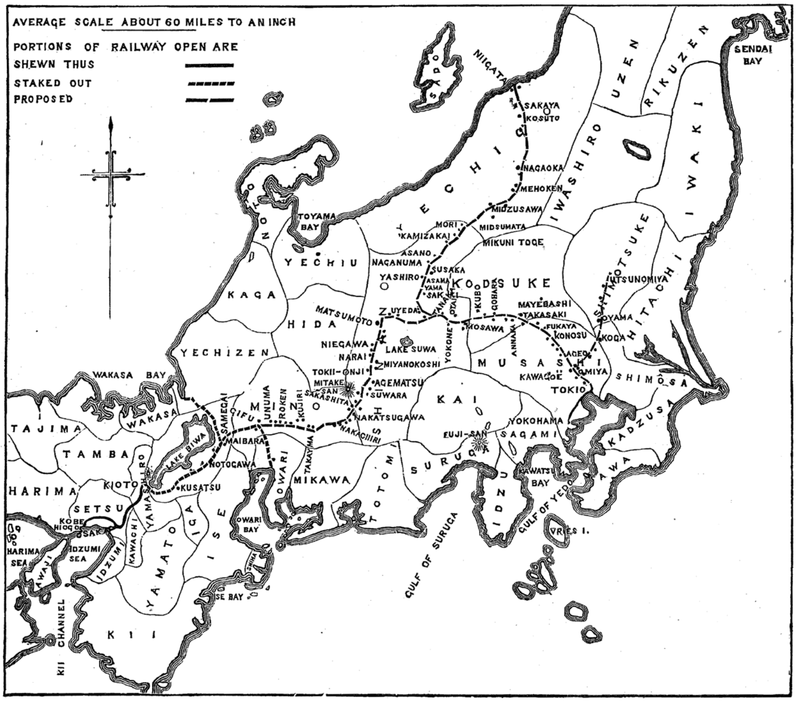


Figure 4.1

The map of central Japan and planned railroad lines. Nakasendo, Echigo, and other railroad lines were shown and explained in Boyle's article in *The Engineer*. (From *The Engineer,* 25 May 1877, vol. 43, p. 362)

Boyle's report.[6] The publication of his long explanatory report with a large map of the planned route of the Nakasendo Line would, however, indicate that readers of *The Engineer* may have had a good interest

6. For the plan and halt of the Nakasendo railroad line, see Nihon Kokuyū Tetsudō (Japanese National Railways), ed., *Nihon Kokuyū Tetsudō Hyakunenshi* (*The Centennial History of Japanese National Railways*) (Tokyo: Japanese National Railways, 1969), pp. 45–55. The details of the plan for the Nakasendo Line is discussed in Naofumi Nakamura, *Nihon Tetsudōgyō no Keisei, 1869–1894* (*The Formation of Japanese Railroad Industry, 1869–1894*) (Tokyo: Nihon Keizai Hyoronsha, 1998), pp. 92–103; the plan and completion of the construction of the railroad across the Usui Pass, the geographical bottleneck of this route, are described in Katsumasa Harada, *Nihon Tetsudōshi: Gijutsu to Ningen* (*A History of Railroads in Japan: Technologies and People*) (Tokyo: Tōsui Shobō, 2001), pp. 48–81.

and some excitement in the national initiation of large engineering activities in a Far Eastern country.

3. The Evaluation of the Japanese Engineering Education

The 1880 issue of *The Engineer* reviewed two books authored by engineers residing in Japan: Henry Dyer's *The Education of Engineers* and Curt Adolphe Netto's book on Japanese mining.[7] Dyer was a Scottish engineer who was invited as principal of the Imperial College of Engineering, established in 1872. In the book, he explained his pedagogical design for the college as a synthesis of the Continental theory-oriented and the English practice-oriented engineering education. The editor of The Engineer who reviewed the book, however, pointed out that Dyer certainly would not know about the conditions of engineering education in France. École Centrale des Arts and Manufactures in Paris, where Kōi Furuichi (Kauy Fourouitsi in his own French-style spelling) had studied civil engineering, did place emphasis on learning engineering in practice. Besides such reservations, the reviewer agreed with Dyer that the training of engineering judgment was important, and that a new type of engineering education was being attempted in Japan.[8]

Before reviewing the Netto book, its reviewer first gave his own view that the cultural growth of the country depended on the accumulation of wealth, inferring from Netto's description of Japanese mining a limitation of natural resources in Japan. He then turned to the fact that many foreign teachers were forced to return to their own country without any reason, and speculated:

> Perhaps the true cause may be sought in the suggestion that neither

7. *The Engineer,* 20 August 1880, vol. 50, p. 143.
8. The pedagogical vision of Henry Dyer on engineering education is discussed in Nobuhiro Miyoshi, *Meiji no Enjinia Kyōiku: Nihon to Igirisu no Chigai* (*Engineering Education in Meiji Japan: The Difference between Japan and Britain*) (Tokyo: Chuo Koronsha, 1983); and idem, *Daiā no Nippon* (*Japan [Viewed] by Dyer*) (Tokyo: Fukumura Shuppan, 1989).

> the wealth nor other environments of Japan as yet fit it for University education, and that the experiment promoted largely by external interests may not improbably in the end collapse.[9]

The review is more the personal expression of a cool and pessimistic view on the endeavor of Japanese modernization than an objective review of a book describing its process.

Robert H. Smith, once an instructor of engineering at the Science School of Tokyo University, sent a letter to the editor of the journal criticizing this review.[10] He first complained that the review neither introduced Netto, the author, nor the content of his book itself. He stated that he had returned to England because he had hoped to do so, and conjectured that that would also apply to other cases as well. He further added that the engineering education in Japan was promoted by the consistent planning and effort of politician Takayoshi Kido and the educator, Arinori Mori, and that the quality of students was high; the concern about the failure of this national experiment as expressed by this reviewer was therefore unnecessary, Smith stated. Neither the reviewer nor Smith referred to the financial burden of the Meiji government to keep hiring these foreign teachers.

4. The Adaptation to Competition and Markets

For several years after the review, there were no articles concerning Japan in *The Engineer.* In 1887, it carried a report on the Industrial Exhibition held in Ueno, Tokyo, in which the anonymous author pointed out that Britain was competing with other European and American countries over the Japanese market.[11] Until then, he point-

9. *The Engineer,* 20 August 1880, vol. 50, p. 143.
10. *The Engineer,* 27 August 1880, vol. 50, p. 164. Before the merger with the Imperial College of Engineering, Tokyo University had a department of engineering in the School of Science, where Smith taught mechanics, thermodynamics, and mechanics of materials. See Tokyo Daigaku Hyakunenshi Henshū Iinkai, ed., *Tokyo Daigaku Hyakunenshi* (*The Centennial History of the University of Tokyo*), *Bukyokushi*, vol. 2 (Tokyo: University of Tokyo Press, 1987), p. 232.
11. *The Engineer,* 7 June 1887, vol. 63, pp. 443–44.

ed out, Japan had been a market dominated by Britain, but it no longer was. British exporters had to compete with Japanese domestic manufacturers, and he advised that British manufacturers like those in Sheffield should take into account the conditions in Japan and make commodities adaptable to the Japanese social and economic conditions. As an example, the editor remarked that Japanese carpenters drew lines on floors and cut wood by pulling rather than pushing a saw on it. The shape of the teeth of Japanese saws all conformed to this carpentry custom, which British tool makers should be aware of if they attempted to export their saws to Japan. To be competitive in the Japanese market, British manufacturers thus had to make goods which were not only of good quality but also adaptable to the customs of Japanese users. Taking another example, the editor also mentioned the steam locomotives for railroads. Since Japan had adopted the metric system, he pointed out that it tended to purchase locomotives from the United States or from Germany.[12] The editorial report reflected the view of British industrialists who competed in the Far Eastern market, with the United States having a geographical advantage and with Germany producing cheaper products.

5. Increasing Interest after the Sino-Japanese War

After Japan won over its war against China, Britain came to have a closer relationship with Japan, and the editors of *The Engineer* planned to report in detail on industrial and technological conditions in Japan. To do so, they sent a special reporter to Japan and asked him to contribute a series of reports on the present Japanese situation. The current information from the reporter stationed in Japan was considered profitable for readers of the journal.

Though the reports were not signed by their author, the contracted journalist for these Japanese reports was Stafford Ransome, who had

12. *The Engineer*, 21 August 1891, vol. 72, p. 161. On the production of steam locomotives in Britain and the United States and the comparison of their exports to Japan, see Steven J. Ericson, "Importing Locomotives in Meiji Japan: International Business and Technology Transfer in the Railroad Industry," *Osiris,* 13(1998): 129–153.

experience in and knowledge of engineering and business.[13] The mission assigned by the editor, according to the reporter, was the investigation of the following three points: first, the present technological conditions of Japan; second, the Japanese market for British engineering products; and third, the possibility for British engineers to advance in Japan. These three investigative tasks assigned to the reporter were a frank expression of interest from the side of British engineers, manufacturers, and industrialists in Japan as a potential market for their products and engineering knowledge and skills. Having announced this planned series, the editor called it to readers' attention, informing them that the first several reports would be on the latter two topics.

Ransome's reports were published from 1896 to 1898 as a series of twenty articles titled "Modern Japan, Industrial and Scientific." They were intended to inform British engineers about the present engineering and industrial conditions and activities in Japan, covering such topics as railroads, ship construction, electricity, patents, engineering education, and business. He narrated the newest information and future prospects of Japan, citing in some cases reports of other experts in the relevant areas and recounting in others his own experiences. The Japan portrayed by Ransome through his twenty reports was a country acquiring growing competitiveness in technology and offering business chances to foreign engineers and businessmen.

6. Technical Capacity through Dead-copying

In his first report, Ransome referred to the issue of making copies of foreign-made products without permission. Some British companies were reluctant to export to Japan because of this copying custom of Japan. Soon after they exported products to Japan, they were copied and sold as cheaply as half of the original price. The steam

13. The reports were later compiled and published as Stafford Ransome, *Japan in Transition: A Comparative Study of the Progress, Policy, and Methods of the Japanese since Their War with China* (London: Harper, 1899). It was cited in Henry Dyer, *Dai Nippon, the Britain of the East: A Study of a National Evolution* (London: Blackie, 1904).

locomotives would also be sooner or later copied and manufactured in Japan. He considered it to be inevitable.[14]

Before Ransome's report on this issue, *The Engineer* had an article of caution on this problem of the production of dead-copied products.[15] Its author expected that the amount of British exports to Japan, China, and Russia would increase, but pointed out that their export to Japan posed a problem. For when machines with foreign patents were brought to Japan, they disassembled the machines, immediately initiated copying and making their duplicate models, and sold them at half the price. British industrialists had to be cautious about providing information to them. The Japanese were skilled at mechanical techniques, and, he continued, they were good at duplication, though not good at invention and innovation. It was expected that the demand for spinning machines would increase, and therefore the editor warned that engineers in Lancashire should be careful and do nothing more than helping the Japanese.

As for patenting in Japan, a newly established patent law was expected to protect patents, trademarks, designs.[16] The patent law would become effective in 1899, when Japan joined the Paris Convention of International Agreement of Industrial Property Rights and began to follow the international rule on this matter.[17]

7. Strict Testing

Ransome picked up the issue of strict testing at the government office responsible for the inspection of imported materials.[18] He even called the level of strict testing "hypercritical" and considered it to be working as one of the trade barriers for exports to Japan. For import-

14. *The Engineer,* 27 November 1896, vol. 82, p. 533.
15. *The Engineer*, 17 August 1894, vol. 78, p. 150.
16. *The Engineer,* 21 December 1894, vol. 78, p. 554.
17. On the history of the Japanese patent system, see Japan Patent Bureau, ed., *Kōgyō Shoyūken Seido Hyakunenshi* (*One Hundred Year History of Industrial Property Rights*) (Tokyo: Hatsumei Kyokai, 1984–85).
18. *The Engineer*, 11 December 1896, vol. 82, p. 581.

ing goods to be used by the government, in particular, Japanese tended to prefer French products to British, since French goods were more meticulously made and strictly tested.[19] To ameliorate the situation, he suggested that Britain should invite Japanese students to British schools and factories, since those students who learned in British institutions would introduce British technical methods and manufacturing processes after their return to Japan.

One of the reasons behind such strict testing for imported materials, Ransome conjectured, would be the existence of a defect in engineering training and education. Although young Japanese engineers were receiving an excellent education, it emphasized theory or theoretical learning. And almost all engineers working on site were young engineers who had graduated from school. They lacked the practical skills and knowledge acquired through long-time experience. The accurate and swift testing of technological products was only possible through such engineering experience. As a consequence, he argued, Japanese officials blocked the import of products with enough quality, although the lack of testing capability usually would lead to importing sub-quality products.

8. Theory-biased Education

Ransome provided a detailed explanation of engineering education in Japan in his thirteenth and fourteenth reports.[20] He introduced the educational curriculum, engineering teachers, and employment of graduates of the Imperial College of Engineering, which became the Engineering School of Tokyo Imperial University. He evaluated the high level of engineering education, and admitted that they could absorb technical knowledge not only through school education, but also through their training at engineering sites such as factories. But he also pointed out that the Japanese were not good at applying the knowledge acquired through education into their own engineering

19. *The Engineer,* 19 June 1891, vol. 71, p. 487.
20. *The Engineer,* 3 December 1897, 10 December 1897, vol. 84, pp. 544–45, 567–69.

practice. The reason for this, he assumed, was that even when they received instruction on site as at ironworks, the number and kinds of practical learning were much more limited than the years-long learning through actual practice. They also could not learn from parents or relatives, even if they had been sons of craftsmen. They were, he quipped, "handling things while wearing gloves," insinuating that they could not reach the engineering level of foreign engineers unless they took off their gloves and directly touched real things.

Ransome also quoted the following episode. Even when the Japanese purchased a machine designed and made by British engineers, they would ask a graduate from the engineering college to see if it were necessary to modify the machine to work in Japan. But the modification of a part of the well-designed machine would lead to destroying its harmonious system, and the inexperienced engineer would never attempt such a modification. Japanese engineers checked if the machine were the same or different from what they had learned from their teachers, and if they found it to be different, they would exercise the spirit of "dead-copying" and correct precisely as they were instructed. The manufacturer who purchased the machine could only follow the instructions of the young engineer who knew engineering only on paper.[21]

To meet the demand of more practical engineers, other engineering colleges were established in Tokyo and other cities. Tokyo Vocational School, the precursor of the present Tokyo Institute of Technology, was established in 1881. It was renamed as Tokyo Technical School in 1890. Students of the Imperial College of Engineering had been trained in the factory at Akabane, but the factory was turned into an arsenal for the army and no longer served for educational training. The machine factory at Tokyo University, Ransome observed, had more the character of a museum than of a practical training place. On the other hand, Tokyo Technical School emphasized more practical education, and produced able graduates. They were, he observed, ranked second to graduates from Tokyo Imperial University.

After the publication of the article about engineering education, the

21. *The Engineer*, 25 February 1898, vol. 85, p. 178.

editors received letters from the above-mentioned Smith and also from Divers, who instructed chemistry at the Imperial College of Engineering. Smith corrected the factual errors in Ransome's description of the history of engineering education, and Divers further corrected Smith's description. They were all concerned with the historical and institutional relationship between the Imperial College of Engineering and Tokyo University as well as the Engineering School of Tokyo Imperial University. However, neither was opposed to Ransome's evaluative and critical observation about the theory-biased engineering education at this university. Ransome pointed out the lack of university graduates in practical training and experience, and both Smith and Divers seemed to agree with this evaluation implicitly.

9. Concluding Remarks

Articles in *The Engineer* in the latter half of the nineteenth century disclose a consistent interest on the part of British engineers in the technological and industrial conditions in modernizing Japan. Their particular interest lay in the potentiality of the Japanese market for British manufacturers and in the new cadre of Japanese engineers who had started to control the industrial conditions in the country. From this viewpoint, they expressed frustration with the Japanese inspection standard for imported goods and patent protection system, and criticized the engineering education initiated by young British engineers, which had been usually evaluated highly as an early successful attempt at engineering education of university level. To the authors of these articles which were largely addressed to British industrial engineers, the educational curriculum at the Imperial College of Engineering, in which Henry Dyer intended to harmonize the theoretical and practical aspects of instruction, was viewed as more theory-biased and as a source of various problems in the Japanese industrial and technological situation. Young engineers with little practical experience were sent to factories without foreign engineers and committed large and small engineering errors, through which, we could say, they experienced their real postgraduate training in engineering practice.

III. Forming Technological Foundations in Modern Japan

5

From Traditional to Modern Metrology

The Introduction and Acceptance of the Metric System

Reprint of "The Introduction of the Metric System to Japan," in Feza Günergun and Shigehisa Kuriyama, eds., *The Introduction of Modern Science and Technology to Turkey and Japan* (Kyoto: International Research Center for Japanese Studies, 1998): 187–203.

Measurement is the basis of a civilization. Uniform standard units, in turn, are the basis of measurement. Based on such standard units, government taxes people, merchants trade goods, and architects build houses. To keep its sophisticated social, economic, and technological mechanisms operating smoothly, the modern world demands ever more precise and more universal measurements.

The introduction of modern measurement to Japan came at the end of the Edo period, when the Tokugawa government started to introduce Western technologies. After the Meiji Restoration in 1868, the new Meiji government became engaged in the more radical project of modernizing every facet of Japanese society. In this project, the establishment of a metrological system was a priority. As Japanese in the Meiji period tried to assimilate the intellectual, institutional, and social systems of the Western world, they encountered two Western metrological systems: the British yard-and-pound system and the French metric system. The introduction of the metric system, which was internationally established almost simultaneously with the Meiji Restoration, naturally attracted Japanese leaders with scientific minds; today, it is the principal metrological system used in Japan. However, the transition from the native standards to the metric measures was by no means quick or smooth. The conversion to the metric system was complicated by the strong influence of British engineering on Japanese industries in the Meiji period, which ensured the prevalence of the yard-pound system in the industrial sector. Thus, three systems of weights and measures—native, British, and metric—coexisted and rivaled one another from the beginning of the Meiji era up until World War II.

This chapter will survey the history of the transition from native to metric metrology, highlighting the following points: (1) how the new Meiji government used the new metrological system to sustain its control over local areas, and how its policies differed from those of Edo times; (2) how the standardization affected, and was affected by, the coexistence of the two Western systems; (3) how champions of the metric system promoted it; and (4) how the opponents of the metric system defended native measurements.[1]

1. The Control of Weights and Measures in the Edo Period

The system of weights and measures in Edo Japan was closely related to its social structure and the relationship among the four social classes: samurai-rulers, farmers, craftsmen, and merchants. Rice was the second currency in Edo Japan, and all samurai salaries were paid in volume (not weight) units of rice taxed from farmers.[2] Instruments to measure the volume of rice as well as the instruments for weighing were exclusively made by a special group of craftsmen. Using these measuring instruments, merchants were allowed to trade fairly freely between producers and consumers.

During this period, the Tokugawa (central) government authorized two trade guilds (*za*) to manufacture measuring instruments: *hakariza* for making balances, and *masuza* for volume measures.[3] Officers of

1. This chapter is primarily based on the following two works on the history of Japanese metrology: Mētoruhō Jikkō Iinkai, ed., *Nihon Mētoruhō Enkakushi* (*A History of the Metric System in Japan*) (Tokyo: Nihon Keiryō Kyōkai, 1967) and Nihon Keiryō Kyōkai, ed., *Keiryō Hyakunenshi* (*A Hundred-Year History of Measurement*) (Tokyo: Nihon Keiryō Kyōkai, 1978).
2. The wealth of a *han* was measured by the estimated volume of rice taxed each year.
3. *Za* had been originally meant for a designated seat (*za*) for privileged tradesmen on the occasion of religious or political festivals. Such monopoly groups, privileged families, were organized around various kinds of consumer goods—oil, gold, and so forth. For *hakariza*, see Hideo Hayashi, *Hakariza* (Tokyo: Yoshikawa Kōbunkan, 1973), and Kesakatsu Koizumi, *Hakari* (Tokyo: Hosei University Press, 1982). For *masuza,* see

the central and local governments periodically inspected balances and measures in use in towns, and confiscated all nonstandard balances and arrested their makers. A law established in 1742 stipulated that makers of deviant measures should be dragged around town and then executed.

Despite such strict laws, measurements of volume and length were less rigorous and less unified than those of weight. Although the central government authorized only two *masuza* in Edo and Kyoto to make authentic volume measures, each domain was responsible for collecting tax tributes from its farmers, and some of them designated local makers of volume-measuring vessels, with some of these vessels differing slightly from officially approved measures.

The size of a standard *masu* (wooden square vessel) was fixed by the government. In 1669 the Tokugawa government defined the unit volume *shō* as a volume of 4.9 *sun* in length and width and a depth of 2.7 *sun*. Standard volume was thus defined in terms of units of length, but the government did not rigorously control the latter. Although there were orthodox units of length and area used in carpentry and in the measurement of rice fields, modified versions of scales were widely used among the public, and the standard of length was not tightly controlled until after the Meiji Restoration.

2. The Meiji Government's Reform of the Weights and Measures System

The control of measures was an urgent task for the Meiji government, because of its pressing need to reform the tax system and replenish the treasury so badly depleted by revolutionary warfare. After the Restoration, the control of weights and measures fell under the control of the Ministry of Finance. In 1870, a Section of Metrological Reform was set up in the Ministry of Finance and charged with developing a new, adequate system of weights and measures.

The 1870s brought the establishment of the international treaty of the metric system. The idea of an international unification of

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Kesakatsu Koizumi, *Masu* (Tokyo: Hosei University Press, 1980).

weights-and-measures systems through the metric system became a possibility, owing to active French promotion efforts at World Fairs and scientific discussions of discrepancies in data from geodetic surveys in the previous decade. The International Commission of the Meter was first held in 1870 in the Congress on the Metric System, and at the second meeting in 1875, the Meter Convention was signed by seventeen countries.

The head of the Reform Section, Eiich Shibusawa (1840–1931) was introduced to the metric system by the physicist, Aikitsu Tanakadate (1856–1952). Shibusawa, the would-be founder of the Japanese business world, had briefly studied economics in the West. Another member of the section was a graduate student of the Nagasaki Naval Training School who had been taught by Dutch naval officers and engineers. Perhaps because of the presence of such members with Western knowledge, the Section attempted to designate the metric system as the standard metrological system. Their first plan, proposed in 1870, was to adopt the native shaku scale, but to define its length simply as one-third of a meter. This radical proposal, however, was flatly rejected by government leaders.

The Shibusawa group had to find an independent method of defining the native unit of length. Partly because there had been no guild in the Edo period specifically responsible for manufacturing scales, various kinds of scales were widely used. Scales for tailors (*kujira jaku*)[4] and those for carpenters (*magari jaku*)[5] both employed the unit *shaku*, but their actual lengths were slightly different. The scales for carpenters required more precision and were regarded as more authentic, but even they displayed variations.

Shibusawa's group consulted Itsumi Uchida (1805–1882), an expert in traditional mathematics, on this matter. Uchida possessed three ancient and apparently authentic *shaku* unit scales. The longest and allegedly the oldest among them was selected for use as a formal

4. The *kujira jaku*, literally meaning "whale scale," was so named because it used to be made of a whalebone whose flexibility was suited for tailoring.

5. The *magari jaku* literally means a "curved (or more precisely, cornered) scale." Carpenters used such cornered scales, with a right-angle corner and two differently calibrated scales, to ease architectural calculation.

standard of length, but it soon turned out that the volume measure made by this unit differed from the volume unit then widely circulating in Japan. They thus switched to the medium-size unit scale, and on the basis of this scale, the Law of the Regulation of Weights and Measures was established in 1875.

That same year, the Convention of the Meter was signed in Europe, and the French government invited the Japanese government to join. The proposal by the Ministry of Finance to sign this international treaty, however, was defeated because of opposition from the Ministry of Home Affairs. In 1881, the management of weights and measures was transferred from the Ministry of Finance to the Ministry of Agriculture and Commerce, which proposed participation in the treaty in 1885. This time, the proposal was approved, and a Committee for the Investigation of Weights and Measures was set up under this ministry.

The Committee included three notable scientists: the meteorologist Seio Nakamura, the physicist Kenjirō Yamakawa (1854–1931), and the mathematician Dairoku Kikuchi (1859–1917) (who later became a member of the House of Peers, President of Tokyo Imperial University, and Minister of Education). The three unanimously endorsed adoption of the metric system, as they were convinced that it would become the future standard in metrology. Nakamura decided, or diplomatically negotiated, that the basis of longitude would be taken from England, while the standard for units would be taken from France.[6] The Committee's proposed plan for the Law of Weights and Measures adopted the native unit *shaku*, but defined it as 10/33 of a meter, which was considered close enough to the length of the medium-size *shaku* scale.

The Law of Weights and Measures was thus established in 1891. It passed the Diet immediately after the protocols for the meter and the kilogram arrived from France. According to this law, the basic units to be used were the traditional *shaku* and *kan*, but they were defined as 10/33 meter and 15/4 kilograms, respectively. The Japanese gov-

6. Seio Nakamura, "Kaikodan (A Recollection)," Doryōkō, no. 137 (1923), quoted in *Nihon Mētoruhō Enkakushi.*

ernment requested the International Bureau of Weights and Measures to construct *shaku* and *kan* protocols in accord with the above sizes, and the request was accepted: the *shaku* protocol was made by truncating a meter protocol, while the *kan* protocol was constructed separately.[7] Upon arrival in Japan, these made-to-order original and suboriginal protocols were preserved at the Ministry of Agriculture and Commerce, and protocols for local governments were replicated, based on the latter.

The actual enforcement of the law required a number of specialist officers as well as authentic protocols. According to this law, those who made, sold, and repaired measures were required to let their instruments be examined and to receive permission in advance to conduct their business; those who used measures for their business were to be tested every five years (the first regular testing took place in 1899). In addition, the local government occasionally tested the instruments used in shops.

To carry out this program, it was necessary to establish a testing station at each prefecture, and to supply metrology specialists to these stations. In order to meet this demand, the Ministry of Agriculture and Commerce requested the Tokyo Physics College to set up a program of metrology and to teach the basics of the subject for would-be metrological bureaucrats. The Tokyo Physics College had been established by graduates of the "French Physics Class" of Tokyo University (the short-lived predecessor of Tokyo Imperial University, which, in turn, was the predecessor of the present University of Tokyo). When the predecessor of Tokyo University had been reformed in 1873, English was chosen as the primary foreign language, and a new Department of Arts was temporarily set up as a refuge for those students who had been studying with French teachers. The Department of Arts, often referred to as the Department of French Physics, existed until 1880.[8] Graduates of the French Physics Department naturally

7. Keiryō Kenkyūjo, ed., *Keiryō Kenkyūjo Hachijūnenshi* (*An Eighty-Year History of Metrological Laboratory*) (Nihari, Ibaraki: Keiryō Kenkyūjo, 1984), unpublished, p. 42.

8. Tokyo Daigaku Hyakunenshi Henshū Iinkai, ed., *Tokyo Daigaku Hyakunenshi* (*The Centennial History of the University of Tokyo*), *Bukyokushi*, vol. 2 (Tokyo: Uniersity of Tokyo Press, 1987), p. 336.

showed strong interest in metrology and the metric system, and many of them played leading roles in introducing and promoting the metric system in Japan. Munanori Takanose, for instance, was one of the founders of the Tokyo Physics College and was in charge of metrological reform at the Ministry of Agriculture and Commerce; he served as a liaison between the College and the Ministry. The Metrological Program at the College continued from 1891 to 1893, and during this three-year span, it produced some sixty experts in metrology as the manpower for local testing stations.

3. The Spread of the Yard-Pound System and the Amendment of the Law

The French physics graduates, however, were a minority among scientists and engineers in Meiji Japan, and their aspirations for an internationally unified metric system was not shared by engineers, in particular. The introduction of Western knowledge from different countries in different disciplines caused the adoption and persistence of the two Western metrological systems. The medical and pharmaceutical fields adopted the metric system because of their almost exclusive reliance on German medicine. Science in general adopted the international system, although many American and British scientists came to teach various scientific subjects in Japan. The army, too, adopted the international metric system, because it learned of it first from the French army and then from the German. The navy, however, adopted the British system because of its close connection with the British navy, despite its earlier connection with French naval engineers through the construction of the Yokosuka Dockyard as was shown in Chapter 3.

As far as industrial technologies were concerned, however, British influence was by far the most dominant. The Ministry of Engineering, which until 1885 was in charge of every facet of technological matters, from engineering education to large construction projects, relied almost exclusively on hired British engineers. The Imperial College of Engineering (the predecessor of the Engineering School of Tokyo Imperial University), too, was dominated by young British engineering teachers. These British engineering practitioners and educators naturally employed their native metrological system. At classrooms and construction sites, things were measured by yards and pounds, and imported materials and machines were measured and calibrated in the British way.

The 1893 law was designed primarily by prestigious scientists, and it did not reach this industrial reality of Meiji Japan. One grave consequence of the widespread use of the yard-and-pound system in Japanese industries was that their measures were not regulated by the Japanese Measurement Law. Foreigners inside some designated areas could live and work under the laws of their own country until their extraterritorial rights were lifted by the Treaty Revision of 1899. Already in 1885, a group of balance makers in Tokyo had petitioned for government regulation of balances and measures based on the British system, complaining of how rival Japanese makers made such measures without official approval. The answer from the Ministry of Agriculture and Commerce was apologetic. It stated that the compulsory enforcement of the metric system was impractical because the pound unit was then ten times more widely used than the gram in Japan; at the same time, compulsory enforcement of the British system was also unwise because the metric system would most probably prevail in future industries.

It was not just in private sectors that the enforcement of the metric system was deemed difficult. The Ministry of Posts and Telecommunications, which had inherited some national projects from the Ministry of Engineering, investigated in 1901 how difficult it would be to shift from the yard-and-pound to the metric system. The report concluded that it would not be difficult to make the switch in the inspection of ships and in telecommunications, but would be very problematic in the case of the railroads.

In 1909, the 1893 law of Weights and Measures finally was amended, and the use of the yard-and-pound for measurement was officially approved. The government now had also to test scales and measures calibrated by the yard-and-pound system. However, it limited such testing to just three stations in Tokyo, Osaka, and Fukuoka, and set their testing fees higher than normal so as to discourage the use of yard-and-pound instruments. Nonetheless, statistics from 1911 show that more than half of the total scales tested at the three designated stations were of the yard-and-pound system.

4. World War I and Standardization

The metric system had so far been largely promoted by a group of leading scientists with a keen interest in metrology. World War I brought significant changes in perception among engineers. The all-out, consuming nature of war strained the nation's industrial power to the utmost. All came to recognize that in order to increase industrial productivity, the standardization of parts and processes was critical.

Before World War I, the military and the government had attempted to standardize some parts of processes. The army tried to standardize the size of nails as early as in 1903, and the navy standardized the method of testing materials for ship building. In 1905 the Ministry of Agriculture and Commerce set up a committee to standardize the testing of Portland cement; the committee fixed the content of its basic components, and the way to test characteristics such as the strength and the rate of expansion in concrete made out of the tested cement. In 1913, the Japanese Association of Engineering was asked by the mayor of Tokyo to standardize the sizes of iron water pipes. It formed a committee consisting of representatives of academia, local governments, and the military, and the committee reported its conclusions to the Tokyo municipal government. But enforcement of the new specifications proved difficult.[9]

After World War I, the Japanese Association of Engineering set up another committee to investigate more systematically the standardization and the improvement of both engineering education and technological development in general. The committee, comprised of representatives of a dozen engineering societies, considered that the

9. Eisuke Yoshida, "Kōgyōhin Kikaku Tōitsu Jigyō no Gaiyō (A Survey of the Project of Industrial Standardization)," *Kōgyō Chōsa Ihō* (*Reports on Industrial Investigation*), 1 (1923), quoted in *Nihon Kagaku Gijutsushi Taikei*, vol. 3 (Tokyo: Daiichi Hōki, 1967), pp. 272–276, on p. 273.

standardization of nuts, bolts, and screw nails was the most urgent and important task, and concluded that they should be standardized by the Whitworth system until an international standard for them became fixed.

The government was now engaged in the problem of standardization. In 1919 the Ministry of Agriculture and Commerce formed an Investigative Committee for Weights and Measures and the Standardization of Industrial Goods. Within the same year, it concluded that weights and measures should be unified by the metric system. By the next year it specified the kinds of materials and parts to be standardized, listing forty-seven items divided into four categories: metallic and nonmetallic materials, electrical equipment, mechanical components, and machine tools. More specifically, it selected twelve items which more urgently required standardization, including the shapes and sizes of such parts and materials as steel and iron materials, pipes, rivets, wires, wood materials, bricks, incandescent lamps, nuts and bolts, valves and cocks. It further recommended that a permanent committee be established to investigate this matter more thoroughly and to discuss procedures for the implementation of these standards. The Investigative Committee for the Standardization of Industrial Goods was thus established in 1921, with about seventy members drawn from governmental departments and engineering societies, as well as from universities and corporations. The committee had four subcommittees, corresponding to the four categories in the report of the previous committee, and they held an intensive series of discussions after the first main meeting held in October 1921. After the conclusions of the investigations were approved in the subcommittees and the main committee, the proposals were submitted to the Ministry of Agriculture and Commerce, and eventually became the Japanese Engineering Standard (JES). The work of this Investigative Committee continued after a part of the Ministry of Agriculture and Commerce was reorganized in April 1925 into the Ministry of Commerce and Industry (the predecessor of the present MITI), and from 1930 it worked under the Special Bureau of Industrial Rationalization. By 1941 it had determined some 520 JES items.

The direct purpose of the establishment of these standards was to make parts interchangeable and improve efficiency, but it also aimed at raising the quality of industrial goods and the level of Japanese industries in general. Kiyoshi Ogawa, who wrote a prewar history of standardization, remarked in 1949 that while units should be standardized according to the metric system, the following points should be taken into account: if a product were still under development, premature standardization should be avoided so as not to hamper its rapid development; tradition should also be taken into account.[10] Reflecting the large influence of United Kingdom and United States industrial technologies, some standards for machines and their basic components were set in the British system. As an engineering professor of Tokyo Imperial University stated as late as 1926, the switch to the metric system from the yard-and-pond system at the University was considered difficult in mechanical engineering and naval architecture, though less problematic in civil engineering, architecture, and aeronautical engineering.

5. The Law of the Metric System and the Promotion of the Ideology of Measurement

Nevertheless, the conclusion of the Investigative Committee promptly led to the complete reformulation of the Law of Weights and Measures. About a year after its conclusion on the metric system was submitted, a proposal for the amendment of the law was submitted to the Congress. The proposed law selected metric units as the basis of weights and measures in general, and, in contrast to the previous law, banned the use of units other than those of the metric system. The minutes of the Diet Committee meeting where this amendment was discussed reveal that the discussion was conducted in a hurried way. A representative asked the estimated costs of changing the entire metrological system, and asked that officers in charge of this job be summoned from each ministry. The chairman, Kaichirō

10. The Japan Society of Mechanical Engineers, ed., *Nihon Kikai Kōgyō Gojūnen* (*Fifty Years of the Japanese Machine Industry*) (Tokyo: The Japan Society of Mechanical Engineers, 1949), pp. 1099–1144, on pp. 1106–7.

Imaizumi (1867–1941), declared that there had already been enough discussion in the Investigative Committee, and that such a summons was unnecessary. The law was passed and promulgated as law on 11 April 1921. The day was then commemorated as the day of weights and measures.

According to the new law, two kinds of moratorium periods were set for the public and private sectors: a ten-year moratorium was given to the public sector, and an additional ten years given to the private. All basic units had to be replaced by the metric system within these moratoria. During discussion in the Diet, Shiryō Kikkawa referred to discussions in the United States Congress, which suggested that if the United States decided to adopt the metric system, its government would need much "propaganda" to implement it because the British system was so widely used in American industry and among the American people. The Japanese government, too, was aware of the need for propaganda to promote the metric system.

The government had a good assistant in this, namely the Japanese Society of Weights and Measures. The Society's predecessor, the Great Japanese Society of Weights and Measures, had been established in 1894, a year after the original Law of Weights and Measures had been enforced; the society had disappeared, however, around the time when opinion leaned toward official approval of the yard-and-pound system. The renamed Japanese Society of Weights and Measures was established in 1911, for the purpose of promoting the metric system and *keiryō shisō*—the thought or ideology of measurement. This measurement ideology perhaps acted as a key word in the spread of the metric system in Japan. The society went far beyond propagandizing for the metric system itself; it promoted a fundamental change in the way of life—the modernization of life style.

After the new Measurement Law with the metric system passed, the Society enthusiastically promoted the metric system in every quarter of Japanese society through such means as pamphlets, exhibitions, and lectures. An exhibition on measurement was held at the Tokyo Educational Museum (the predecessor of the present National

Science Museum) two months after the promulgation of the law.[11] It aimed to promote both the metric system and the use of precise measurement to improve efficiency and equality. The Society decided to make a film for this occasion, and put out a call for scripts in its official journal, *Doryōkō* (*Weights and Measures*). The winning script, "Keitarō Nikki (Diary of a Measure Boy)," was written by a graduate of a law school, and was made into a movie by a curator of the Tokyo Educational Museum. The original script followed the hero from his childhood into his twenties, but the curator-director remade it into a film about one day in the life of nine-year-old Keitarō.

In the film, Keitarō learned at school about measurement and became fascinated with it. Returning from school, he asked his mother if she had a balance at home. She answered that they had previously had one, but the father had sold it when the house had been cleaned at the end of the previous year, because they had used it only very rarely and considered it unnecessary. Disappointed, Keitarō emphasized the importance of measurement, imitating his teacher's way of speaking, and he asked his father to buy a new balance. He and his father then went to the center of Tokyo and bought one. Back home, Keitarō immediately started to weigh everything around him, small or large, from small goods to people such as himself and the servant. Happy, Keitarō went to bed clutching his own cherished balance.

The film continues with the next day, a Sunday. Keitarō pursued his game of measuring all things at home. And he made an amazing discovery. The actual amounts of sugar, *miso* (Japanese fermented soybean paste), and beef—all differed slightly from the amounts ordered from the shops. The next day, he and his father visited the Tokyo Metrological Bureau and observed the metrological instruments and the tests conducted with them. On their way back, they purchased a set of all essential measuring devices for domestic use. The following

11. Tokyoto Keiryō Kenteijo (Tokyo Metrological Station), ed., *Tokyo no Doryōkō Gyōsei Shiwa* (*Administrative History of Metrology in Tokyo*), unpublished, p. 483. The exhibition, however, was not mentioned in the official history of the National Science Museum, *Kokuritsu Kagaku Hakubutsukan Hyakunenshi* (*The Centennial History of the National Science Museum*) (Tokyo: The National Science Museum, 1977).

day, shop servants showed up and tried to sell goods to Keitarō's family. It turned out that the liquor, the rice, the sugar, and the charcoal they had brought were actually all less than the amount they claimed to be selling, so the boys from the shops were told to leave. The only exception was the boy from a meat shop who luckily had heard about what was going on inside, and managed to devise cunning tactics on the spot. Keitarō's diary of that day opened with the words: "I was very pleased. Every boy from the shops was hard pressed [to explain the discrepancy]."[12]

This film was displayed at the exhibition in Tokyo, which successfully attracted 30,000 visitors. Even after the exhibition in 1921, the film was kept at the office of the Japanese Metrological Society and a copy was loaned out upon request.[13] Following this success, the Society went on to make other promotional films and other events.

The next year, a similar but larger exhibition—perhaps the largest in the period – was held in Osaka. The materials displayed in this Osaka exhibition were compiled and published as a book. This book contains numerous illustrations, and shows us how seriously the Japan Society of Weights and Measures, backed by the Ministry of Agriculture and Commerce, tried to promote the diffusion of the metric system, seemingly targeting the Japanese middle class. The exhibition occupied a large space, and used several buildings to display its five sections. Each section was designed to explain some aspect of the metric system, and the importance of measurement in education, at home, in society, and in industry. One of the displayed posters showed the thermal efficiency of pots of different shapes under the title "Which pot is economical?" Another showed the scene of an elderly traveler arguing about his bill with the cashier of the hotel where he had stayed, while a departing ship was visible through the window. Under the title "A penny for an Englishman," the caption explained that the ever-exact Englishman was meticulous about one penny, even if his scheduled ship was departing from the port.

The exhibition on measurement held in Tokyo was part of a series

12. *Tokyo no Doryōkō Gyōsei Shiwa*, op.cit., pp. 484–486.

13. It was unfortunately destroyed at the great earthquake in 1923. Ibid., p. 486.

of special exhibitions at the Tokyo Educational Museum, which aimed at the scientific enlightenment of the wider public. The series was organized under the leadership of Gentarō Tanahashi, a museum specialist who emphasized the importance of visual displays in science. From 1916, the Tokyo Educational Museum held exhibitions on such themes as "The Prevention of Cholera," "The Great War and Science," "Domestic Science," "Time," and "The Improvement of Domestic Life." The last exhibition, which was intended to rationalize every facet of domestic life, led to the formation of the Association for the Improvement of Domestic Life with Tanahashi at its head, which subsequently organized similar exhibitions nationwide.[14] This and later exhibitions on measurement seem to have resonated with the movement to improve domestic efficiency.

6. The Conservative Reaction to the Metric System

When the ten-year moratorium for the enforcement of the metric system came to a close, a conservative group gathered to strongly oppose its compulsory enforcement. The leader of this group was a member of the House of Peers, Nagakage Okabe. He organized scholars and lawyers who opposed the enforcement of the metric system, and published pamphlets, one of which was titled, *A Collection of Opinions against the Enforcement of the Metric System*.[15]

Its opening essay was Okabe's "Opposing the Enforcement of the 'Metric System Law' in View of the Mission of Japan." His argument against the metric system, though seemingly naïve and unpersuasive in our eyes, reflected contemporary views on the relationship between the East and the West and the particular place of Japan. Before criticizing the metric system, Okabe discussed Japan's mission as the harmonization of the cultures of the East and of the West, the Eastern culture excelling in spirituality and the Western in materiality.[16] He

14. *Kokuritsu Kagaku Hakubutsukan Hyakunenshi*, op.cit., pp. 192–201.
15. Nagakage Okabe et al., eds., '*Mētoru*' *Hō Kyōsei Shikō Hantai Ikenshū* (*A Collection of Opinions against the Enforcement of the* '*Metric System*') (1933), unpublished.
16. Ibid., pp. 1–2.

pointed to the economic crisis in America and Europe from 1929, stating that "it was caused by the decline of the spiritual culture, despite the progress of science and material world, and it has resulted in a confusion of thought and ideology, which has led many Westerners to turn to Eastern spiritual cultures." After the Meiji Restoration, Japanese eagerly assimilated Western cultures and technologies, but Okabe believed it went to an extreme. He then criticized the adoption and enforcement of the metric system, for the system embodied Western science and its emphasis on industrial efficiency. The Japanese should not easily abandon native units of weights and measures such as *shaku* and *kan*, which were linked with, and indispensable in, everyday life in Japan. He respected the Meiji rulers' decision to keep the native *shaku* and *kan* system while defining them in terms of the metric units, and he condemned the 1921 Measurement Law which exclusively adopted the metric system.

Several scholars joined Okabe's conservative group. Chūta Itō, a notable architect and historian of Japanese architecture, stated that the design and construction of traditional Japanese buildings inherently required the use of the native scale, *shaku*, especially for specifying the size of wooden props and beams. Kiyotsugu Hirayama (1874–1943), an astronomer renowned for his theory of asteroid distribution, argued that there was nothing wrong with the parallel use of different measurement systems, or the use of non-decimal systems —as witnessed by our use of two logarithms, or our way of measuring time and angles. The seven-day week was by no means rational, and yet people experienced no inconvenience. Hirayama concluded that the use of *shaku* and *kan* did not need to be replaced by the metric system, and could remain useful and convenient in Japanese daily life. In the end, the opponents were not championing the exclusive use of native weights and measures. Rather, they were objecting to the compulsory conversion of every unit into the metric system under a pressing time schedule. Moreover, they did not necessarily agree with one another on all the details; the architect and the scientist may well have rejected Okabe's grandiose ideology. But their concerted opposition exerted significant influence on politicians at the time.

In response to this conservative opposition, a group of promoters of the metric system vigorously fought back. They edited a collection of pro-metric articles, *Opinions on the Metric System by Practical People*.[17] "Practical people" defended the adoption of the metric system against each objection raised by the opposition party. All land estates at the time were measured by the native system, and an opponent pointed out the enormous costs of calculating and rewriting all the registered numbers. But Kaichirō Imaizumi, the leader of the promotion group, estimated that the approximate cost of conversion would be around three million yen, which was within the government's capacity, and added that in any case the rewriting of the land register was not for the next year, but ten years away. Referring to the objections of the architect Itō, Imaizumi also argued that the size of wood materials could be rendered in metric terms, though not in round numbers, and that this would not in any way hinder traditional architectural construction. Another "practical man" referred to commercial reasons for adopting the metric system, stating that the adoption of the metric system would give Japan a better position to compete in trade with the United States and the United Kingdom, and to export to China and Manchuria, where the metric system was already employed.

The debate between the promoters and the opponents went to the floor of the Diet, but with no quick resolution. A few years later, the government finally decided to postpone the enforcement of the metric system until 1959.

7. Conclusion

I have surveyed the history of the introduction of the metric system from the Meiji Restoration to World War II. A notable feature of the metrological system in modern Japan was the coexistence of the three systems of weights and measures and the long persistence of the British yard-and-pound system, due to the strong reliance of Japanese

17. K. Yokoyama, ed., *Jissaika no Mētoruhō Iken* (*Opinions on the Metric System by Practical People*) (Osaka: Metoru Kyokai, 1934).

industries on British engineering. Against those who were used to the native or the British system, proponents of the metric system engaged in an active promotion campaign. And they were quite successful.

I called attention to the roles played by the graduates of the French Physics class and the Japanese Society of Weights and Measures. The French physics graduates were enthusiastic in introducing and establishing the metric system in Japan. The Tokyo Physics College they formed offered a training curriculum for the first officers at the metrological testing stations in local prefectures.

The Society of Weights and Measures was extremely active in promoting the popularization of the metric system. After the Measurement Law was established in 1921 and the metric system was formally adopted as the official unit system, the Society mobilized every effort to popularize both metric measures and, more generally, the ideology of measurement. It could be pointed out that the "time is money" ethos, so deeply ingrained in the mindset of most Japanese people today, had one of its historical roots in the Taisho era movement to improve social and domestic life and make it more efficient.[18]

Table 5.1: A chronological table of the history of metrology in modern Japan

Acronyms of the ministries
MF Ministry of Finance
MAC Ministry of Agriculture and Commerce
MHA Ministry of Home Affairs
MCI Ministry of Commerce and Industry

1869.11	Metric system under the control of the MF
1870.8	Section (MF) in charge of reform of the metric system
1871	New Coinage Law
1875	Law to regulate the metric system; MF proposed to join the treaty of international metric system but was opposed by MHA
1881	The enforcement of the metric system under MAC
1883	Committee (Ministry of Interior) to investigate the British and the French metrological systems
1885	Ministry of Agriculture proposes joining with the Convention of the Meter
1886	Japan joined the Convention of the Meter

18. See Chapter 1 on this historical problem.

1890	The meter and the kilogram standard prototype arrived in Japan
1891	The Law of Weights and Measures passed, relying on the metric system as its standard but using the terminology of the native system of weights and measures. Metric testing station was set up in each prefecture.
1892	Training would-be prefectural inspection officers in the MAC
1893.1	The Law of Weights and Measures enforced
1894	The establishment of the Great Japanese Society of Weights and Measures, which continued until 1903
1903	The Central Testing Station of Weights and Measures was established
1909	The amendment of the Law of Weights and Measures; approved the use of yard-and-pound
1911	The establishment of the Japanese Society of Weights and Measures (renamed the Japanese Society of Measurement in 1951)
1919.6	The Committee for the Investigation of Weights and Measures and Industrial Standardization was set up in the MAC
1921.4	The amended Law of Weights and Measures was passed
1922.6	The Exhibition of Measurement was held in Tokyo; the promotion film "Keitarō Nikki" attracted 30,000 spectators
1922	The Exhibition of Measurement was held in Osaka
1924	The law was enforced with a 10-year moratorium for the public sector and 20-year moratorium for others
1925	The metric system started to be used and taught in primary schools
1933.10	The Association for the Preservation of the Native Shakkan System was established
1933.12	The enforcement of the metric-system law was postponed
1938	The Committee for the Investigation of Weights and Measures was advised to admit the use of the native system
1939	The further amendment of the Law of Weights and Measures
1952	The Law of Metrology was established to enforce the metric system universally in the public from 1959

Table 5.2: Japanese native units as defined by the Law of Weights and Measures of 1891

Length		
bu	1/100 shaku	3.03 mm
sun	1/10 shaku	3.03 cm
shaku		30.3 cm (defined as 10/33m)
ken	6 shaku	1.82 m
jō	10 shaku	3.03 m
chō	360 shaku (60 ken)	109 m
ri	12,960 shaku (36 chō)	3927 m

Area		
bu or tsubo	6 shaku × 6 shaku	3.3 m^2
se	30 bu	99 m^2

Volume		
momme	1/100 shō	18.0 cm^3
gō	1/10 shō	180 cm^3
shō		1.804 liter
tō	10 shō	18.0 liter
koku	100 shō	180 liter

Weight		
bu	1/10,000 kan	0.375 g
momme	1/1,000 kan	3.75 g
kan		3.75 kg (so difined)
kin	160 momme	600 g

6

The Historical Evolution of Power Technologies*

Translation with revisions of "Dōryoku Gijutsu no Suii," in Tetsuro Nakaoka et al., eds., *Sangyō Gijutsushi* (*A History of Industrial Technologies*) (Tokyo: Yamakawa Shuppansha, 2001): 37–72.

Power technologies have formed the foundation of industrial technologies and modern society. In the West, watermills were widely used in medieval society, steam engines played a central role in the Industrial Revolution, and electric power station lighted cities and drove streetcars. These technologies were introduced into Japan from China and from the Western countries in different periods. They were brought to function in each historical context of medieval and modern Japan to drive mills, machines, ships, and trains. This chapter will survey the introduction, construction, and use of water, steam, and electricity power technologies in Japan. In addition, it will also see the use and development of wind power in prewar and postwar periods.

1. Water Power

Water Power in the Edo Period

Waterwheels were introduced from the Continent to Japan in the seventh century, and were used mainly to pump water for irrigation

* This chapter is a translation of a slightly shortened version of the chapter on the history of power technology in Tetsuro Nakaoka et al., eds., *Sangyō Gijutsushi* (*A History of Industrial Technologies*) (Tokyo: Yamakawa Shuppansha, 2001). The book covers other industrial technologies: mining, steel, machinery, transportation, textile, chemistry, information, and so forth. Its shorter version was also reprinted in Nihon Sangyo Gijutsushi Gakkai, ed., *Nihon Sangyō Gijutsushi Jiten* (Encyclopedia of the History of Industrial Technologies in Japan) (Kyoto: Shibunkaku Shuppan, 2007), which comprehensively covers the history of industrial technologies, including power technologies.

purposes. In the middle Edo period, water power was also used for extracting oil and cleaning rice. The staple food of Japan is rice, and flour was historically used only for several kinds of food, such as noodles. As a result, the demand for water power for milling flour was limited in Japan, unlike in other countries such as northern China.

In Japan, the use of oil lamps dates back to ancient times. Rapeseed was widely planted, beginning in the seventeenth century, and the extracted rapeseed oil made an excellent fuel for lamps. Water power was used to grind the rapeseeds, and the powdered seeds were steamed and squeezed to produce rapeseed oil.

Starting at the end of the seventeenth century, white rice became preferred to brown rice, and water power was widely used for polishing and converting brown rice to white rice. Polished rice was also needed for making saké (rice wine), and as the demand for refined rice wine increased in Edo city, more waterwheels began to be used. In the Nada area, around present-day Kobe, many waterwheels were used, both for grinding rapeseed, and, especially in the latter half of the 18th century, for polishing rice. In Nada, rice was typically polished and whitened by waterwheels for three days, and saké of good quality was produced in large quantities.

Water wheels were used for other purposes as well during the Edo period. The historian Tsutomu Demizu lists the uses of waterwheels during the Edo and later periods as follows:

> Pumping for irrigating rice fields, polishing rice, milling, making noodles, crushing clay for ceramics, stroking clay, washing potatoes, cutting woods, preparing tea leaves, thrashing, spinning cotton, making tobacco, making *konnyaku* (paste made from arum roots), pressing sugarcane, twisting threads, making starch, grinding rapeseeds, making dried bean curd, making agar, elongating copper, sending wind to bellows for metallurgical use, crashing saltpeter.[1]

Bellows were used to melt mined ores and iron sand. The unique Jap-

1. Tsutomu Demizu, *Suisha no Gijutsushi* (*A History of Technology of Waterwheels*) (Kyoto: Shibunkaku Shuppan, 1987), pp. 30–32.

anese method of iron making called *tatara* used iron sand, and required water powered bellows to melt it.

Another important function of waterwheels was their use for irrigation. Waterwheels provided a powerful motive power, and sometime disrupted the impartial allocation of water resource among farmers. This sometimes caused conflict among interested parties. For this reason, waterwheels were not used in summer and fall.

Waterwheels in Shibuya

Today, Shibuya is a prosperous shopping district crowded with young people. In the late Edo to Meiji periods, this area contained numerous waterwheels, along the Shibuya and Meguro Rivers. The area stood between a populated downtown area and farmlands. The waterwheels were used to polish rice for Edo citizens. Geographically, the region was on the boundary between the plateau of Musashino and the lower Edo area, and it abounded with steep slopes, providing excellent conditions for setting up waterwheels. Since the Tamagawa waterworks provided water to Shibuya River, the river contained enough water to run a number of waterwheels.

The novelist Doppo Kunikida, residing near Shibuya, described its landscape in 1898 as follows:

> Water flow runs through the garden and goes through the gate to cross the street and enter a forest. Out of the forest, the land is suddenly lowered and the roof of a small cottage appears. Its waterwheel rotates. There are many waterwheels around there, and this is a smaller one.[2]

The History of Waterwheels in Shibuya, written by local historians, records the historical change in use of each of the waterwheels in Shibuya, from the Edo to the Meiji period.[3] Most waterwheels were used for polishing rice in the Edo period, but they were converted

2. Doppo Kunikida, "Wakare (Departure)," in idem, *Musashino* (Tokyo; Shinchosha, 1949), p. 51.
3. Shirane Kinen Kyōdo Bunkakan, ed., *Shibuya no Suishashi* (*The History of Watewheels in Shibuya*) (Tokyo: Shibuyaku Kyōiku Iinkai, 1986).

and used for various industrial purposes during the Meiji period. For instance, the old waterwheel of the Ishida family, made in the 1730s, had been originally used for polishing rice, but was used in the early 20th century for crushing graphite to prepare lead for pencils. During the Meiji period, other wheels were used for making cotton cloth and silk threads, elongating copper, and grinding lenses. The conversion of waterwheels was approved by the government in most cases, except for as a method of producing gunpowder. These changes reflected the industrial condition of a rapidly modernizing Japan.

Waterwheels in the Meiji Period

Many modern textile factories in the Meiji period relied on water power. National spinning factories in Hiroshima and Aichi were furnished with Western waterwheels, as well as Western spinning machines. They were made of iron and therefore had a larger size and increased power. Many of them were constructed by French engineers at the Yokosuka Dockyard. Until the late 1870s, the power at factories was mainly provided by water.

In his book *Suiryoku Kaihatsu-Riyō no Rekishi Chiri* (*A History and Geography of the Development and Use of Water Power*), technology historian Yoshiyuki Sueo explains, in detail, the usage of waterwheels in the Meiji period, based on several historical documents.[4] The examination of historical documents led him to the conclusion that water was an important source of power to various industrial sectors throughout the Meiji period.

Waterwheels were especially used for industrial purposes during the second decade of the Meiji period. "Nōshōmu Tōkei Hyō (Statistical Tables of Agriculture and Commerce)" was compiled on the basis of several statistical investigations during the second and third decades

4. Yoshiyuki Sueo, *Suiryoku Kaihatsu Riyō no Rekishi Chiri* (*A History and Geography of the Development and Use of Water Power*) (Tokyo: Daimeidō, 1980). Sueo relies on such statistical records: "Kyōbu Seihyō," national statistics compiled by the General Staff Office of the Army, "Yamatokoku Suisha Shirabe (Investigation of Waterwheels in Yamato)," an investigative report on the usage of waterwheels around Nara and its vicinity, "Nōshōmu Tōkei Hyō (Statistical Tables of Agriculture and Commerce)," and "Kōjō Tsūran (The Survey of Factories)," compiled by the government

of the Meiji period. According to the data in the report, the total number of factories in the nation in 1886 was 942, of which 405 were furnished with motive force. Of them, 193 used waterwheels, 101 used steam power, and 111 used both water and steam power. Later statistics, from 1888, excluded factories without power. According to that report, the total number of factories with motive power had increased to 657. Of them, 239 had water power, 253 had steam power, and 164 had both types. The number of factories using water power subsequently decreased to one quarter by the end of the third decade of the Meiji period. Waterwheels, however, continued to be used as a source of motive power, especially at small factories.

Water Power Policy

Bureaucrats in the Meiji government followed a policy of promoting water power for industrial use. In introducing modern Western production technologies, they did not attempt to rely on steam power, which was prevalent in the Western countries, but tried to use water power for as long as possible. A Japanese visitor to the World's Fair in Vienna, Austria, in 1872, where the Japanese government officially participated and displayed its industrial products, expressed his opinion in the report on their visit:

> Our country abounds with coals and is capable of using steam power. But wherever it is possible to install waterwheels, we should do so to replace or assist steam engines... There is no place without water in our country. We should make full use of water and should not waste [coals] by using steam engines.[5]

In 1879, Masayoshi Matsukata, who was responsible for restoring the financial condition of the Meiji government, also made a statement supporting the development of water power. At the time, he was head of the Bureau of Promoting Agriculture in the Ministry of Agriculture and Commerce and hoped to promote the domestic spin-

5. Takenobu Hirayama and Yoshio Tanaka, *Ōkoku Hakurankai Sandō Kiyō* (*Proceedings of the Participation of the World Exposition in Austria*) (Tokyo, 1897), vol. 2, p. 88.

ning and weaving industry, and prevent an increase in the importation of cotton products. He pointed out that, at the time, waterwheels were used only for polishing rice and extracting oils and stated:

> There are waterfalls in places accessible by transportation and therefore possible to install a large machine. But they have only served as scenic views to amuse poets and painters and not as motive power for practical purposes. It goes without saying that this is wasting a heavenly gift, and failing to take financial advantage.[6]

The historian of technology Tetsuro Nakaoka emphasized, based on several case histories, that Meiji Japan succeeded in introducing Western technologies by using intermediate or "hybrid" technology, which was adapted to the economic and technical conditions of Japan at the time.[7] Use of water power to drive imported machinery could be considered as another example of such an intermediate technology. As will be discussed later, water power was also used for generating electricity. After the invention of the turbine, water as a source of electric power became particularly important to the Japanese economy.

2. Steam Power

The Attempt to Make a Steam Engine at the End of the Tokugawa Era

Even before the arrival in Japan of United States Commodore Matthew Perry in 1853, an attempt had been made to build a steam-driven ship. In 1844, the Dutch government conveyed the invention of the steam ship to the Tokugawa government, explained that the invention reduced the distance between countries, and recommended

6. Ōkurashō Daijin Kanbō, ed., *Matsukata Haku Zaisei Ronsakushū* (*Financial Papers of Count Matsukata*), repr. in Hyōe Ōuchi and Takao Tsuchiya, eds., *Meiji Zenki Zaisei Shiryō Shūsei* (*Collection of Financial and Political Documents in the First Half of the Meiji Period*) (Tokyo: Hara Shobō, 1978), p. 529.
7. Takeshi Hayashi, *The Japanese Experience in Technology: From Transfer to Self-Reliance* (Tokyo: United Nations University Press, 1990), p. 213.

opening up the country. The Japanese government did not follow the recommendation. However, Nariakira Shimazu, the feudal lord of the Satsuma clan, was strongly attracted to the steam ship and became interested in constructing one. He acquired a Dutch manual for building a steam engine and ordered scholars fluent in Dutch to translate the book. It explained the physical nature and action of steam, as well as the structure and function of a boiler, a steam engine, and a steam ship with a paddle wheel. He then ordered a group of scholars and craftsmen to construct an actual steam engine, based on this single textbook. They visited a Dutch ship in Nagasaki, viewed the internal mechanism and structure, and finally succeeded in making a small workable steam engine in 1855. Installing it on a small boat, they made the first Japanese steam ship, named Unkō Maru. It was a wooden boat with paddle wheels of 16m in length, and it greatly surprised invited guests when the boat they were aboard started running on its own.

Around the same time, the Saga clan also attempted to construct small scale models of a steam ship and a steam locomotive. Clan lord Naomasa Nabeshima established a factory complex called *Seirengata* and invited scholars and inventors, like Hisashige Tanaka, to construct the models. The group completed their construction in 1854. They then made the Satsuki Maru, a ship which used a small steam engine, and sailed it from Hayatsue to Nagasaki.

It is a long and difficult process to move from understanding a textbook on the construction of a steam ship to realizing the actual construction of such a ship. Though they had been able to make a small-scale model of a steam ship, craftsmen found it far more difficult to construct a practical full-scale ship. Late Edo engineers experienced this difficulty. Traditionally, sword-smiths and other craftsmen were engaged in metallurgical processes, but the technique they were accustomed to was different from that necessary to make the parts of a steam engine. When they constructed a model of a steam ship in Satsuma, the craftsmen made all of the necessary parts through forging, even though they could have made them more easily by casting. One of the participants in the project, Shiro Ichiki, quickly realized the difficulty and recommended that it would be better to purchase a ship from the Dutch. As he later recalled:

> Without iron machines, I realized that traditional craftsmen alone could never construct practical military steam ships, and immediately after my return expressed my opinion that the clan had better purchase a steam ship from Dutchmen.[8]

After the arrival of Commodore Perry, the Tokugawa government established the Naval Training Center in Nagasaki, with help from the Dutch government, and began building a modern navy. A ship for training was donated by the Dutch King William III. The ship, originally named the Soembing, was renamed the Kankō Maru, and became the first steam operated naval vessel owned by the Japanese government. The Tokugawa government then ventured to construct a steam ship by themselves and successfully made a steamer named Chiyodagata in 1866. The body of this steam ship was constructed at the Ishikawajima dockyard, and its engine was made at the Nagasaki Ironworks. To build it, the government purchased machine tools from the Netherlands. It took four years to complete its construction. Later, the Yokosuka Dockyard was established, under the direction of French naval engineers, on the eve of the Meiji Restoration, and the new government proceeded to build military steam ships. The dockyard's first ship was the Yokohama Maru, one of many ships that it went on to produce.

Steam Locomotives

Commodore Perry brought gifts of various modern machines to the Tokugawa government. A steam locomotive was one of them, which greatly impressed the Japanese people. They called the steam locomotive *okajōki* (steam on land). The Seirengata factory of the Saga clan was engaged in making a model of a steam locomotive, and the Choshu clan purchased a locomotive made in France. The British merchant Thomas B. Glover imported a large-scale model of a British

8. Shidankai, ed., *Shidan Sokkiroku* (*Stenographic Records of Historical Recollections*), no. 40 (Tokyo: Shidankai, 1895), p. 54.

locomotive and, after having displayed it in motion in Nagasaki, donated it to the Shogun. A plan was made to build a railroad between Edo and Yokohama, travelled by the locomotive, but the plan was not realized, due to the upheaval of the Restoration.

The British government officially recommended the construction of railroads to the new, post-Restoration Japanese government. The first railroad, between Shinbashi and Yokohama, was opened in 1872. After that, most locomotives were imported from Britain or the United States. The first domestic locomotive was made in Kobe, at a factory owned by the government bureau in charge of railroads, and was constructed under the direction of Richard F. Trevithick. In 1896, *Kisha Seizō Gōshi Kaisha* (Joint-Stock Company for Making Locomotives) was established. The construction of the first locomotive by Japanese engineers, without the assistance of foreign engineers, was completed in 1901, though various imported parts, such as wheels and axles, were used.

Throughout the end of the Edo period, and during the Meiji period, the primary use of the steam engine was for transportation. However, steam engines were also used at some factories. Nariakira Shimazu attempted to use steam engines, as well as waterwheels, to drive spinning machines. He imported machines (consisting of 3,640 spindles) to spin cotton threads in 1866, built a spinning factory driven by steam the next year, and began its operation, under the supervision of British engineers. In 1872, a spinning factory in Tomioka opened which used steam-driven spinning machines. Steam engines were also used at dockyards as a source of power.

Steam engines were also used in the mining industry. At the beginning of the Meiji era, the Takashima mine in Nagasaki introduced the use of steam engines for transportation, for lifting, and for driving factory machinery. The Chikuhō Coal Mine attempted to introduce steam engines for pumping in 1875, but was unsuccessful. The Shakanoo (目尾) Coal Mine in Fukuoka prefecture successfully introduced the use of steam engines for pumping in 1881, and other mines followed.

Domestic Production of Steam Engines

Attempts to make steam engines started at the beginning of the Meiji era. Craftsmen were successful at making small engines, but unsuccessful at making large ones. The first domestically-made large steam engine was constructed at the Shibaura Engineering Works, which was established by Hisashige Tanaka and which would later become the Toshiba Corporation. This 1300 horsepower engine was used to drive 40,000 spindles, at the Hyogo factory of the Kanegafuchi Spinning Company (Kanebo). According to *An Illustrated History of the Development of Steam Industry in Japan*, the Shibaura Engineering Works was not furnished with machine tools, and the construction of such a large steam engine for factory use must have been a difficult task.[9] This feat was accomplished by the engineer Tomokichi Yoshida, who worked both for Shibaura and Kanebo, and his success amazed engineering experts. However, this engineering success was a managerial failure for Kanebo. The manager of the Kanebo's Hyogo Factory recalled that the decision to use a domestic engine was "a big mistake." Although a large number of imported spindles arrived at the factory from England on time, the delivery of the engine by Shibaura Company was so late that Kanebo missed the important business opportunity created by an economic boom after the Sino-Japanese War. For factory managers like him, to import a whole set of machines, including a steam engine, from abroad would have been more reasonable.[10]

Unfortunately, the Meiji government did not pay much attention to the introduction and development of machine tools, which were needed to make machines precisely. This neglect subsequently led to the weakness of the Japanese machine industry.

The Problem of the Cost of Fuel

The use of steam engines at factories meant a need for fuel. For the

9. Watto Tanjō Nihyakunen Kinenkai, ed., *Zusetsu Nihon Jōki Kōgyō Hattatsushi* (*An Illustrated History of the Development of Steam Industry in Japan*) (Tokyo, 1939), p. 318.

10. See Jun Suzuki, *Meiji no Kikai Kōgyō* (*Machine Industry in Meiji Japan*) (Kyoto: Minerva Shobō, 1994).

daily operation of steam engines, factory managers had to purchase coal. As has been previously mentioned, during the Meiji era many factories employed water, instead of steam power, to drive their machines. This was mainly because the cost of coal was considered too high. At the time, silk was Japan's main export, and producing silk required the use of hot water, prepared by a boiler, to heat silkworm cocoons. Thus, at silk manufacturing factories, the implementation of steam engines should have been easy, due to the existence and daily use of boilers. Even so, few silk factories introduced steam engines.

The decision on whether or not to introduce steam engines depended on the availability of coal. Steam engines were relatively easier to use for transportation purposes, since locomotives and ships could move to ports and garages by themselves. To use steam engines at factories, however, meant transporting coal to factory sites. According to the estimate of Fuji Paper Making Company, the cost of installation of a waterwheel and a steam engine, in the later Meiji era, was almost equal, but the cost of operation and maintenance of the two was significantly different, about half of the cost of installation in the case of water power, but more than double the cost in the case of steam power. Most of the cost associated with steam power was due to the use of coal. For this reason, only a limited number of factories, like privileged national factories, and those near coal mines, introduced steam engines in the early Meiji era. However, as Japan's land and sea transportation network developed, and the price of coal decreased, the use of steam engines spread more widely among factories nationwide.

3. Electric Power

Building a Power Network in Meiji Japan

The construction and operation of an electrical power network requires a high level of knowledge of electrical engineering, and therefore such a project needs to include numerous electrical engineers and technicians who have studied at higher educational institutions. The

Imperial College of Engineering, established in 1872, played a role in producing such electrical engineers. It had the Department of Telegraphy, whose original purpose was to generate engineers to be in charge of the construction of an electric telegraphy system. The college's first professor of electrical engineering, William Ayrton, and his student assistants, constructed and powered arc lamps at the assembly hall of the college on March 25, 1878, the date now commemorated as the memorial day for electricity in Japan. With the development of an electrical network in the West, the department's focus turned increasingly to electric power technology, and it was renamed the Department of Electrical Engineering. During the 1880s, the senior theses of students of the department changed from those concerned with telegraphic inventions, like measuring devices, to those concerned with inventions related to power technology, such as incandescent lamps, dynamos, and power transmitters. Junsuke Miyake's thesis of 1888, for instance, was entitled "On Incandescent Lighting," and within it, he recorded his own experimental preparation and construction of a dynamo, a distribution facility, and of incandescent lamps.[11]

In 1883, Sakuro Yajima installed arc lamps on the street in Ginza and fascinated Tokyo citizens. He then established the Tokyo Electric Lamp Company in 1886, and started to distribute electricity in Tokyo city, through the establishment of power stations at four locations downtown: Kojimachi, Nihonbashi, Kanda, and Asakusa. The company invited an associate professor at Tokyo Imperial University, Ichisuke Fujioka, to join. A student of Ayrton, Fujioka had taken a position at the university, but accepted the company's invitation and resigned from the university to concentrate his work as engineering chief.

By 1891, Tokyo Electric Lamp Company was powering about 10,000 lamps, which included those in the Imperial Palace. After seeing the company's success in the power distribution business, entrepreneurs established companies in other regions of Tokyo, and in

11. Junsuke Miyake, "On Incandescent Lighting," unpublished diplomat essay, the College of Engineering, 1888, preserved at the library of Department of Electrical Engineering, the University of Tokyo.

other large cities, such as Kobe, Osaka, Kyoto, Nagoya, and Yokohama. The Edison Company of the United States provided direct-current generators to all of these new companies, except for one company, Osaka Electric Lamp Company. That company instead purchased an alternating-current generator from Thomson Houston Company. This decision was made by its chief engineer, Kunihiko Iwadare, who had studied electrical engineering in the United States, and had learned of the superiority of transmitting high voltage through an alternating current. After graduating from the College of Engineering, Iwadare had worked at the Bureau of Telegraphy, and went on to work at an Edison Company factory. Although he had worked at the Edison Company, he recommended that the Osaka Electric Lamp Company employ the alternating-current electricity offered by its rival. Whereas Edison Company distributed power through three electrical lines of 110 and 220 volts, Thomson Houston Company transmitted power through lines of 1000 volts. As Edison Company criticized the danger of high-voltage transmission, Tokyo Electric Lamp Company too criticized the dangerous use of high-voltage alternating current by Osaka Electric Company. Truthfully, high-voltage electrical transmission had caused some deaths. Following an increase in fatal accidents by electrification, the Ministry of Post and Telecommunication warned corporate suppliers and private users to deal with electricity more carefully and safely.[12]

Once power stations had been built in several places in Tokyo, a plan to build a larger power station was hatched. The new power station, equipped to generate 2000-volt alternating current, was built in Asakusa. Its dynamo was designed by Tokyo Imperial University Professor Hatsune Nakano and was manufactured by Ishikawajima Shipbuilding and Engineering Company. The dynamo generated three-phase 50Hz alternating current, which was distributed to various places in Tokyo. Subsequently, 50Hz became the de facto standard frequency for distributing alternating current to the Tokyo region.

12. Shigenori Katōgi, *Nihon Denkijigyō Hattatsushi* (*A History of Electric Industry in Japan*) vol. 1 (Tokyo: Denyūsha, 1916), pp. 657–669.

In the third decade of the Meiji era, a water power station was built in Kyoto city. It used water from the canal connecting the city to Biwa Lake, and installed an Edison dynamo to generate low-voltage direct current. In 1892, it imported an alternating current generator from Thomson-Houston Company and started to distribute alternating current to Kyoto city. In this decade, water power stations using river water were built in Hakone Yumoto, Nikko, Toyohashi, Maebashi, Kiryu, Sendai, and Fukushima.

Using Electric Motors

The use of electricity as a motive force only came into play after its use for illumination had been established. The *Ryōunkaku*, a twelve-story tower built in Asakusa in 1890, was furnished with an elevator driven by an electric motor, and at the third National Industrial Exhibition in 1890, an electric train ran within the site. However, the cost of running these machines was high. Motors and generators were investigated at the Imperial College of Engineering. The first domestically manufactured generator was made at the Miyoshi Denki Company in 1884. Ishikawajima Shipbuilding Company and Shibaura Engineering Works followed Miyoshi Denki in manufacturing generators and motors. At the Ashio Mine, electric motors were used for operating trains, lifting machines, and pumping, and the company started to manufacture motors in the 1910s.

The construction of street car lines in a city was important for the early development of a power network. Sakuro Yajima and Ichisuke Fujioka of Tokyo Electric Company planned and proposed to the government the establishment of a new street car company, Tokyo Electric Motor Company, but it was not approved, apparently because no experts in the Bureau of Railroads were able to judge the engineering adequacy of the proposal. Proposals made in other cities were also all turned down. The government experts worried not only about the safety of an electric railway, but also about the influence of aerial electric currents on telephone lines, and of the rails' currents on water pipes. The director of the Electric Testing Station, Ōsuke Asano, and other electrical engineers, such as Saitarō Ōi and Gitarō Yamakawa, were sent abroad to investigate the safety and plausibility of a street car system.

A street car was first officially approved and built in Kyoto in 1895. When the fourth National Industrial Exposition was held in Kyoto in 1893, a businessman named Bunpei Takagi proposed a plan for the construction and operation of an electric railway, and his proposal was approved for the first time by the Ministry of the Interior and the Ministry of Post and Telecommunication. In sanctioning the proposal, the government was most concerned with the safety of the streetcar itself. They set its speed limit at 25 km/h, and ordered the company to let a boy run before the streetcar so that he could warn walkers on the street. In Tokyo, streetcars were first built in 1903, between Shinabashi and Yokohama, and between Yurakucho and Kanda.

The Development of Water Power Generation and the Spread of Electricity

The History of Meiji Industry describes three periods in the development of electrical transmission, in its volume on electricity.[13] Until 1899, electricity was distributed only within the boundaries of a city. From 1899 on, electricity was transmitted beyond city boundaries. Finally, starting in 1907, electricity was transmitted between distant areas. Long-distance transmission lines were constructed when a large water power station was built in a mountain area, so as to transmit electricity to cities. The construction of these water power stations was needed because of the rise in price of coal, and consequently, of electricity. Yokohama Kyodo Electric Lamp Company, for instance, spent a quarter of its income on the purchase of coal in 1893, but had increased its spending to one half of its profits by 1897, which led to its decision to raise the price of electricity.

The Tokyo Electric Lamp Company recognized the need for water power, and investigated geographically suitable places for building stations. It also sent its chief engineer, Iwasaburō Nakahara, to visit and study American and European water power stations. Based on the results of these investigations, it constructed a power station in

13. Nihon Kōgakukai, ed., *Meiji Kōgyōshi, Denki Hen* (Tokyo: Nihon Kōgakukai, 1929), pp. 311–318.

Komahashi in 1907, which transmitted 110,000-voltage electricity to its substation in Waseda. The Komahashi station was furnished with six Swiss-made water turbines and six Siemens three-phase alternating current generators.

The late 1900s, despite an economic depression, saw an increase in the construction of water power stations. To search for sources of water power, the Special Bureau for the Investigation of Water Power for the Generation of Electricity was set up at the Ministry of Post and Telecommunication and executed a five year plan of surveying and investigating potential water resources throughout the country. Starting roughly in 1907, traditional steam engines were replaced by newly invented and more efficient steam turbines at power stations. Because of the expansion and improvement of the power generation facilities, the price of electricity dropped significantly, which, in turn, led to the rapid growth of the electric power industry.

In 1914, a large water power station was built by the Inawashiro Lake, and electricity it generated was transmitted through a long-distance line to Tokyo. After the establishment of this power station and long-distance line, the power distribution network was further expanded throughout the country. Water power generation companies started to target industrial customers. During the Taisho era, factories in various industrial sectors increasingly replaced steam engines with electric motors. The rate of diffusion of electrification in the spinning and weaving industry was 55% in 1919 and had jumped to 91% by 1923. By that time, that rate had become almost 100% within the machine industry.[14] Electricity was also used to refine copper and carbide through electric heating and electro-chemical reaction. The newly emerging electrochemical industry was becoming a large new customer of the electric power companies.

Unification of Power Networks and the National Management of Electricity

World War I brought an economic boom to Japan. With the rise

14. Teijirō Kanbayashi, "Nihon Kōgyō Denka Hattatsushi (The Development of Industrial Electrification in Japan," in Hirotake Koyama, Teijirō Kanbayashi, and Michitsura Kitahara, eds., *Nihon Sangyō Kikō Kenkyū* (*Researches on Japanese Industrial Structure*) (Tokyo: Itō Shoten, 1943): 149–308, on pp. 284–285.

in the demand for electricity, many water and steam power stations were constructed. After the establishment of the Komahashi power stations, other companies built power stations in the Kanto area and supplied electricity to the Keihin industrial region, along the coast of Tokyo Bay. However, following an economic recovery in Europe, Japan's exports decreased and its economy went into decline. The demand for electricity decreased, causing an overabundance. Market competition led to the consolidation of the power supply companies.

Until then, the power industry had been decentralized. Five hundred and ten companies generated and supplied electricity to Japan in 1915. Among them were five big companies: Tokyo Electric Lamp, Tōhō Electric Power, Ujigawa Electricity, Daidō Electric Power, and Nippon Electric Power. A plan was proposed to manage the whole electric power industry under the aegis of the government, and to create and operate a more rational and efficient system for the generation, transmission, and distribution of electricity. After World War I, the governments of the United States and Britain planned and constructed such a national system of electricity, connecting hitherto isolated networks. In Britain, a central electricity board was established to manage the nationwide network system, called the "National Grid." In order to manage the nation's electricity centrally, voltage and frequency, which widely varied from region to region, had to be standardized. In the United States, the New Deal policy was executed under President Franklin Roosevelt, and a large power generation facility was built at the Tennessee River Valley under the Tennessee Valley Authority.

In Japan, too, a national management plan was developed, modeled on the British Grid System. Government bureaucrats took the initiative in planning and realizing the national system. In 1937, a special investigative committee for electric power was set up to explore the possibility of a national system. As a result, the Electricity Management Act was enacted in 1938, and the Japan Electric Generation and Transmission Company (JEGT) was established, to manage the national electric power industry. Under this company, Japan was divided into nine blocks, for each of which a single power distribution company was responsible for distributing electricity.

The role of JEGT in the nationally managed power industry was to purchase electricity supplied by power generation companies, allocate electricity to distributing companies through JEGT's transmission lines, and if necessary, generate power through its own steam power stations. In 1939 and 1940, a shortage of rain caused a shortage of electricity and of coal, and the government further tightened the control of electric power.

Frequency was standardized in this period. Before the emergence of JEGT and the national consolidation of electrical power suppliers, numerous corporations had supplied and distributed electricity, with frequencies which varied from region to region. The Investigative Committee for the Standardization of Frequency had been set up after World War I, but it had reached no practical agreement on the national unification of frequencies, due to the high cost of realizing standardization. It was, however, agreed by the committee that eastern and western Japan should have two different standardized frequencies—50Hz and 60Hz. Only after World War II was over was this standardization realized.

Postwar Reorganization of the Electric Power Industry

After the war, the General Headquarters (GHQ) of the allied powers democratized Japanese society and reorganized its industrial institutions. Under the Government Section of the GHQ, the JEGT was disbanded and the nine distribution companies were allowed to become independent suppliers and distributors. The plan to establish a new company to "interchange electricity" between user companies was rejected because of its basic policy of disbanding all regulative institutions organized during wartime. The rise in the demand for electricity and the increasing need for new electrical resources led to the establishment of the Electric Power Development Company (EPDC), under the 1952 Act of Electric Power Development.

After its establishment, the EPDC received a government order to build a dam and water power station in the Sakuma region, on the Tenryū River. This was an area where a strong section of the river ran through a narrow valley. It was appropriate for power generation but a difficult place to construct a dam. To realize this project, the EPDC introduced large American transportation machines and cooperated with American corporations on a technical level, which led to the completion of the dam and power station within a remarkably short period. This project was held up as an example of successful technical cooperation with foreign companies. Under the government's electric power policy of "water first, steam second," dams and power stations were constructed in Tagokura, Okutadami, and Miboro (御母衣). However, with the discovery of oil fields in the Middle East, and the improvement in the efficiency of turbines, more emphasis was placed on steam power plants. The emergence of nuclear power further reduced the significance of hydroelectricity.

4. Wind power

Wind power has had a long history of use in the West, but was basically not used until the 20th century in Japan. In pre-war Japan, wind power attracted the attention of an electrical engineer, Tamaki Motooka. As an engineer in Navy, Motooka observed the shortage of electricity on small islands in the Pacific. He investigated German literature on wind power generation, and realized its usefulness not only for islands but also for many other geographical areas. He resigned from Navy, and became a member of the Continental Science Institute in Manchuria, where he surveyed wind conditions in the area and developed windmills for power generation and irrigation. He planned the construction of a large wind power plant in Manchuria towards the end of the war, but the costly plan was not realized.

After the war, the "Yamada" style of windmill spread throughout farms in Hokkaido and other regions. Developed by the engineer Motohiro Yamada before the war, the windmills were made of silver fir. As such, their blades were light enough to be driven by weak winds but strong enough to withstand strong winds. Yamada established the Yamada Wind Power Electric Facility Company and produced small three-blade windmills which were able to generate 300W. The windmills were sold for 60,000 yen, but farmers were able to buy them at a government-subsidized price of 20,000 yen.

Because of the high performance and low price of the windmills, the company was able to sell 10,000 units in Hokkaido in the 1950s. The windmills were also exported to Africa and South America.

After the oil price shock of 1973, American and European countries developed further wind power technology as an alternative source of energy. In the United States, NASA developed large new windmill models, using synthetic materials for the propeller blades. In Japan, the Science and Technology Agency launched the Fūtopia (Wind Utopia) project, and the Ministry of Industry and International Trade (MITI) launched their Sunshine project, to develop technologies for alternative energy. In response to this government policy, the New Energy Development Organization (NEDO) was established in 1980. In the 1980s and 1990s, Tokyo and Tohoku Electric Power Companies constructed experimental wind power facilities, such as the "wind park" built on Tappi Cape in 1991.

We have seen above the development of various power technologies in Japan. The observation of their historical evolution shows the close relationship between their technological development and the economic, social, and geographical conditions of the period and the area they were used. Water power was continued to be used even after the steam power technology was introduced chiefly for economic and geographical reasons. The first construction of steam engines by Japanese engineers alone was a difficult engineering venture, whose technological success was regarded as a managerial failure. The development of electric power network was deeply influenced by the availability of water power stations and long-distance transmission lines. They evolved in the contemporary social milieu, shaped by it technical and economic conditions and in turn helping to construct a new Japanese society.

7

The Trans-Pacific Flight Project and the Re-examination of Aeronautical Standards

Reprint of "The Contest over the Standard: The Project of the Transpacific Flight and Aeronautical Research in Interwar Japan," *Historia Scientiarum*, 11 (2002): 226–44.

1. Introduction

There are six volumes of old albums preserved in the library of the Research Center for Advanced Science and Technology (RCAST) of the University of Tokyo.[1] They are collections of newspaper clips whose dates ran from November 1, 1923 to April 6, 1928. The albums were apparently made by a professional company at the request of the Aeronautical Research Institute (A.R.I.), the predecessor of RCAST, and all the thousands of newspaper clips contained in them concerned with various aspects of aviation, especially adventurous and record-making flights all over the world.

Among other topics domestic and abroad filling the pages of these albums, there was a project which dominated Japanese journalists' attention in the years of 1927 and 1928. It was a project organized by the Imperial Aeronautic Association to make a non-stop flight across the Pacific Ocean. The plan of this project was conceived immediately after Charles Lindbergh's successful trans-Atlantic flight in May 1927. Lindbergh's flight is so famous in the world that everyone

1. *Zenkoku Shimbun Kirinuki* (*Kōkū*) (*Clips from National Newspapers* (*Aviation*)), 6 vols. (1923–28), preserved at the Research Center for Advanced Science and Technology, the University of Tokyo. The dates stamped on clips starts on 1 November 1923 and ends, abruptly, on 6 April 1928. The albums were professionally made by the Tokyo Kirinuki Tsūshinsha (Tokyo Clipping Communication Company), apparently at the request from the Aeronautical Research Institute, and all newspaper clips are neatly arranged in each page of album. I appreciate Takashi Tachibana for drawing my attention to these albums.

knows his historic event today. But how about the flight across the Pacific? Here we encounter a question: while Lindbergh first flew across the Atlantic, who first flew across the Pacific? Most people, do not know its answer nor have ever thought about such a question. But considering the enthusiasm generated by Lindbergh, we wonder why the first trans-Pacific flight did not generate such enthusiasm nor was remembered in history in countries like Japan adjacent to the Pacific.

Though forgotten from our collective memory, there certainly were many attempts to fly across the Pacific in the 1920s and the early 1930s, and they did attract nationwide attention in Japan. And as the existence of the albums testifies, such adventurous attempts also caught the attention of A.R.I. engineers. Indeed, some of its members were deeply involved with the trans-Pacific project of the Imperial Aeronautic Association. Although the story of the trans-Pacific project was usually not referred to in a history of the A.R.I., the frustrated experience with the project had an important influence on its following activities, especially the development of a long-range monoplane called Kōkenki.

This chapter concerns with this forgotten episode of the trans-Pacific project and the involvement of A.R.I. engineers with the project. The most controversial issue arising from this project was over the applicability of the aeronautical standard to different types of airplanes. The chapter will discuss a process in which an aeronautical standard was constructed through their involvement with the project. It will particularly discuss the work of the young A.R.I. researcher Hidemasa Kimura who investigated the engineering foundation of aeronautical standards.

2. The Origin and Early Activities of the Aeronautical Research Institute

The organized effort of aeronautical research and development in Japan originated at the establishment of the Special Research Committee on Military Balloons (臨時軍用気球研究会) in 1909, a year after the Wright brothers' flight demonstration in Europe. Despite its name, it aimed at broader investigation on aeronautics, and consisted of civilian and military experts on aeronautics, including the physicist Aikitsu Tanakadate, the mechanical engineer Ariya Iguchi, and the meteorologist Seio Nakamura. Tanakadate and Iguchi were professors at the Schools of Science and Engineering of Tokyo Imperial University, and their early involvement with aeronautical matters worked in a sense as a seed for the later expansive growth of aeronautical research at the university.

In response to the rapid development of aviation, Tokyo Imperial University set up in 1916 a Committee for the Investigation of Aeronautics to explore the possibility of establishing an engineering department as well as a research institute solely devoted to the research and development of aeronautics. Its seven members gathered from Departments of Physics, Chemistry, Mechanical Engineering, and others, and they proposed a plan to establish such a department as well as a research institute. Not only making a plan, they also initiated aeronautical researches such as the one by Iguchi's team who carried up an engine to the top of Mt. Fuji to test its performance at high altitude.

In 1918, the university established the Aeronautics Department at the School of Engineering, and the Aeronautical Research Institute in Ecchūjima adjacent to Tokyo Bay.[2] They selected this location for the convenience to test seaplanes. The construction of its whole facilities including a wind tunnel and several factories was completed by 1920. In 1921, the Institute became an "attached institute" which had a more independent institutional status inside the university than the former adjacent institute. However, owing to the demolition of the new Ecchūjima facilities by the great Kanto Earthquake in 1923, the university had to rebuild the facilities, and decided to relocate the Institute to Komaba, about 10 km west from downtown. The facilities of the renewed Institute were substantially expanded from the original institute at Ecchūjima. It now included several factories,

2. For an institutional history of the Aeronautical Research Institute, see Nihon Kōkū Gakujutsushi Henshū Iinkai (the Editorial Committee of the History of Aeronautical Research in Japan), ed., *Nihon Kōkū Gakujutsushi* (*The History of Aeronautical Research in Japan*), *1910–1945* (Tokyo: Maruzen, 1990), pp. 259–290.

some with most advanced machine tools, and consisted of the following eight research divisions: physics, chemistry, metallurgy, material, wind tunnel, engines, aeroplane, and instruments. But their construction was not completed until 1931, and until then, most members either worked at Ecchūjima or the university campus in Hongō without good experimental facilities.

In 1921, the year when the A.R.I. acquired a new institutional status, an Aeronautical Council (航空評議会) was established at the Ministry of Education as an advisory body to "discuss important issues relating to basic researches on aircraft and advise relevant Ministries."[3] It may be comparable to the Advisory Committee for Aeronautics in Britain or the National Advisory Committee for Aeronautics in the United States, but it seemingly had more limited functions than those foreign committees. The A.R.I. did not function to work under the Aeronautical Council, but many of its members served at the Council's committees and were naturally engaged in related work back at the A.R.I. There remain no archival records of minutes of Council meetings. The Annals of the Ministry of Education in those years only recorded the list of topical issues discussed at the Council from 1921 to 1925.[4] Most of the topics discussed at the Council concerned with the standardization of various aspects of the development and production of aircraft: units and instruments of aeronautical measurement, nomenclature of Japanese technical terms, measurements at wind tunnel, methods of testing materials to be used aircraft construction, and so forth.

The standardization of wind tunnel experiments, for instance, was a research item discussed at the Council in 1923 and 1924. The Annals in 1928 recorded that the Subcommittee on the Standardization of Wind Tunnel Experiments held seven meetings in the year to discuss the matter.[5] The topic was in fact a hot issue among aeronau-

3. See Takehiko Hashimoto, "Kōkūkenkyūjo to Kōkūhyōgikai (The Aeronautical Research Institute and the Aeronautical Council)," in Sentanken Tankendan, *The Third Report* (Tokyo: Sentanken Tankendan, 1997): 22–26.

4. *Nihon Teikoku Monbushō Nenpō* (*The Annals of the Ministry of Education of Imperial Japan*), 50(1921–22), p. 315, 51(1922–23), pp. 366–367, 52(1923–24), p. 388, 53(1924–25), p. 392, 54(1925–26), p. 403.

5. *The Annals of the Ministry of Education*, 57(1928–29), p. 489.

tical engineers around the world. By then each country constructed numerous wind tunnels which generated indispensable aerodynamic data for aircraft design. But the structure and performance of wind tunnels were widely varied, and it was strongly hoped that test results at one wind tunnel could be consistently compared with those at another tunnel. For that, the standardization of wind tunnel testing was necessary. The above mentioned British Advisory Committee for Aeronautics consequently organized an international project of comparing the performance of major wind tunnels of all leading countries using one and the same experimental wing model.[6] The work required theoretical and experimental knowledge to perform exactly the designated measurement. The A.R.I. in Japan was a suitable institution to perform such a project and did conduct the experiments.

The Council also discussed the standardization of licensing the airworthiness of aircraft in 1925. The examination of the airworthiness of aircraft required to tackle with complex problems. It had to consider the structural strength of aircraft body and wings, aerodynamic forces, and meteorological conditions. For this complex problem which required theoretical and practical considerations, A.R.I. members were involved with the work to examine its standardization. And the standard of airworthiness became a controversial issue in the project aiming at trans-Pacific flight.

3. The Project of a Trans-Pacific Flight

After the First World War, aviators attempted to fly farther from Europe and America to conquest skies around the world. The atmosphere of the age is well expressed in the title of the book by the aviation historian C.R. Roseberry, "The Challenging Skies: The Colorful Story of Aviation's Most Exciting Years, 1919–39."[7] Aside from

6. On this project, see Takehiko Hashimoto, "The Wind Tunnel and the Emergence of Aeronautical Research in Britain," in Peter Galison and Alex Roland, eds., *Atmospheric Flight in the Twentieth Century* (London: Kluwer Academic Publishers, 2000): 223–239.
7. C.R. Roseberry, *The Challenging Skies: The Colorful Story of Aviation Most Exciting Years, 1919–39* (Garden City: Doubleday, 1966), Chapter 18 "Wide Rolls the Pacific."

the non-stop trans-Atlantic flight of Charles Lindbergh, there were many stories of adventurers in the sky, most of which are now forgotten from our memory. *Challenging Skies* as well as the albums of the A.R.I. are filled with such episodes of successes and failures of pilots who attempted to make long-distance flights over continents and oceans.

Of these challenging flights, Charles Lindbergh's trans-Atlantic flight was certainly a highlight. Two weeks after the failed attempt by French aviators in early May in 1927, Lindbergh flew across the Atlantic, and accomplished the first non-stop flight over the ocean on May 21, 1927. This success at the opposite side of the world spurred enthusiasm of the whole Japanese nation and the event turned their nationwide attention to the possibility of the flight over the Pacific Ocean, as *Tokyo Asahi Newspaper* put it: "What remains Is Pacific! Who Flies First? Now Center of Attention."[8] Immediately after Lindbergh's flight, an Aeronautical Social Meeting (航空懇談会) was organized in Japan, calling in aeronautical leaders from the Army, the Navy, the Aeronautical Bureau (航空局), the Imperial Aeronautic Association (帝国飛行協会), and the A.R.I.[9] The primary purpose of the meeting was to discuss the possibility of the flight across the Pacific. And at its second meeting, the members agreed on the possibility and decided to conduct the project at the initiative of the Imperial Aeronautic Association.

The Imperial Aeronautic Association, the key player of this project, had been established in 1913, three years after the first Japanese flight of an airplane at Yoyogi, Tokyo. Its financial basis relied on the original donation from the Imperial family, and subsequent donations from private individuals and institutions. Its primary function was to promote every aspect of aeronautical activities in Japan, organizing events of flight and representing Japan at the International Aeronautic Federation. And three years before this 1927 project was launched, it

Yūsuke Edo, *Misu Bidoru wa Tonda: Nihon kara Tonda Taiheiyo Muchakuriku Ōdanhikō* (*Miss Beadle has flown: Non stop Trans-Pacific Flight from Japan*) (Tokyo: Kenyukan, 2000).

8. *Tokyo Asahi Shimbun*, May 27, 1927.

9. *Tokyo Asahi Shimbun* and other newspapers, on May 28 and May 29, 1927.

had already raised the fund of two million yen to promote various aeronautical projects including the flight across the Pacific.

The Association publicly announced in June 1927 its plan of the trans-Pacific project. To plan and prepare the project, it set up an Investigative Committee which included as its member, A.R.I. Professor Shūhei Iwamoto, an expert in structural analysis. At this moment, a sense of optimism prevailed among members of the Committee. A naval officer associated with the project theoretically calculated the distance of a possible route and the performance of best available airplanes, and concluded that it was not difficult to accomplish the flight of the route.[10] Based on this preliminary consideration, the Association officially decided to proceed the project in August, and established an Executive Committee for the project. Its member included Iwamoto and another A.R.I. professor, Toyotarō Suhara. Under this Executive Committee, it set up an Engineering Committee, where Iwamoto and Suhara respectively took charge of the airplane's body and its engine.[11] Soon afterwards, the Imperial Aeronautic Association announced its more specific plan to make the flight by a Japanese airplane with four Japanese pilots, and finally designated the Kawanishi Machinery Manufacturing Company as a company to design and construct the airplane.

Kawanishi Machinery Manufacturing Company (川西機械製作所) was established in 1920 as a spin-off company from Nihon Airplane Manufacturing Company (日本飛行機製作所) which had been established by Chikuhei Nakajima three years earlier. After the conflict between Nakajima and the cofounder Ryūzō Kawanishi, the company split and both entrepreneurs established independent companies. Since its foundation, Kawanishi produced excellent K series airplanes designed by its chief aircraft designer, Eiji Sekiguchi. Of them, K-6 and K-8B succeeded in their flight all around Japan in 1924, which

10. *Tokyo Nichinichi Shimbun*, July 8, 1927.

11. Mineo Yamamoto, "Taiheiyo Ōdan no Omoide (A Recollection of the Trans-Pacific Project)," in *Kawanishi Ryūzō Tsuikairoku* (*Recollections on Ryūzō Kawanishi*) edited and published by Shin Meiwa Kōgyō Company in 1956. Shin Meiwa Kōgyō Company is the successor of Kawanishi Machinery Manufacturing Company, and Kawanishi Ryūzō was the founder and longtime president of this original company.

was a small-scale version of the previous successful flight around the world by American aviators.

Kawanishi Company also had been establishing its close relationship with the A.R.I. The A.R.I. member Masami Ono joined Kawanishi by the time when Kawanishi initiated the design work of the trans-Pacific airplane, and even after he had left A.R.I., kept in touch with the Institute frequently contributing papers to its journal.[12] Students of Aeronautics Department at Tokyo, too, visited Kawanishi to receive apprentice training from its practicing engineers. Kawanishi also invited the world-famous aeronautical engineer Theodore von Kármán in 1927 and 1928. Born and educated in Hungary, Kármán had investigated aerodynamics at the Göttingen University under Ludwig Prandtl and was widely known for the concept of "Kármán vortex street."[13] Kármán was then a professor at the Technical Institute of Aachen, and, just after his acceptance to visit Japan, received an invitation from California Institute of Technology, where he would be settled several years later. Kawanishi invited him to design and construct its new wind tunnel. For its construction, he needed his assistant and called, Erich Kayser, from Aachen.[14]

Kármán was not directly involved with the trans-Pacific project, but assisted the design of the propeller of the airplane. The airplane was mainly designed by Kawanishi's chief designer Sekiguchi. It was Kawanishi's twelfth plane, therefore designated as K-12, and later named as Sakura. It was a two seater monoplane whose structural design was based on K-9. Its cantilever wings were wooden structure covered with cloth and plates, while its body was made of riveted

12. *Jiji Shimpō*, September 27, 1927, reports Ono as a Kawanishi engineer who participated the design work together with Sekiguchi and Theodore von Kármán. Masami Ono contributed numerous papers to Journal of the Aeronautical Research Institute as its faculty member until 1925, and as a Kawanishi engineer from 1928. He measured aerodynamic performance of the model of Kawanishi, K-7 for instance, at a wind tunnel. Masami Ono, "Huto-Zikken no Hokoku (A Report on Wind Tunnel Experiment)," *Miscellaneous Works of the Aeronautical Research Institute*, no 16 (1925): 395–410.

13. Paul Hanle, *Bringing Aerodynamics to America* (Cambridge, Mass.: MIT Press, 1982).

14. Theodore von Kármán and Lee Edson, *The Wind and Beyond: Theodore von Kármán, Pioneer in Aviation and Pathfinder in Space* (Boston: Little, Brown and Company, 1964), p. 131.

metal tubes and covered by cloth. And it had a large fuel tank inside its body around its center of weight.[15] The proposed design of the airplane was displayed at the Examination Committee of the Imperial Aeronautic Association. A few days later, the design was approved by the members of the Engineering Committee of the Association,[16] and Kawanishi proceeded to receive an approval from the Aeronautical Bureau.[17]

Receiving the official approval, the project started with full steam from November 1927. But it needed money. According to its preliminary estimation, the cost of the project including the award would amount to seven hundred thousand yen.[18] Because it was a private association and did not receive the fund from the government, the Association had to make a nationwide fund-raising campaign. And the campaign should be vigorous considering the amount of the cost. Accordingly, it founded an association of supporters for the project and attempted to collect donations from the public.[19] Newspapers functioned as useful media for this campaign. They frequently reported about donations from a variety of people, wealthy and poor, old and young. Even a criminal in prison sent one and a half yen to the Association, a newspaper reported, assuring the Association that the money was not foul because it was from his ill mother to have him buy bread.[20] Children spared their stipends and sent them, while the Imperial family, municipal governments, and aristocrats donated a large amount of money.[21] As a part of this campaign, an exhibition on this trans-Pacific flight was held at a department store, and attracted

15. *Nihon Kōkūki Sōtokushū* (*All Japanese Aircraft*), vol. 3 Kawanishi Hiroshō Hen (Kawanishi and Hiroshima Arsenal) (Tokyo: Shuppan Kyodo Sha, 1982), pp. 30–33, 71–73; *Nihon Kessakuki Kaihatsu Dokyumento: Sekkeishano Shōgen* (*Documents of the Development of Excellent Airplanes in Japan: Testimony of Designers*), (Tokyo: Kantōsha, 1994): 81–82.

16. *Jiji Shimpō,* September 27 and 28, 1927.

17. *Osaka Mainichi Shimbun*, October 1, 1927.

18. *Chuo Shimbun*, June 14, 1927. The Board of Trustees of the Imperial Flight Society officially sanctioned the project in August 1927. *Tokyo Asahi Shimbun*, August 5, 1927.

19. *Kokumin Shimbun*, September 21, 1927.

20. *Osaka Asahi Shimbun*, November 1, 1927.

21. E.g. *Osaka Mainichi Shimbun*, November 27, 1927, and *Hochi Shimbun*, November 29, 1927.

hundreds of people as well as donation.[22] It was a national event, or it was to be.

4. The Battle over the Standard: the Association vs. the Bureau

A grave problem emerged over the project in early February of 1928.

The Aeronautical Bureau of the Ministry of Communications, which was in charge of various aeronautical standards, claimed that the Kawanishi airplane was too weak to meet the standard of airworthiness set by the Bureau in the previous year.[23] The representative of the Bureau and leading members of the Committee for this project, including the two A.R.I. professors, discussed the matter. According to newspapers, the Bureau side concluded that its wings and body were not strong enough to satisfy the new official requirement; the Kawanishi side, on the other hand, counter-argued that the constructed plane aimed only at the single purpose of flying across the Pacific, and therefore argued that it did not necessarily have to satisfy the official standard set by the Bureau for general airplanes.

The Rule of Testing Aircraft established in 1927 required that the wings of the airplane should withstand the force represented by the following load factors.[24] Here the airplane was divided into three categories: the first for ordinary transportation, the second for record making, and the third for acrobatic flight. And the rule covered three different cases in which the center of pressure on the wings is forward, central, and rear, respectively. The report of *Chūgai Shōgyō Newspaper* on February 14, 1928, referred to more technical details of the problems of the Kawanishi airplane in that it was below the standard at all

22. *Jiji Shimpō,* November 15, 1927.
23. *Chuo Shimbun, Miyako Shimbun*, on February 3, 1928; *Hochi Shimbun, Tokyo Asahi Shimbun, Kokumin Shimbun, Chūgai Shōgyō, Jiji Shimpō*, on February 4, 1928; *Osaka Mainichi Shimbun*, on February 5, 1928.
24. "Kōkūki Kensa Kisoku (The Rule of Testing Aircraft)," Ordinance No. 9 of the Ministry of Communications in 1927, in *Hōrei Zensho* (*The Collection of Ordinance*) (1927), no. 4, pp. 40–70.

the three cases. As shown in Table 7.1, the load factors required for the airplane of the second category were 4, 3, 1.2 for those over 5 tons. But the strength of K-12 were lower than these limits. In the third extraordinary case, in which the plane dropped vertically, the standard coefficiency for the airplane of the second category was 1.2, while that of the Kawanishi plane was 0.45.[25] Kawanishi engineers reportedly argued against these judgement, claiming that the standards which the administration relied upon was the decade-old international standard, and further proclaimed that Kawanishi based their calculation on the new theory especially through the assistance of a German aeronautical engineer named Rennetz whom they recently invited.[26]

Table 7.1: The designaed load factor to calculate the strength of wings [From Aricle 16 of "Kōkūki Kensa Kisoku (The Rule of Testing Aircraft)," Ordinance No. 9 of Ministry of Communication in 1927, in *Horei Zensho* (The Collection of Ordinance) (1927), no. 4, p. 42.]

1. The case in which air pressure exerts on the front part of the wings

	weight < 1t	1t ≤ weight < 5t	5t ≤ weight
Category 1	7	7 to 5	5
Category 2	5	5 to 4	4
Category 3	9	9 to 7	7

2. The case in which air pressure exerts on the central part of the wings

	weight < 1t	1t ≤ weight < 5t	5t ≤ weight
Category 1	5.25	5.25 to 3.75	3.75
Category 2	3.75	3.75 to 3.00	3.00
Category 3	6.75	6.75 to 5.25	5.25

3. The case in which air pressure exerts on the rear part of the wings

Category 1	1.5
Category 2	1.2
Category 3	2.5

25. Measured results in the other two cases varied from position to position of the wings, but all results were below the standard. For the first case, they were 2.5, 2.25, 2.9, which were below 4, and for the second case, 2.5, 1.45, and 1.95, which were below 3.
26. *Yamato Shimbun,* February 17, 1927.

Representing the Executive Committee, Iwamoto visited the Kawanishi factory informing them of the Committee's tentative conclusion and investigating himself the conditions of the airplane and its construction. On his return to Tokyo, they held another meeting where they had a seven-hour long heated debate.[27] Having admitted that the plane under construction had structural weakness, Iwamoto proposed that it should be used for destruction test, a test through deforming its components, and that two more planes should be constructed for the experimental flight and for the trans-Pacific flight. After the debate, the Committee concluded that another plane should be constructed and if the Kawanishi insisted, the second plane could attempt the trans-Pacific flight. A few days later, the Committee discussed with Kawanishi, which finally answered to redesign and construct the second airplane in cooperation with Suhara and Iwamoto and other Committee members, and to attempt to make the flight with this second plane.[28]

In the meantime, one of the four selected pilots training for the trans-Pacific flight was killed by an accident during a flight near a hill in a foggy weather.[29] The death of the pilot led to the compromise of the Aeronautical Bureau to permit the construction of the second plane only with minor modifications from the original design. Kawanishi also agreed to redesign the plane and to make it meet the Bureau standard.[30] The structural problem was temporarily solved and other problems on the engine and other components were to be checked at the A.R.I. They also started to consider shortening the distance of the flight course. The original route from Tokyo to Seattle was now changed to the new one from Hanasaki, the eastern end of Hokkaido, to Sitka, the southern end of Alaska, which substantially reduced the flight distance.[31]

Iwamoto and Suhara kept close contact with Kawanishi to modify the design. They intensively worked on calculation to modify the

27. *Tokyo Nichinichi Shimbun*, February 18, 1928.

28. *Osaka Mainichi Shimbun*, *Osaka Asahi Shimbun*, February 28, 1928.

29. *Osaka Mainichi Shimbun, Hochi Shimbun, Tokyo Nichinichi*, March 1, 1928.

30. *Osaka Asahi Shimbun*, March 18, 1928.

31. *Kokumin Shimbun*, March 21, 1928..

design, frequently visiting Kobe with Iwamoto's assistant Hidemasa Kimura.[32] The reports at newspapers became confounding during this month. As Iwamoto told reporters, some essential matters were kept secret. The prospect of the project reported in articles at newspapers oscillated between optimism and pessimism. While they were working on the redesigning calculation, Kawanishi had already accelerated the construction increasing the number of its staff mechanics and the amount of payment for them. And it turned out that the process of construction of the plane was so advanced that it was no longer possible to adjust its design to the new specification resulted from the calculation of the two professors.[33] To solve this problem, it was suggested that the plane should fly with the speed not as high as the two professors assumed in their calculation, consequently making it stand the required structural strength, but the reduction of the speed caused the decrease of the cruising range.

On April 4, the Engineering Subcommittee held a six-hour-long meeting on the problem, and Executive Committee Chairman Yamada announced a statement on the conclusion of their discussion.[34] According to the calculation by its members, the cruising range of the strengthened second airplane would be 5,500km. But this calculation was based on the condition that the airplane was examined as the first type of the airplane categorized in the standardization of airworthiness by the Aeronautical Bureau. Although the Kawanishi plane evidently should be categorized as the second type, the Subcommittee conjectured that if it was approved as a second type airplane, it could not be put into practical test of flight performance. Therefore, they decided that they first made and tested the plane as the first type, and that they would later modify it as the second type so that it will increase its cruising range. According to their calculation, whereas its range would be only 5,500km when it was the first type, its range would increase up to 8,150km if modified to the second type. Hav-

32. *Osaka Asahi Shimbun, Chuo Shimbun*, March 20, 1928. Iwamoto did not state explicitly the condition of the work to the newspaper reporters, but he stated that he may have to come to Kobe every week to solve technical problems piece by piece.

33. *Chūgai Shōgyō Shimbun*, March 31, 1928.

34. *Jiji Shimpō, Chūgai Shōgyō Shimpō, Tokyo Asahi Shimbun*, April 5, 1928.

ing adopted this expediential policy, they decided to postpone the final conclusion until the actual flight test of the first airplane would be performed. At the same time, the airplane was named as "Sakura" meaning cherry.[35]

The construction of the first plane was completed by mid April 1928, and its components were transported to Kagamigahara Airfield in Gifu prefecture, where the reassembled no. 1 airplane started its flight test from May 18.[36] Its preliminary tests did not bring about good results, however. It occasionally damaged its parts during the test, and its performance was not so good as Kawanishi had claimed.[37] Because of the poor performance of the first plane, they came to infer that the second plane would also have the flight range as short as 5,700km, though its construction was just completed.[38] Because of this conclusion based on the official flight test of the first plane, the Committee concluded that the original plan of the trans-Pacific flight should be changed so that the second plane with the shorter cruising range could attain a new goal.[39]

The construction of the second plane was almost completed in June, but its flight test was postponed until August for unknown reasons, thereby generating a suspicion among journalists that a grave problem was recognized and discussed hidden behind the official statements of the Committee.[40] Its flight performance was tested during August.[41] On September 5, the Executive Committee held a meeting to discuss the test results and the prospect of the project. Their publicly announced conclusion was to continue its performance test increasing its weight up to 5 ton, and to receive the certificate of airworthiness from the Aeronautical Bureau.[42] However, no news was informed on the matter for more than a month. On October 30, newspapers reported a sudden news on the resignation of

35. *Jiji Shimpō, Chūgai Shōgyō Shimpō,* April 6, 1928.

36. *Tokyo Asahi Shimbun*, May 18, 1928.

37. *Tokyo Asahi Shimbun*, May 18, 19, 20, 23 and June 1, 9, 15, 17, 29, 30.

38. *Tokyo Asahi Shimbun*, July 2, 3, 4, 1928.

39. *Tokyo Asahi Shimbun,* July 8, 1928.

40. *Tokyo Asahi Shimbun*, June 16, 1928.

41. *Tokyo Asahi Shimbun*, August 4, 10, 16, 28, 1928.

42. *Tokyo Asahi Shimbun*, September 6, 1928.

the trustee members of the Imperial Aeronautic Association.[43] Because of the failure of the project, the members of its Board of Trustees once resigned and gathered again to restart the board. On November 8, the council of the Imperial Aeronautic Association held a meeting, and concluded that it entirely reset the project.[44] Although they stated that they decided to continue, the new plane should be redesigned holding the design competition. The date and course were not set, but *Tokyo Asahi Newspaper* speculated that the flight would be postponed until the year after next. As the original project failed, the Executive Committee was disbanded, the remaining pilots dismissed, and the ill fated Sakura dismantled.

The Association also stated in 1929 to plan to make the flight by the next summer or fall, but it was never done.[45] Despite its determination to make another attempt, the Association gave up the second-round project as well by December 1929. It had considered the possibility to use a modification of a German airplane which had been offered to the Association. It was told to have a flight range over 6,000km, and the Association expected it to fly over 8,000km through some improvements. But all approached manufacturing companies responded that such an improvement was impossible. The problem derived from its structural strength. Its flight test showed that it would withstand against the required load factor only for the first fourteen to fifteen hours. The representative of the Association thus stated to reporters that if the administration modified the safety coefficients, they would venture to fly, but he commented that such a chance was improbable.[46] The final complaining words from the Association pointed to the crucial point of the problem—the legitimacy and appropriateness of the standard.

43. *Tokyo Asahi Shimbun*, October 30, 1928.
44. *Tokyo Asahi Shimbun*, November 9, 1928.
45. *Tokyo Asahi Shimbun*, March 1, April 12, and August 6, 1929.
46. *Tokyo Asahi Shimbun*, December 13, 1928.

5. Hidemasa Kimura on the Essence of Standardization

Through the personal involvement of its, the A.R.I. had close relationship with the project of the trans-Pacific flight. Iwamoto and Suhara were responsible members of the project, and had to tackle with engineering problems deriving from the project. Iwamoto, in particular, was involved with the crucial analysis of structural strength of the airplane. In September 1928, Iwamoto gave a lecture on the trans-Pacific project at a lecture hall of Tokyo Imperial University.[47] It attracted more than seventy people for its audience which was twice as many as its ordinary attendants. Although only the title and not the content of his lecture was recorded in the *A.R.I. Journal*, he probably explained about the present difficult situation of the project as well as technical details of the calculation on structural strength and of the theoretical estimate of the cruising range of the airplane.

Besides Iwamoto, several faculty members and students at Tokyo Imperial University were also engaged in related engineering work. According to the recollection of Mineo Yamamoto who graduated Aeronautics Department at Tokyo in 1928, Ogawa at A.R.I.'s Aircraft Body Department made loading tests of components of the K-12 airplane, and Shigenao Kaneko at Aeronautics Department assisted the calculation of its strength.[48] Hidemasa Kimura, a fresh graduate from Aeronautics Department, also worked under Iwamoto on the structural calculation and experiment. Whereas his classmates, including the future Zero designer Jirō Horikoshi, went to private aircraft companies and administration after their graduation, Kimura continued his scholarly study at the graduate school and became a research associate at the A.R.I. The first job given to him was the examination of the strength of the components of Sakura.[49] He was engaged in the problem of calculating the strength of the modified version of Sakura, and if necessary made experiments of the strength of materials.

47. *Journal of the Aeronautical Research Institute,* no. 62(1929), p. 552.

48. Yamamoto, op.cit., p. 147. Yamamoto refers to the name Agawa, but this must be Ogawa.

49. Hidemasa Kimura, *Waga Hikōki Jinsei* (*My Life Devoted to Airplanes*) (Tokyo: Nihon Keizai Shimbunsha, 1973), p. 90.

Born in 1904, Kimura spent his entire life devoted to design and construct airplanes, as is explicitly shown in the title of his autobiography, *My Airplane Life*.[50] Since when he had witnessed at his childhood historic flights near his home in Tokyo, he had been fascinated with the airplanes and had determined to become an aeronautical engineer. When he finally entered Aeronautics Department of Tokyo Imperial University, he recalls in his autobiography, he was too glad to sleep staying up whole night to build an airplane model. This young airplane enthusiast privately subscribed the German journal *Flugsport,* and read it while commuting in train every morning and evening. The scene caught the attention of an A.R.I. Professor Taichirō Ogawa, who encouraged Kimura to visit his laboratory in Ecchūjima in 1921, two years before the Kantō Earthquake. Ogawa was then engaged in the investigation of the structure and strength of various types of captured German and Austrian airplanes sent to Japan.[51] While assisting Ogawa, he noticed specific structural characteristics of supportive wing planes of a German airplane, on which he wrote an article in *Journal of the A.R.I.*[52] During this period, Kimura and his classmate were introduced through Ogawa to Kawanishi Company and was sent to work under the airplane designer Eiji Sekiguchi. They visited its factory at Kizugawa in Osaka, and tried to redesign the Kawanishi K-3 airplane so that they could switch its engine from a German to an English one. Kimura recalls that although the supervisor Sekiguchi "corrected many points and severely criticized" the results of the students, they managed to pass his strict check.[53] Kimura thus received invaluable practical instructions

50. Ibid.

51. Ibid., pp. 71–73. Taichirō Ogawa, et al., "Doku Ō Ōshū Hikōki Chōsa, Dai Ippō (The Investigation on German and Austrian Captured Airplanes, Part 1)," *Journal of the Aeronautical Research Institute*, no. 14(1925): 329–358; Part 2, ibid., no. 21(1926): 176–201; Part 4, ibid., no. 24(1926): 334–370.

52. Hidemasa Kimura, " Doku Ō Ōshū Hikōki Chōsa, Dai Sanpō, Eruron no Sekkeini Tsuite (The Investigation on German and Austrian Captured Airplanes, Part 1, On the Design of the Aileron)," *Journal of the Aeronautical Research Institute*, no. 23(1926): 286–298; "Dai Gohō (Part 5)," Ibid., no. 25(1926): 421–438.

53. Hidemasa Kimura, *Waga Hikōki Jinsei* (*My Life Devoted to Airplanes*) (Tokyo: Nihon Keizai Shimbunsha, 1973), pp. 73–74.

from the future designer of Sakura.

Involved with the trans-Pacific project under Iwamoto, Kimura was now in a position to assist the examination of the airplane designed by his former instructor at Kawanishi. Because the main wings of Sakura were made of wood, he tested the strength of the wood material with Iwamoto. As Kimura recalls, Iwamoto even suggested that Kimura continue his research on structural analysis of wood as his dissertation topic, but he did not follow this suggestion because the problem was so complicated.[54] Years later, Kimura published with his collaborator an article on the results of his research on the strength of wood and its standardization which he had initiated for the trans-Pacific project.[55] The table of the results of his experiment appears to be so usefully and frequently consulted that its pages are entirely worn out in the copy preserved at the RCAST library. For his experiment, he used for this experiment a Canadian spruce of 2.6m diameter and 2.1m length, cut it methodically into one-hundred-and-four pieces, and measured its shrinkage when pressed. In part based on Kimura's such structural investigation, the second version of Sakura passed the test of the Aeronautical Bureau. During this work, he also recalls that he frequently commuted between Tokyo and Kobe with Kawanishi engineers to discuss the problem.[56]

The trans-Pacific project ended up with the failure. The two planes were constructed, modified to pass the official test of airworthiness, but did not obtain the expected cruising ability. The project was over, but it left a fundamental and complex problem to concerned engineers: the reconsideration of the aeronautical standard so that it be applied more appropriately and efficiently to the actual practice of aviation. The work required the substantial reexamination of the presupposition of the existing standards. After the failure of the project,

54. Kimura, *Hikōki Jinsei,* op.cit., p. 93.

55. Hidemasa Kimura and Yoshiro Udo, "Hikōkino Sekkeini Hitsuyōna Mokuzaino Seishitsu (Characteristics of Wooden Materials Necessary for the Design of Airplanes)," *Journal of the Aeronautical Research Institute*, no. 101(1933): 1–54.

56. Kimura, *Hikōki Jinsei*, op.cit., pp. 93–94. As has been stated above, the assistant of Iwamoto referred to on newspapers when he visited Kawanishi in April 1928 was most probably Kimura.

Kimura proceeded from the specific investigation of the structural strength to this fundamental problem of the standardization of the strength of the airplane. For that purpose, he initially examined various national and international standards of the strength of the airplane and reached the conclusion that the German standard established as recent as in 1929 was most advanced of all.[57]

Iwamoto and Kimura published an article on the newly established standards on the strength of the airplane body.[58] Iwamoto was chairman of the committee on the airplane body of the Aeronautical Council under the Ministry of Education. As was mentioned earlier, the Aeronautical Council's basic function was to investigate various aeronautical standards and related works on standardization, and the A.R.I. played an important role to assist its work which was critically important at the early stage of aeronautical development in Japan. Its work naturally included the standardization of strength of airplanes which some professors like Iwamoto had been engaged in before the fiasco of the trans-Pacific project. According to the opening statement of the article coauthored by Iwamoto and Kimura, Iwamoto took the initiative to reformulate again the standard, and the Council held more than one hundred meetings to reach an agreement on its final form. To do it, they relied on foreign aeronautical standards as well as opinions of notable designers and manufacturers actively working in Japan, to which Kimura certainly contributed an important service. The outcome of this long discussion, the new Regulation of the Strength of the Airplane Body, first explained about the division of the five categories of the airplane with different degrees of strength. And it gave an additional comment on the relationship between these five categories and the uses of the airplane. The first weakest category was only permitted for those planes intended for making record or

57. Hidemasa Kimura, "Doitsu Hikōki Kikaku Kyōdo no Kenkyū, Sono 1 (A Research on the German Standard of the Strength of the Airplanes, Part 1)," *Journal of Aeronautical Research Institute*, no. 77(1931): 58–74; idem, "Sono 2 (Part 2)," Ibid.: 173–197. Kimura consulted French, English, American, Italian, Japanese, German, and International standards of the strength of the airplanes.

58. Shuhei Iwamoto and Hidemasa Kimura, "Kōkū Hyōgikai Hikōki Kitai Kyōdo Kitei Kaisetsu (Explanation on the Air Council Standard for the Strength of Airplanes)," *Journal of Aeronautical Research Institute*, no. 97(1932): 695–760.

research. The second for the cargo and postal planes. The third for passenger and practice planes, and the fourth and fifth for acrobatic planes. To make this standard, they based their discussion on several recent investigations including those done at the A.R.I. such as Taichiro Ogawa's research on the strength of wing parts.

After his involvement with the reformulation of the standard of airworthiness, Kimura wrote two short articles in which he discussed the "essential points" of the standardization of the strength of airplane body, in a sense, a philosophical aspect involved in this engineering problem. In the first article "The Rationalization of Load Factor," he first emphasized that the standard strength necessarily derived from the compromise between safety and economy, and the standard only determined the minimum required strength of the airplane.[59] He continued to explain about the actual procedure to determine the minimum standard of the strength. He discussed how to estimate the amount of load on the airplane body and its components and the structural condition of these components to withstand the load estimated. The minimum possible standard was to be determined as the maximum value of these loads among all possible cases.

In so doing, Kimura emphasized the contingent factors inherent in this quantitative estimation of the load factors. He divided various contingent factors into three categories: the specific characteristics of an individual airplane, of an individual pilot, and of weather at each day and location. As to the characteristics of the maneuvering operation of an individual pilot, he referred to the experiment of Richard V. Rhode at the National Advisory Committee for Aeronautics in the United States, which made several pilots fly three types of airplanes, and which concluded that each pilot having distinctly different sensitivity to maneuvering. Each pilot flew three airplanes and operated the same maneuver to pull them up to large angle of attack. Rhode's experiment showed that the deviation of the acceleration over different pilots exceeded that over different airplane. In addition, the same pilot

59. Hidemasa Kimura, "Fuka Jōken no Ichibu: Hikōki Kyōdokikaku Honshitsuron no Ichibu (The Rationalization of Load Factor: A Part of the Essential Discussion of the Standard of the Strength of the Airplane)," *Journal of Aeronautical Research Institute*, no. 99(1932): 814–20.

would maneuver differently under different circumstances, most notably under different meteorological conditions. Although engineers could develop the airplane design to standardize the characteristics of the airplane, it could be difficult to standardize the pilot's performance and the meteorological conditions. It was therefore inevitable to make the standards more and more complicated. Kimura suggested that after the load coefficient had been decided, pilots should keep the acceleration within the limit of that decided value. For that purpose, he suggested that the instrument to indicate the acceleration of the plane would help a pilot to keep it within the safe limit of acceleration.

After he wrote this article, Kimura received a question from an engineer at Aichi Tokei Company on the inevitability to complicate the aeronautical standard. In response, he wrote a second article on what he conceived as the essential point of the standard.[60] In it, he first contrasted the standard of the strength of the airplane in the United States and Germany. Whereas the German standard tended to be more complicated since it considered load factors as close as possible to reality, the American standard tended to be simpler even though it made the airplane heavier and stronger. In the American standard, the load factor of diving, for instance, was determined and applied to all categories of airplanes. But Kimura commented that this uniform application of the standard would necessarily cause some redundancy for certain types of airplanes. He thus regarded the American standard inferior to the German one, despite its simplicity. In conclusion, he stated that before the standard reach an ideal simplicity, it should first be rationalized in the sense that it should take into account different conditions of various cases more appropriately and efficiently, even though such rationalization necessarily led to the complexity of the standard.

Kimura's paper on the strength of wood shows the ways in which he analyzed structural strength and perceived the function of the standardization. Following the new German standard, the new Japanese standard determined the minimum strength of the materials basically

60. Hidemasa Kimura, "Fuka Jōken no Kan-yaku: Hikōki Kyōdokikaku Honshitsuron no Ichibu (The Simplification of the Condition of Load Factor: A Part of the Essential Discussion of the Standard of the Strength of the Airplane)," *Journal of Aeronautical Research Institute*, no. 103(1933): 143–145.

by the limit of elasticity of the materials. Metals and woods have elasticity, and conform to the Hooke's law up to some point called the limit of proportionality. There were, however, another method to determine the limit of elasticity. It was to measure the remaining deformation, the amount of deformation which did not disappear even after the applied force was returned to zero. The new German standard designated that the strength of all materials be the force causing a remaining deformation to be 0.02 percent of the total length of the tested material. The Japanese standard established in July 1932 designated, in a slightly different way, that the strength be the force causing the remaining deformation to be 2 percent of the total deformation of the material. Referring to the possibility of other candidates for the definition of the elastic limit, Kimura concluded from this investigation that it was difficult to determine which point was to be defined as the elastic limit, and that they should check whether these candidate definitions could work well in actual design practice. The standards were after all decided by the convention of the authoritative committee. Kimura considered that engineers should take into account this conventionality of standards in applying them to actual design practice.

6. Kōkenki and A26 as the A.R.I.'s Follow-up Projects

In 1932, the A.R.I. decided to be engaged in the project of the design and construction of an airplane to make a world record of longest distance. The story of the development of this airplane named "Kōkenki," meaning the airplane of A.R.I., has been recounted in the recently published book by one of the then A.R.I. members, Kiyoshi Tomizuka.[61] Tomizuka states that the origin of the Kōkenki project

61. Kiyoshi Tomizuka, *Kōkenki: Sekai Kiroku Juritsu eno Michi* (*The Airplane of the Aeronautical Research Institute*) (Tokyo: Miki Shobō, 1998). The book is based on the manuscript of Tomizuka Kiyoshi and its content is edited by Seiichi Awano who worked with Tomizuka at A.R.I. in prewar years. Nihon Kōku Gakujutsushi Iinkai, ed., *Tōdai Kōkūkenkyūjo Shisaku Chōkyoriki, Kōkenki* (*The Long Range Airplane of the Aeronautical Research Institute of Tokyo Imperial University, the Airplane of the A.R.I.*) (Tokyo:

derived from these two professors Iwamoto and Suhara. Both professors were involved with the previous trans-Pacific project by the Imperial Aeronautic Association, but Tomizuka does not mention the specific connection between the two project. A recollection of Mineo Yamamoto, another A.R.I. member, more explicitly states the motivational link between the two projects:

> A.R.I. Professors Iwamoto and Suhara, who had worked as members of the Executive Committee of the Imperial Aeronautic Association for this trans-Pacific project, felt strongly their responsibility after the failure of Sakura, and, triggered by this, planned the development of a long range airplane. Together with A.R.I. Director Chuzaburo Shiba, they proposed the experimental construction of a long range airplane to the Ministry of Education. This became motivation for later developing Kōkenki and making the world record of the longest flight distance.[62]

As is recounted in this recollection, it is natural to assume that Iwamoto and Suhara became eager to construct a long range airplane and that they persuaded Shiba to pursue the project.

For the project of the development of a long range monoplane, the A.R.I. received 500,000 yen from the Ministry of Education. Kimura now as a formal associate of the A.R.I. was engaged in the project. In his autobiography, he refers to some criticisms raised on the project by university scholars and military officers: some stated that scholars without practical experiences could not construct such an airplane, and other that university professors should devote their energy to scholarly research. Whereas Kimura does not concretely describe such criticisms, Tomizuka provides a substantial account of the inside story. Tomizuka confesses in his book that younger members including himself in fact were opposed to this project. They even made a plea to new Director Koroku Wada that the project was illegitimate and difficult to be realized without modifications. Despite their criti-

Maruzen, 1999), reproduces technical documents with some historical accounts.

62. Yamamoto, "Recollection of Trans-Pacific Project," op.cit., p. 153.

cisms, the project started in the spring of 1934. Tomizuka briefly mentions about the process of the selection of the basic design of the airplane. Sakura made by Kawanishi was one of them, but the idea was rejected, because its performance was not as good as expected, and because Kawanishi was on the side of Navy whereas the A.R.I. had closer relationship with Army. A company which emerged at this selection process was Tokyo Gas Electric Company, which was making such products as automobile and airplane engines, and it agreed to manufacture the airplane designed by the A.R.I. The chief designer at the Tokyo Gas Electric was a former engineer at the French airplane manufacturing company, DeWoitine. Accordingly, the basic design of the planned airplane closely followed its monoplane, D33. The only notable difference between the two was to make the new airplane's gears retractable. The retractable gears became widely used during the 1930s. But when the A.R.I. plane was planned, they were not popular and the modeled DeWoitine D33 was without retractable gears, because its wings were too thin to hold them. Banri Hirotsu, who was in charge of the design and construction of this retractable gears, consulted American aeronautical journals, and adopted the design which used ropes to retract the gears. But this work turned out the bottleneck of the whole project. The retraction necessitated the complex mechanism owing to the already fixed design of the wing construction. Tomizuka discusses retrospectively that designers of other parts should have compromised for the sake of the gear designer so that the wing would have a enough space for the appropriate position. However, the work of the wing design had been already finished, and director Wada decided to do with the problem of gear design with minor modification without changing the already fixed wing design.

Tomizuka provides an adequate institutional analysis on the cause of this technological problem. For a large engineering project, it is necessary that the project leader should take an initiative to judge the total efficiency of the project as a system. The leader thus should have to order the decrease of efficiency of some components so as to increase the efficiency of other parts. However, the A.R.I. consisted of fairly independent departments, and the role of the director was no more than a reconciliator when it came to the details of the component design. The problem of the retractable gears delayed the whole project one year. The initial construction of the airplane was completed and tested in April of 1937, but the retractable gears were immediately damaged. To redesign it, Tomizuka was called in and successfully redesigned. The complete airplane was thus made in December that year. Its flight was waited until May 1938 following advice of meteorologists. And on May 15, it attained the record of 11,651 km after its 63 hour flight.[63]

The success of Kōkenki was followed up, by the project of A26. In his autobiography, Kimura recalls that during the process of the performance test of the Kōkenki, he came up with many new ideas about further improvement of the design of this plane.[64] A few years later, Kimura's dream became realized. In 1940, the A.R.I. was approached by the Asahi Newspaper Company which proposed to develop and construct a long range airplane.[65] The A.R.I. responded affirmatively, and many of its members started to be involved with the new project. At the first meeting, President of the Asahi Newspaper Company stated that the proposed airplane, later named as A26 standing for Asahi and the first two digits of the year in the new century of the Japanese calendar, should have a cruising range of 15,000 km to fly from Tokyo to New York with 3 to 5 crew members.

Thirty five year old Kimura was responsible for designing important parts of the airplane. According to his autobiography, he considered that the aspect ratio of its wings was a key factor in designing the new airplane. The project was conducted by the two divisions of engineers working on the airplane body and the engine, and the division of the airplane body consisted several subcommittees including the basic design, propeller, structure, seat, material, and instruments.

63. The record was superseded by an Italian airplane next year. Takehiko Hasimoto, "Kōkenki," in Nihon Sangyo Gijutsushi Gakkai, ed., *Nihon Sangyo Gijutsushi Jiten* (*Encyclopedia of the History of Industrial Technology in Japan*) (Kyoto: Shibunkaku Shuppan, 2007): 248–249.

64. Kimura, *Hikōki Jinsei*, op.cit., p. 142.

65. On this project, see ibid., pp. 140–147, and Nihon Kōkū Gakujutsushi Iinkai ed., *Wagakuni Kōkū no Kiseki: Ken 3, A-26, Gasu Tābin* (*The Orbit of Japanese Aeronautics: Ken 3, A-26, and Gas Turbine*) (Tokyo: Maruzen, 1998), pp. 123–227.

Kimura participated all these subcommittees. At the divisional meeting of the airplane body, they discussed the appropriate aspect ratio and decided it to be 11 after the comparison between 10 and 13. For that decision, Kimura studied the function of the cruising range taking into account a variety of aerodynamic and structural factors and reached this conclusion.

As for the standard of the strength, it was discussed at a meeting of the division of the airplane body that the standard of the strength in principle was to follow the standard designated by the Aeronautical Council. But it also added that any inappropriate items in the official standard to be applied to the long range airplane should be investigated at the subcommittee of structure and modifications should be proposed.[66] The problem over the standard which had been crucial at the trans-Pacific project was in a sense built in as a constitutional factor in the project conducted at the A.R.I. For that, Kimura certainly should have played a crucial role.

7. Conclusion

I have shown above that though entirely forgotten from our memory, the trans-Pacific project of the Imperial Aeronautic Association after Lindbergh's success in trans-Atlantic flight developed into a national event, partly due to the successful effort of the propagation committee of the project as well as of editors of various national newspapers. It however did not become a historic event and quickly disappeared from pages of newspapers after the frustrating failure of the project. The constructed two airplanes for the project only showed poor performance, and the project was entirely halted.

Many historical accounts of this project blame the Aeronautical Bureau for its too rigid application of the newly established standard of airworthiness to these airplanes designed for special purpose. Kawanishi side claimed that their airplane should be able to make the

66. The minute of the first meeting of the Division of Airplane Body held on March 18, 1940. Ibid., p. 132.

flight at their calculated strength. Yamamoto at the A.R.I. more specifically recalls that the Bureau regarded the Kawanishi plane in the different category from the one usually allocated for special purpose planes. Consequently, the compromised planes gained their redundant weight and decreased their cruising range. However, close reading of newspaper clips tells us that the real story was not so simple as accounted by Yamamoto. At its initial test, the Aeronautical Bureau regarded the plane as the second category, and yet it concluded that the strength was below the standard. And later on the Executive Committee decided to register the plane initially as the first category, but apparently the Bureau refused to permit the change of its category despite the Committee's intention. Besides, we could say from the side of the Bureau that their members duly followed the recently established the aeronautical standard, and apply it strictly to the Kawanishi plane. Their conduct was ethical. It was so for sensible engineers, considering the possibility that the imperfect plane would have flown and disappeared over the Pacific, and the disastrous effect of such an accident on the recognition of Japanese engineering.

The crux of the problem centered around the standardization of the structural strength of the airplanes. Iwamoto and Kimura at the A.R.I. sharply realized the problem, and initiated the fundamental analysis of the engineering problems of the standardization. Kimura closely studied the newest German standard of airplane structure, and compared it with the American one. He concluded that the German one was more efficient though more complicated, while the American one was simpler but less efficient. He judged so, because he realized the fundamental conflict between standardization and individuality. Standardized airplanes cleared minimum safety standards, but necessarily had redundant performance in specific conditions. The consideration on these characteristics of the standard setting led to the selection of the German standard, and the new Japanese standard thus basically followed the German one.

Kármán who visited Kawanishi to assist its engineering work including the construction of its wind tunnel and the design of the propeller of Sakura, made a few comments on the Japanese characteristics of engineering work in his autobiography. He recalled an episode at Kawanishi that its technicians followed what was designated on Kármán's drawing so exactly that the constructed apparatus became useless having the two holes which did not meet. Realizing this Japanese tendency of the "slavish imitation," he stated he came to emphasize the importance of originality while in Japan. At its footnote, he added a comment after the war he witnessed the good performance of the Zero:

> Japan's reputation for copying the designs of other nations led a number of foreigners to conclude that Japan would never be a first-rate power in the air. But Japan startled the world when she unveiled the Zero, an excellent fighter plane in World War II. The result was the discovery that Japan had learned not to copy slavishly but to select the best aspects for imitation. So while I urged the Japanese to do original work when I was there, and I think this was the correct approach for them, I must admit now that talent for copying sometimes can lead to surprisingly good results.[67]

Kimura at the A.R.I investigated the standard of airworthiness precisely as Kármán characterized Japanese engineering in this footnote. He compared and examined German and American standards, and selected the German one to follow closely in order to develop the Japanese original standard. Although the selection was reasonable on the standpoint of making higher performance airplane, it would be possible to point out that the selection of complex standard made it more difficult to attain mass producing manufacturing system in Japanese aircraft industry.

Based on these experiences, the A.R.I. succeeded in making two long range airplanes in the 1930s and the 1940s. The A26 plane was originally designed to fly from Tokyo to New York over the Pacific Ocean, but was unable to do so because its construction was not completed until a year after the Japanese attack on the Pearl Harbor. Its aim to attain friendship between the two countries was unrealized due to the war.

67. Kármán, op.cit., p. 132.

The answer to the trivial quiz stated in the introduction of this chapter was Clyde Pangborn and Hugh Harndon. They succeeded in making two-day-long non stop trans-Pacific flight from Sabishiro in Hokkaido to Wenatchee in Washington State in October 1931. Yusuke Edo, who has written a book on the story of their accomplishment, analyzes the reasons of their success as well as of its quick neglect in history. He calls attention to Pangborn's skillful operation as a pilot, and to the political backdrop of increasing antagonism between Japan and the United States which finally led to the war.[68] During the difficult flight, Pangborn, a noted acrobatic pilot, hanged out of a window and dropped ices stuck on a wing by a stick. After he had flown over the Pacific and finally made risky landing without wheels at Wenatchee, he allegedly offered to his waiting mother the apple he had brought across the ocean, saying, "Friendship from Japan."[69]

68. Edo, op.cit, pp. 182–184 and 191.
69. Edo, op.cit, p. 189.

IV. University, Industry, and the Government in Postwar Society

8

Science after 1940

Recent Historical Research on Postwar American Science and Technology

Reprint of "Science after 1940: Recent Historical Researches and Issues on Postwar American Science and Technology," *Historia Scientiarum*, vol. 8, no. 1 (1998): 87–96.

The Cold War is over. However, historical studies of the Cold War are now actively under way. The 1992 issue of *Osiris*, entitled "Science after '40," focused on papers about the history of science and technology during and after World War II.[1] The emergence of large-scale sciences during this century has been discussed in articles collected in *Big Science*.[2] With the financial support of the NSF, a workshop including a dozen historians was held to discuss "science, technology, and democracy during the Cold War."[3] Following that, good amounts of historical works are being done about science and technology during the postwar and especially the Cold War period. [4]

The central issue in these works is concerned with the role of the military in the postwar history of American science and technology. This chapter introduces some of these historical works and the important interpretive issues raised in these historical studies. I will first

1. Arnold Thackray, ed., *Science after '40, Osiris*, second ser. vol.7 (1992).
2. Peter Galison and Bruce Hevly, eds., *Big Science: The Growth of Large-Scale Research* (Stanford: Stanford University Press, 1992).
3. "Science, Technology, and Democracy in the Cold War and After: A Strategic Plan for Research in Science and Technology," *A Report Prepared for the National Science Foundation*, n.d. The workshop was held in September 1994.
4. This paper does not aim at a comprehensive survey of recent historical research on this topic. For those who are interested in a more extensive list of recent literature on this theme, consult the bibliography provided at the following web site: <http://www.cmu.edu/coldwar/bibl.html> (as accessed on 26 January 2009). This site was created by the staff of Carnegie Mellon University and provides a variety of useful information about historical research about science and technology during the Cold War.

briefly survey the history of American science and technology during and after the war, and demonstrate how the military increased its role in funding scientific and engineering research in this period. Then, I will discuss some of the interpretive issues raised by these historical studies.

1. American Science and Technology after 1940

During World War II, American scientists and engineers were mobilized to develop a variety of weapon systems and received an enormous budget to facilitate this. The nerve center of this wartime mobilization was the Office of Scientific Research and Development (OSRD), organized by former MIT Professor and Director of the Carnegie Institution of Washington, Vannevar Bush. In creating this new office, Bush argued that only scientific experts familiar with the latest laboratory research could posit the best way to develop new weapons.[5] Whereas scientists had previously been government advisors whose function was to solve requested problems from government leaders, they were now considering the feasibility of new weapons and taking the initiative to develop and produce them. Under the OSRD, scientists and engineers successfully developed a host of high-tech weapons, including radar, the proximity fuse, and the flame-thrower, to name the few.[6]

Although all the creation of these weapons was a harbinger of doom for Japanese military and people, the development of these wonder weapons was an eye-opening event for Americans, especially for military leaders. Before the war, they had tended to be skeptical about most of the ideas presented by scientists. They agreed with physicists on the technological feasibility of making the atomic bomb but considered the idea flatly unrealistic and unpractical. Most scientists, they felt, only made useless gadgets while wasting a large amount of money. But facing the significant achievements of scientif-

5. Daniel Kevles, *The Physicists* (New York, 1971), p. 308.
6. James P. Baxter, *Scientists against Time* (Boston: Little, Brown, 1946).

ic and technological mobilization under the OSRD and the Manhattan Project, they completely changed their perspective and began to recognize the importance of high-tech weapons devised by scientists. As General Dwight Eisenhower put it: “The lessons of the last war are clear. The armed forces could not have won the war alone. Scientists and business men contributed techniques and weapons which enabled us to outwit and overwhelm the enemy.”[7]

Scientists and engineers engaged in projects were demobilized after the end of the war. Bush, who wrote a pamphlet, “Science: the Endless Frontier,” hoped to create a civilian agency to support basic science modeled after the OSRD, which was to become the National Science Foundation (NSF). Its establishment, however, was delayed due to the debate over its basic policy and management. Democrat Congressman Harry Kilgore criticized the OSRD during the war, despite its accomplishments. Kilgore argued that the management of the OSRD was controlled by a few elite scientists affiliated with elite academic institutions, and that the OSRD failed to mobilize scientific and engineering manpower effectively, especially those affiliated with local or minor institutions. An antitrust ideology lay behind Kilgore's criticism toward what he considered was a monopoly of elite scientists controlling the OSRD. Kilgore and his followers recognized and criticized the elitist nature of the OSRD and attempted to organize a more democratic funding agency. The NSF was established only in 1950, after being modified from Bush’s original plan.

The five-year blank was filled with several defense agencies financially supporting civilian researchers who returned to their home universities after the demobilization. Among others, the Office of Naval Research (ONR) of the U.S. Navy played a substantial role for this purpose. It allowed many university scientists to continue with their wartime research, which was more or less related to weapons development. The Radiation Laboratory responsible for radar development during the war, for instance, was reorganized into a new

7. Dwight Eisenhower, “Memorandum for Directors and Chiefs of the War Department,” quoted in William S. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993), p. 24.

Research Laboratory of Electronics (RLE), as an adjacent facility to MIT. The RLE staff, many of whom were Ph.D. physicists, continued to investigate the behavior and characteristics of microwave devices, after receiving a handsome annual budget ($600,000) from the ONR as well as from the Army.

After the birth of Communist China, the Soviet success of their atomic bomb, and the eruption of the Korean War, the U.S. military increased their spending for military R&D for various technological developments, including the development of hydrogen bombs and guided missiles. Despite the establishment of the NSF, the ONR continued to offer a significant amount of financial support to basic research conducted by civilian scientists. Some scientists, such as the former Radiation Laboratory Director Lee DuBridge, requested the continuation of the ONR's support because he considered the NSF "wholly unsuitable for the support of large research projects at large research centers" [8]. Military support was key for helping science expand into large-scale science. After the Korean War, President Eisenhower proposed the "New Look" policy, which attempted to reduce the defense budget while maintaining or increasing military power by increasing the R&D budget, thereby improving the performance of weapons systems. Eisenhower's policy helped to sustain steady growth in military spending for R&D at universities and government institutions. Research directors and department chairmen at academic institutions actively approached the military and received significant financial aid to develop and conduct substantial research projects.

RLE of MIT also expanded its facilities and consequently further fostered the electronics industry in the region. The Pentagon decided to build an early-warning strategic radar system to counter-measure the development of guided missiles, and recognized the necessity of establishing a new separate facility—Lincoln Laboratory—to accomplish this mission. To make such a radar warning system, Lincoln Laboratory relied on a digital computer in its infancy, Whirlwind,

8. Quoted in Daniel Kevles, "Cold War and Hot Physics: Science, the Security and American State," *Historical Studies in the Physical and Biological Sciences*, 20 (1990): 239–264, on p. 259.

which was being developed by another division at MIT. Computer Whirlwind, together with basic hardware technologies, was eventually sold to IBM, which in turn redesigned it into a very profitable airline reservation system. RLE also helped to create and expand electronics corporations such as Raytheon. Raytheon expanded with the help of its military contract as well as through its close ties with MIT faculty and graduates. It manufactured a variety of electronic equipment for military and scientific use, and also invented and sold the microwave oven. The Sputnik shock in 1957 again increased the financial support for scientific research and education at American universities. In response to the need for promoting space-related technology, the Department of Defense (DOD) created an Advanced Research Projects Agency (ARPA).[9] However, soon afterward, NASA (National Aeronautic and Space Administration) was organized, based on the previous National Advisory Committee for Aeronautics, and it started to support basic and applied research related to space science and technology. The ARPA's mission consequently shifted toward more general, basic research at universities, but its funding policy was markedly different from the NSF. It offered large grants, each about ten times more than an NSF grant, to a few young faculty members who were recognized as pursuing promising research, primarily affiliated with elite academic institutions. The ARPA grants-in-aid are now widely recognized to have promoted the development of new materials and computers among others.[10]

The ARPA, or as was later renamed DARPA (Defense Advanced Research Projects Agency), however, was not welcomed by all military officials.[11] Its support for basic research received criticism from some quarters of the DOD. Among many projects conducted under the DOD, there was a project called "Project Hindsight," which aimed at evaluating the usefulness of militarily supported R&D for weapons.

9. ARPA soon changed its name to the Defense Advanced Research Projects Agency (DARPA). Its name recently returned to the original ARPA.

10. For mission oriented research at Stanford and MIT in the disciplines of material science, electronics, nuclear science, and aeronautics, see Leslie, *The Cold War and American Science*, op.cit.

11. It now has returned to its original name ARPA.

The project conducted a historical survey of the past development of a variety of weapons, and reached the conclusion that military research was not useful for the development of weapons. It was immediately followed by another project, called "Project TRACES," which conducted a similar historical investigation and found a more positive correlation between military funding for basic research and the development of weapons systems. What this difference reveals is that such an investigation tends to be influenced by the intention of clients. In this case, the clients for Project Hindsight in the DOD were not pleased with spending a significant portion of the defense budget for basic research. With the notable increase of federal support for basic research, universities enjoyed a "golden age" of expansion and American science grew, as the sociologist of science Derek J. de Solla Price has called, from "little science" to "big science." But a significant part of their financial support from the government came from the DOD and defense related grants. Most university research was thus mission-oriented research. Research on materials was connected to the development of new parts and materials for missiles, for instance. The department organization was accordingly modified and shaped under the influence of such military support. This raised many concerns among university faculty and students. In the late 1960s, students and some faculty protested the fact that university research was financially dominated by the military.

2. "Distortion" of Postwar American Science

Did military sponsorship really distort postwar American science? The question seems to be one of the fundamental issues discussed by recent historians of science and technology in the United States. The new social constructivist historiography, according to which many facets of scientific and technological activities are socially constructed rather than derived from internal logic and motivations, seems to have generated a renewed scholarly interest regarding this question. A historian of engineering, Stuart Leslie, closely traced the postwar growth of engineering departments at MIT and Stanford, and examined "profit and loss" with regard to military sponsorship.[12] He points out many weapons-related topics permeated scientific textbooks, for example John Slater's Microwave Electronics. Paul Forman and others argue that physics research was greatly influenced by military funding and changed its course from what it would have been otherwise. He cites a comparative study of American and European research on atomic physics and attributes the American pragmatist and instrument-oriented tendency to American scientists' involvement with weapons development projects. Leslie states in the conclusion of his book, *The Cold War and American Science*, that "the full costs of mortgaging the nation's high technology policy to the Pentagon can only be measured by the lost opportunities to have done things differently," although no one can know exactly about such an alternative path. He concludes the nation should consider relocating substantial funds to rebuilding the infrastructure of civilian science and technology that more than two generations of war, and preparing for war, has so badly depleted.[13]

However, other historians have a different view on the postwar military sponsorship of university research. A historian of physics, Daniel Kevles, questions the existence of the "true" physics implied in Forman's paper and in the "distortion" thesis in general.[14] He admits that certain subjects in physics, such as particle physics, are driven by an internal logic of science toward a deeper understanding of nature and the universe, but points out that many other subjects draw significantly from their relevance to technology as fluid mechanics draws from its engineering relevance to ships, airplanes, and missiles.

A historian of education, Roger Geiger, presents a more apt criticism on the "distortion" thesis. Based on his comprehensive research on the history of American universities before and after the war, in his article that was published in a history-of-science journal, he calls attention to the positive as well as negative aspects of military finan-

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12. Stuart W. Leslie, "Profit and Loss: The Military and MIT in the Postwar Era," *Historical Studies in the Physical Sciences*, 21(1990): 59–85.
13. Leslie, *The Cold War and American Science*, op.cit., p. 256.
14. Kevles, "Cold War and Hot Physics," op.cit.

cial support on American universities.[15] The influence of military sponsorship, he argues, varied depending on the purpose of funding. He characterizes the complex relationship between the military and universities by three different functions: a contract research center, support for the development of critical technologies, and more "benign" support for general university programs. In addition, he feels that focusing on a few exemplar cases such as MIT and Stanford, as in Leslie's work, only offers a partial view of the whole relationship between the military and universities. He also calls attention to the change in the funding policy of the military over time. Whereas programmatic research projects were greatly emphasized in the Cold War era, support for basic research significantly increased after the Sputnik shock. The Sputnik shock led to the reconsideration of the importance of scientific and engineering education, and NASA, aside from more direct space programs, started the "Sustaining University Program." The DOD, initially reluctant to offer such a program, started Project THEMIS, which distributed $94 million to 82 institutions from 1967 to 1971. He thus states: "Support from the defense establishment may have distorted university research, but the absence of such support without question would have produced a greater 'distortion'—in that it would have remained a far smaller enterprise."[16]

Benign support, however, ended because of the enactment of the Mansfield Amendment in 1971, which forbade the DOD to support basic research unless it had a "direct or apparent relationship to a specific military function or operation." The reduction of support from the government actually caused a financial crisis for universities in the 1970s. The effects of this amendment upon the nature of scientific research at universities during this decade still need to be analyzed.

15. Roger L. Geiger, "Science, Universities, and National Defense, 1945-1970," *Osiris*, second ser. vol.7 (1992): 26–48. His following two works respectively cover the prewar and postwar history of American universities: *To Advance Knowledge: The Growth of American Research Universities, 1900–1940* (New York: Oxford University Press, 1986), and *Research and Relevant Knowledge* (New York: Oxford University Press, 1993).

16. Geiger, "Science, Universities, and National Defense," p. 39.

3. Commercial vs. Military Technologies

The word "distortion" would be more appropriately applied to technology than science in the United States. Massive funding for the development of military technology has, in all likelihood, displaced technological resources away from civilian technology and industry, and weakened its competitiveness. In 1984, scholars from Harvard Business School raised this issue and published the work *The Militarization of High Technology*.[17] The book mainly discusses the negative effect on American industries of spending for military R&D. They point out the following defects:

1. Excellent researchers and equipment were utilized for military R&D, which tends to devalue research for social and economically beneficent purposes.
2. Military research was classified and investigators involved in those projects were kept ignorant of research being conducted by other groups, thereby causing specialization among scientists. The investigators were not very useful in industrial R&D.
3. The military tends to select and support large corporations and neglect small and innovative corporations.

It is true that some of the parts and machines developed for military purposes would be utilized for industrial purposes. Many cases of this type of spinoff of military R&D can be found in postwar history. But it is often noted that, in many cases, the military requirement for specification was too strict to be utilized for civilian purposes. In a word, the product is "overdeveloped." The performance and durability of electronic equipment or synthetic materials attained high standards but consequently they became too expensive to be competitive in the civilian market. Transistors for TV sets did not need to withstand severe circumstance like strong radiation and temperatures over 100°C. The Bell Laboratory, where the transistor was created,

17. John Tirman, ed., *The Militarization of High Technology* (Cambridge, Mass.: Ballinger, 1984).

pursued the development of a silicon transistor instead of the germanium transistor to meet an order from the military. In contrast, the Japanese electronics industry focused on the development of the germanium type under an initiative of the MITI (the Ministry of Trade and Industry).[18] Whether the development of industrial technologies in postwar Japan was caused by MITI or by initiatives from corporate engineers is a matter of debate and it would be fallacious to overestimate the value of MITI in the technological development of postwar Japan. But we can say that the difference in emphasis regarding technological R&D between Japan and the United States created two totally different characterizations of technology development and production in the two countries.

Tirman's *Militarization of High Technology* presents in its conclusion an exception, the DARPA. The present global computer network, Internet, has its origin in the R&D sponsored by the DARPA. It was originally designed as a communication network, even after the eruption of a nuclear war. The authors of *Militarization of High Technology*, in the year 1984, evaluated the significance of the DARPA to be very high in the age of what they called "the second Sputnik," an age of economic and technological challenge from Japan.[19]

More recently, another Harvard group proposed a new vision of integration between military and civilian industries through what they call 'dual-use' technology. Harvey Brooks and Lewis Branscomb, both Harvard professors of Public Policy, initiated the dual-use tech-

18. Thomas J. Misa, "Military Needs, Commercial Realities, and the Development of the Transistor, 1948–1958," in Merritt Roe Smith, ed., *Military Enterprise and Technological Change: Perspective on American Experience* (Cambridge, Mass.: MIT Press, 1985): 253–87. The same argument would apply to the Japanese weakness in developing space technology. Electronic parts do not meet the same high standards of space technology. That was one of the important bottlenecks for the development of space technology in Japan. The frequent failure of Japanese rockets was due to their electronic parts failing under severe physical circumstances. See Shigebumi Saito, *Nihon Uchū Kaihatsu Monogatari* (*A Story of Space Development in Japan*) (Tokyo: Mita Shuppannkai, 1992), pp. 114–17 and 190–207.

19. For the development of computer technology including ARPAnet under the sponsorship of DARPA, see Arthur L. Norberg and Judy E. O'Neill, *Transforming Computer Technology: Information Processing for the Pentagon, 1962–1986* (Baltimore: Johns Hopkins University Press, 1996).

nology project to examine the complex relationship between military and commercial technologies.[20] Their results are summarized in their work, *Beyond Spinoff: Military and Commercial Technologies in a Changing World*.[21] Like Tirman and others, they criticized the often overestimated concept of spinoff. Raytheon's microwave oven, they point out, was not as commercially and economically successful at first as is usually believed. The product, designed for restaurant use, was too expensive to be commercially viable and the company had to cover the difference. They also highly evaluate the performance of the DARPA and favorably mention the unrealized plan for its conversion into the demilitarized agency, the NARPA (National Advanced Research Projects Agency).

But unlike *Militarization of High Technology, Beyond Spinoff* does not oppose the development of military technology itself. The authors propose the integration of military and commercial technologies so that they be freely converted each other. By developing "dual-use technologies," they argue, both the military and industry can share the spoils of the R&D efforts. The book explains this technology policy by using the three model fields of dual-use technology: microelectronics, computer software, and manufacturing. As to microelectronics, the authors refer to Sematech, a consortium of several semiconductor-manufacturing firms that pool together large-scale R&D funds. Their funds together with the matching support from the government are allocated through the DARPA to various commercial R&D programs related to microelectronics technologies, such as dynamic random access memory chips (DRAM) and fine-line lithography. And yet, the authors of *Beyond Spinoff* are aware that the development of each of these cutting-edge technologies does not necessarily mean efficiency in commercial, high-volume production. It is a fallacy and an ill-conceived idea of American engineers, they argue, to believe that optimizing the building blocks of a production system will suffice to optimize the system as a whole.

20. "Rethinking the Military's Role in the Economy: An Interview with Harvey Brooks and Lewis Branscomb," *Technology Review*, (1989): 55–64.

21. John A. Alic et al., *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston: Harvard Business School Press, 1992).

Their dual-use technology policy was, however, questioned by some scholars. In their book, *Dismantling the War Economy*, Ann Markusen and Joel Yudken from Rutgers University pointed out the limits of the dual-use policy.[22] They first point out that only limited industries took advantage of this during the Cold War years. What they call the ACE complex (aerospace-communication-electronics complex) benefited from many advantages during those years after receiving R&D resources and being guaranteed their product markets. In contrast, they point out, "industries that have not benefited from this closet industrial policy, such as steel, machine tools, tractors, autos, and consumer electronics, have stagnated and seen their markets invaded successfully by competitors from rich and poor nations alike."[23] They could have perhaps added some contrastive episodes in Japanese history that show the transfer of wartime aeronautical technology to postwar civilian industry. For instance, a former engineer of the Nakajima Aircraft Company designed a Japanese version of a Volkswagen, the Subaru 360. No doubt he used his experience as an aircraft equipment engineer in designing a car as light and small as possible.[24]

Markusen and Yudken admit that Branscomb and others' dual-use policy would be counter to the military's aerospace-centered industrial policy of the past forty years, but they argue "the high-tech dual-use strategy is seriously deficient in a number of ways." They argue: First, it does not address a number of critical national needs—such as protecting and cleaning up the environment, improving public infrastructure, mass transportation, occupational health and safety, and education, and

22. Ann Markusen and Joel Yudken, *Dismantling the War Economy* (New York: Basic Books, 1992).

23. Ibid., p. 34.

24. Takanori Maema, *Man-Mashin no Showa Densetsu* (*A Legend of Men and Machines in Showa Era*) (Tokyo: Kodansha, 1993), chapters 11 and 12. Many more cases of postwar conversion from military to civilian technologies are explained in the following report: Nihon Gakujutsu Shinkokai, Sentan Gijutsu to Kokusai Kankyo, the 149th Committee (日本学術振興会先端技術と国際環境第149委員会), ed., *Gunji Gijutsu kara Minsei Gijutsu eno Tenkan: Dainiji Sekai Taisen kara Sengo eno Wagakuni no Keiken* (*The Conversion of Military Technologies to Civilian Technologies: The Japanese Experience from Wartime to Postwar Period*), 2 vols (Tokyo: Japan Society of the Promotion of Science, 1996).

developing renewable energy sources. These efforts will require carefully tailored investments in science and technology. A national industrial policy dominated by the agenda of a relatively small number of military and civilian high-tech industries is unlikely to cover all economically or socially important areas of S&T development.[25]

The emphasis on high technology, they went on, would divert R&D resources away from more incremental improvements in process technologies and product design, which are equally important for vitalizing civilian industries. They also point out that the difficulty inherent in the implementation of technology into production lines is greater than the ideologues of the dual-use policy have considered. They refer to "middle-ground" engineering linking generic R&D to manufacturing and production. "It is at this 'middle-ground' level," they argue, "that the divergence between military and civilian interests presents the greatest difficulties…. The way DARPA would test a new state-of-the-art parallel-processing computer chip for a 'smart' guided munitions system is not remotely similar to its potential for desktop or workstation computers."[26]

4. Toward a More Comprehensive Understanding of Cold War History

Based on the recent research and discussion about the history of postwar science and technology, social studies workshops about science, technology, and democracy during the Cold War have been held with the financial support of the National Science Foundation.[27] The report it prepared for the NSF had six points on the basic research agenda:

1. The interaction of science, technology, and democracy in the Cold War
2. The production of knowledge during the Cold War
3. Institutions of Cold War science and technology

25. *Dismantling the War Economy*, op.cit., p. 128.
26. Ibid., p. 129.
27. See note 3.

4. Economic impact of the Cold War and the economics of the Cold War
5. Comparative and international dimensions of the Cold War
6. The Cold War and American Culture

For each of these problems, a basic discussion on the topic is provided and a list of supplemental questions is added. In it, the "distortionist thesis" has also been referred to as a starting point of discussion for the second agenda, posing the question, "How might scholars evaluate this essentially counterfactual issue?" The report tells us that they placed the development of the university and its relationship to industry and government in a long-term perspective, and that they discussed the continuities and discontinuities marked in the Cold War period. As to the discontinuities, they refer to the increasing entrepreneurship in the academe during the Cold War, and also to the question left by the participants, who wondered "whether the scientific and technical meritocracy fostered by the Cold War is consistent with democratic principles, and whether it will optimize the social benefit of knowledge production in the long run."[28]

The historical examination and evaluation of scientific and technological R&D during the Hot and Cold War eras are important not only for scholarly purposes but also for present political and economic goals. They are expected to provide indispensable information and insights on the basis of which they will reconstruct the relationship between the university, the industry, and the government in post Cold War society. They are especially so in the attempt to shift the emphasis of the allocation of scientific and technological resources from military to civilian industrial sectors. It is sincerely hoped that this active historical research generates fruitful dialogues with social scientists, policy makers, and the like, and that their research results are integrated into the effort to "optimize the social benefit of knowledge production in the long run."

28. "Science, Technology, and Democracy in the Cold War and After," op. cit.

9

A Hesitant Relationship Reconsidered

University-Industry Cooperation in Postwar Japan

Reprint of "The Hesitant Relationship Reconsidered: University-Industry Cooperation in Postwar Japan," in Lewis M. Branscomb, Fumio Kodama, and Richard Florida, eds., *Industrializing Knowledge: University-Industry Linkage in Japan and the United States* (Cambridge, Mass.: MIT Press, 1999): 234–251.

1. Introduction

The need for more intensive collaboration between universities and industry has been well-recognized in recent years in Japan, and various attempts are being made to construct a closer relationship between the two sectors. Although such collaboration existed on a much smaller scale in the past, the student protests of the late 1960s inhibited it. However, university-industry collaboration was strong in prewar Japan, when universities were funded by foundations as well as the government. This chapter explores the differences before and after the Second World War, first surveying funding from industry to universities in the prewar period. It will then analyze three important events that may have influenced the relationship: the Occupation, technology importation, and the student protests.

2. Prewar Background

A symbolic episode showing the close tie between universities and industry was the Furukawa family's donation to the foundations of Kyushu and Tohoku Imperial University. Furukawa owned a large mining corporation and had made a fortune during the Sino-Japanese and the Russo-Japanese Wars, but its mine caused a serious pollution in Ashio, which developed into a political scandal. The Furukawa family decided to donate a large sum of money for the establishment of new departments of the above two universities at the suggestion of Takashi Hara, Minister of Interior, who was serving as an advisor for the Furukawa Corporation.[1]

Although less dramatic than this example, many large *zaibatsu* and industrialists, some of whom had made fortunes during the above two wars and the First World War, donated handsome sums to assist the establishment and consolidation of universities and their attached research laboratories. For example, the Sumitomo Corporation helped support a major expansion of the Metallurgical Research Laboratory of Tohoku Imperial University, and the industrialist Ginjirō Fujiwara helped establish the Engineering Department of Keio University.

Donations from industrialists and corporations were an important financial source for the universities, though they also received government funding. As in the United States, philanthropic foundations were also important financial supporters of university investigators in prewar Japan. The following foundations provided actively for social welfare as well as the advancement of research and development: Morimura Hōmei Kai (1913), Tōshōgū Sanbyakunensai Kinenkai (1914), Keimei Kai (1918), Harada Sekizen Kai (1920), Saitō Hōon Kai(1923), Taniguchi Kōgyō Shōrei Kai (1929), Hattori Hōkō Kai (1930), Asahi Kagaku Kōgyō Shōrei Kai (1934), and Mitsui Hōon Kai (1934). The word "Hōon (報恩)" in the names of some of these foundations means the requital of kindness, indicating that their mission was nationalistic and patriotic as well as philanthropic; financial support for research and development at universities was considered a patriotic deed in these periods.[2]

Just as many corporations contributed financially to universities, so many university faculty members served as technical consultants for corporations in prewar Japan. At one Diet meeting, it was suggested that university professors were too frequently engaged in consulting work for private corporations, to the detriment of the education of

1. Akira Tachi, "Kigyō to Daigaku: Senzen no Sobyō (Corporations and Universities: A Sketch of Prewar Period)," *IDE*, no. 244 (1983): 3–11.
2. Yujiro Hayashi and Yoshinori Yamaoka, *Nihon no Zaidan* (*Foundations in Japan*) (Tokyo: Chuo Koron Sha, 1984), pp. 43–130.

their students. It was, however, argued that the raison d'être of the universities was to serve the nation and that professors' consulting work should be considered national service.[3]

Because of this consulting work, the quality of research work at universities appeared lower than those at Western universities. Hidetsugu Yagi, the father of Japanese electronics research and director of the Board of Technology—the Japanese counterpart to the OSRD (and so highly regarded that Karl Compton called him "the Vannevar Bush of Japan")—recalls the following prewar episode when his German mentor Heinrich Barkhausen visited Japan. Barkhausen, a leading electronics engineer, told him that he had expected large corporations such as Mitsui and Mitsubishi to have excellent research laboratories. Surprised to find none, he pointed out the need for such research laboratories if the companies were to be competitive in the world, and further remarked that university professors were instead engaged in the kind of R&D activities that would be more naturally pursued at industrial corporations.[4] Yagi could only answer that Japanese shareholders expected high dividends and did not respect corporate R&D efforts which, they considered, would not increase their dividends.

The above two episodes reveal that there were generally very few R&D efforts at industrial corporations, and therefore that the engineering faculty from Japanese universities took the role of pursuing industrially oriented research and development.

3. The Wartime Mobilization of Science and Technology

After the war began, university and industrial research was geared

3. James R. Bartholomew, *The Transformation of Science in Japan: Building a Research Tradition* (New Haven: Yale University Press, 1989), p. 230.
4. Hidetsugu Yagi, *Gijutsujin Yawa* (*Night Stories of an Engineer*) (Tokyo: Kawade Shobō, 1953), pp. 130–31, quoted in Shigeru Nakayama, "Kigyōnai Kenkyū Kaihatsu Katsudō no Kōryū: Chūo Kenkyūjo Būmu," in *Tsūshi Nihon no Kagaku Gijutsu* (*The Social History of Science and Technology in Contemporary Japan*) vol. 3 (Tokyo: Gakuyō Shobō, 1995): 44–50.

to military purposes. The government took measures for rapid expansion of scientific and technological departments at universities and a variety of new research laboratories were set up to conduct war work. At Tokyo Imperial University, the Second School of Engineering was established to meet the sharply increased demand for young engineers for military R&D. The number of engineering faculty and students was doubled.

Other universities also established various research laboratories before and during the war. The following is a list of such academic research institutes established in the 1930s and 1940s.

1930s: Architectural Materials (TIT), Telecommunications (Tohoku), Resource Chemistry (TIT), Industrial Science (Osaka), Precision Machinery (TIT)

1940s: Ore Dressing (Tohoku), Low Temperature (Hoku), Fluid Engineering (Kyushu), Ceramic (TIT), Scientific Measurement (Tohoku), Elastic Engineering (Kyushu), Ultra Short Wave (Hoku), Catalysis (Hoku), High Speed Dynamics (Tohoku), Aeronautical Medicine (Nagoya), Acoustics (Osaka), Wood Materials (Kyoto & Kyushu), Glass (Tohoku).[5]

Some research laboratories were planned but not built during the war. The Research Institute for Aerial Electricity at Nagoya Imperial University was designed to investigate the technology of meteorological forecasting in the southern areas by measuring the disturbance of aerial electricity. Its research initiated during the war, but it was not established until afterward.

Two points should be mentioned on the prewar and wartime origins of many of these university research laboratories. First, although some of them had long traditions of relevant research and many continued to pursue significant investigations in their own technological fields, the nationwide arrangement of research laboratories at Japanese universities was not designed to adapt to the postwar Japanese econo-

5. TIT: Tokyo Institute of Technology. Tohoku: Tohoku Imperial University. Hoku: Hokkaido Imperial University. Osaka: Osaka Imperial University. Kyushu: Kyushu Imperial University. Kyoto: Kyoto Imperial University.

my. Because of the tenacity of the national university system and their wartime origins, some university laboratories found it difficult to adjust to postwar industrial conditions.

Second, some of these research laboratories were beneficiaries of adjunct foundations, which formed a financial conduit between industry and university in order to fund their parent research institute. The Foundation of the Advancement of Telecommunications Technology, for instance, was established in 1944 to support the Telecommunications Research Institute of Tohoku Imperial University. The foundation, however, did not take an active role as a financial conduit until around 1953. In 1956, seventeen percent of the total budget of the Telecommunications Research Institute came from this foundation.[6] These adjunct foundations served as financial supporters of postwar university laboratories.

Another notable feature of the Japanese wartime mobilization was the establishment of a research group called "Kenkyū Tonarigumi (Research Neighborhood Group)." These groups, each of whose missions was intended for investigation into a specific technological field, consisted of academic and industrial engineers and facilitated the exchange of fresh technical information among its members. The discovery of a new dielectric characteristic of a titanium alloy was reported at the 8012th Kenkyū Tonarigumi, which consisted of engineering professors from Tokyo, Kyoto, Nagoya, Osaka, and engineers from Toshiba, Hitachi, and others. The information network developed by this wartime arrangement would serve university-industry collaboration in postwar Japan.

4. The Occupation and the Reorganization of the University System

With the end of the war, the institutional system of research and development in Japan was forced to change radically. The emerging postwar framework of the university-industry relationship was deeply

6. Tohoku University, ed., *Tohoku Daigaku Gojūnenshi* (*The Fifty Year History of Tohoku University*) (Sendai: Tohoku University, 1960), pp. 1651–53.

influenced by the educational and industrial policy implemented by relevant sections of the Occupation's General Headquarters (GHQ) under the Supreme Commander of the Allied Powers. Their initial and primary purpose was to demobilize and democratize the entirety of Japan. For this purpose, they ordered the Japanese leaders to abolish old institutions and organize new ones. Accordingly, the military R&D activities in wartime Japan were thoroughly investigated, and most of them stopped and disbanded. The experimental cyclotron of the Institute of Physical and Chemical Research (Riken) was destroyed and thrown into the sea, and all aeronautical research was forbidden.[7] While the GHQ attempted to create a new national system of research and development at universities and industries, their policy was not entirely consistent among their sections and throughout the period of the Occupation. These policies and their inconsistencies cast a shadow on the postwar relationship between universities and industry in postwar Japan.

Reparations were the main issue during the first phase of occupation, and the original policy of GHQ was to reduce Japan's economic level to that of other Asian countries that had been exploited by military Japan during the war, for which they planned to confiscate half the equipment and facilities still in Japanese factories. But around 1947, they significantly moderated their former economic policy owing to the advent of communism in China and the rise of the Marxist movement inside Japan. The National Security Council announced a change of policy toward Japanese economic recovery due to the movement of Communist threat; instead of reducing the economic power of postwar Japan to the prewar level, they began to promote Japan's economic activities.

One of the organizations chiefly responsible for the reorganization of Japanese scientific and technological R&D was the GHQ's Economic and Scientific Section (ESS). It helmed a Scientific Division, later renamed the Scientific and Technological Division (ESS/ST),

7. On the disposal of the cyclotron and the demobilizing process during the Occupation, see Morris Low, *Science and the Building of a New Japan* (New York: Palgrave Macmillan, 2005), chapter 3 "The Impact of the Allied Occupation: Nishina and Nakasone."

which was in charge of scientific and technological matters relating to economic problems. Many New Dealers, it is told, joined the ESS, and they were active in disbanding large Japanese concerns. But some officials at the ESS tried to reorganize and reestablish a new Japanese R&D system in order to help the restoration of the postwar Japanese economy. Harry Kelly, at ESS/ST, was one of them.

Kelly, a young physicist who had worked on the development of radar at the U.S. Radiation Laboratory during the war, was invited to assist with the technical details in investigating Japanese devices and facilities. In communicating with Japanese scientists, Kelly found that GHQ did not need to concentrate on the demobilization of wartime research activities, but rather should pay more attention to restoring the devastated Japanese economy and reforming its research and development system.[8]

ESS/ST accordingly emphasized the importance of industrial applications of academic research, and attempted to strengthen the tie between universities and industry. In 1947, under Kelly's initiative, it sponsored a "science advisory group" organized by the American National Academy of Sciences, which turned in a report on the "Reorganization of Science and Technology in Japan" and suggested that they set up an Advisory Council on Higher Education and Research be established, following its own model. This eventually led to the establishment of the Science Council of Japan (日本学術会議). At the same time, the report mentioned the condition of university research. It criticized its orientation toward basic research, saying that too much emphasis on basic research was detrimental to applied research.[9] The ESS/ST proposed this report as a basic policy text, and emphasized the importance of education in science and technology for the sake of the economic recovery of Japan.

8. Hideo Yoshikawa, *Kagaku wa Kokkyō o Koete: Kerī Hakushi Hyōden* (*Science Crosses over the National Boundary: A Biography of Dr. Kelly*) (Tokyo: Mita Shuppankai, 1987) recounts Kelly's biography and activity in postwar Japan.

9. "Report of the Scientific Advisory Group to the National Academy of Sciences on the Reorganization of Science and Technology in Japan." See Takashi Hata, "Shinsei Daigaku to Rikō Kyōiku (New-system Universities and Education of Science and Technology)," in *Tsūshi Nihon no Kagaku Gijutsu*, op.cit., vol. 1, pp. 143–51.

However, the proposal of ESS/ST was strongly opposed by the Civil Information and Education Section (CIE) which was responsible for the reformation for the newly democratized educational system. The CIE worked to reform the Japanese educational system, beginning by implementing the American 6-3-3 system in primary and secondary education. In reforming the universities, they emphasized the importance of liberal education at the college level.

In opposition to the policy of the ESS/ST, the CIE argued that scientific research was only one of the many functions of the university, and that the university's primary goal was to "train and produce all kinds of leaders needed for a free society." It therefore proposed that the report should be accepted only insofar as it was not against the policy and plan already adopted by the CIE. In this way, CIE argued for the importance of the autonomy of university professors and university education away from industrial goals. Scientists and engineers were certainly necessary for the economic recovery of postwar Japan, it said, but their number had grown so greatly during the war that there were enough of them for postwar Japanese needs.

In the end, the ESS/ST policy was not implemented in Japanese universities, which were largely shaped by the policies of the CIE.

5. The Importation of Technology

By the early 1950s, the San Francisco Peace Treaty ended the Occupation, and the Japanese government started to implement its own economic and industrial policy. As foreign capital regulation was greatly relaxed, Japanese corporations began vigorously to introduce the advanced technologies of foreign companies. To introduce foreign technologies, a Japanese company had first to submit a proposal and receive permission from the government. The proposals were examined by government officials and academic engineers. The abovementioned Yagi was one of these examiners. Between 1950 and 1960, over a thousand technical innovations had been introduced (most of them from U.S. companies), at a total expenditure of more than 100 billion yen.

There were various forms of purchasing foreign technologies. The Japanese companies could simply buy patent rights relevant to a specific industrial product, but in many cases they obtained not only such patent rights and design drawings but also the services of engineers to provide on-site technical know-how. This was especially helpful in introducing technologies relating to new production systems such as oil refining and automobile production.[10]

The introduction of Western technologies has been the most important concern of Japanese industrial leaders from the Meiji Restoration onward; the direct introduction of cutting-edge technology from foreign to Japanese companies significantly influenced the relationship between university researchers and industrial corporations. University researchers had no doubt played an indispensable role as technological consultants in earlier technological transfers, being able to understand the foreign technologies, to explain them to industrial engineers, and even occasionally to transform them for domestic industrial needs. But now the technical staff of Japanese companies was in touch with their counterpart companies, and they learned directly about advanced technologies from U.S. or European companies. Because of this cooperation, the previous role of the university researchers as technology transfer agents became minimized.

Between 1955 and 1963, in an attempt to introduce foreign technologies, Japanese firms established a total of 108 "central research laboratories," and invested heavily in new facilities. Especially in the electrical and chemical industries, technology importation required a substantial research and development effort was required to digest advanced technologies from foreign countries. These "central" laboratories were established during the last phase of the investment boom. Many were the result of the reorganization of small laboratories within the same company, and aimed at introducing and digesting foreign technology. But others aimed at developing their own new technologies.

During this period large corporate research laboratories recruited

10. Katsuhiro Arai, "Gijutsu Dōnyū (the Importation of Technology)," in *Tsūshi Nihon no Kagaku Gijutsu*, op.cit., vol. 2, pp. 158–69, on p. 166.

many university researchers, and some corporate researchers even boasted that universities were unnecessary for industrial research and development in Japan. While certainly an exaggeration, this implies the superiority of research facilities at corporate laboratories to those at universities. By the mid-1960s, however, the boom was over; the recession forced companies to cut the budget of their research laboratories.

6. The Research Institute as a National Engineering Forum

Some industries soon recognized the need for research and development of their own technologies, and the need for domestic technology, in which academic engineers played critical roles. Episodes from the two leading Japanese industries—steel and shipbuilding will serve examples.

In the Japanese steel-making industry, corporations adopted advanced foreign technologies—machines, processes, and designs. However, such technological transfers impeded further development of industry: As the Japanese corporations grew larger and more competitive in the international iron and steel market, foreign corporations became less willing to share their advanced technology with their potential competitors. Secondly, and more importantly, Japanese metallurgical engineers gradually became aware of the potential problem of technical reliance on foreign companies. They recognized that because the users of their steel products also relied on other foreign technologies, they lacked information on the physical properties of the materials they purchased were thus unable to develop reliable new products.

For this reason the National Research Institute for Metals (金属材料研究所) was established in 1956 under the newly established Science and Technology Agency. Its official function was to perform (1) research on the production and processing of metallurgical materials which required equipment outside the scope of one corporation; (2) basic research on a consistent production processes from materials to products; (3) research on the production and processing of metals appropriate to the natural resources of Japan; (4) research on metallic materials for nuclear and aeronautical technologies; (5) research on the production of pure metals; and (6) materials testing requiring large-scale facilities, and the development of metallic materials that private corporations were unable to produce.

The same year, the Science Council of Japan further requested that the Science and Technology Agency establish a new research laboratory on the physical properties of metallic materials. And the next year, in 1957, an Institute for Solid State Physics (物性研究所) was established at the University of Tokyo. Its first director was Seiji Kaya, a notable metallurgical physicist. At the Research Institute for Industrial Technology (生産技術研究所), a blast furnace for experimental purposes was built in 1955 and metallurgical research and development began. Research laboratories were also established at private corporations. In 1959 and 1960, such research laboratories were set up at Fuji Seitetsu, Yawata Seitetsu, Sumitomo Kinzoku, Nihon Kokan, and Kobe Seikojo. From these corporative research laboratories important industrial innovations emerged, some of which were transferred to foreign corporations.

The Japanese shipbuilding industry also recognized the need for cooperative research, especially for the construction of supertankers of greater than 50 thousand tonnes capacity. For this purpose a Shipbuilding Research Society was established. In the postwar development of the Japanese shipbuilding industry, both prewar and wartime naval engineering played an indispensable role, and in postwar Japan it provided new key technologies as well as niche for those leading naval engineers who had gone into the private sector due to postwar restrictions on bureaucratic positions. In 1955 a 45,000-tonne supertanker was built by Mitsubishi, and the shipbuilding companies received orders for still larger tankers. But the design and construction of ships larger than 60,000 tonnes required technological breakthroughs on welding, structure, and performance of such large ships: As an example, thicker steel plates were harder to weld, which required the development of both special steel and special welding techniques.[11]

11. Eiichi Kaneko, ed., *Gendai Nihon Sangyō Hattatsushi* (*A History of Industrial Develop-*

Because of this necessity to develop new technologies, a new Japanese Society for the Research of Naval Architecture was established as a forum for representatives from shipbuilding companies, ship-owners, academic laboratories, and the government. Their three-year research on the subject brought new technological information which was fully utilized for the subsequent construction of the new class of ships. Among others, *Nisshō-maru*, a 130,000-tonne tanker, attracted worldwide attention.

The above two industries, based on a prewar accumulation of relevant technologies, were perhaps exceptional. But they show how academic engineers were able to contribute to important developments of industrial technologies. The national and academic research institutes served as a forum for the exchange of technological information between engineers from both academia and the industry; annual meetings of professional engineering societies also provided an important forum for information exchange not only between academia and industry but also between industries, through academia. Japanese corporations were a fairly closed world, and these public forums were catalysis for one corporation to provide technical information to another.

7. Collaboration Encouraged and Discouraged

As Sputnik in 1957 had a great impact on scientific and technological research and education at American universities, the Ministry of Education in Japan also decided to promote scientific and technological education at universities. In that year, Chūō Kyōiku Shingikai, the main advisory board of the Ministry of Education, proposed measures to promote scientific and technological education. The report pointed out the poor financial and material conditions at universities and the need to improve both their research facilities and the quality of their graduates. As to university and industry cooperation, the report stated that universities should engage in "closer cooperation

ment of Contemporary Japan), vol. 9 (Zōsen) (Tokyo: Kojunsha, 1964), p. 474.

with industry by taking into account requests from industry and by sending students to industrial factories," and that "attached university laboratories should be able to re-educate engineers in industry."[12] The University of Tokyo accordingly changed its rules, and began to encourage industrial engineers to visit its laboratories.

Industrial leaders, too, acknowledged the urgent need to cooperate more closely with the university in recruiting competent engineers and collaborating on industrial research. "Keizai Dōyūkai (経済同友会)," a group of such industrial leaders, actively promoted such collaborative relationships between industry and universities, and even planned to establish a center for industry and university collaboration.[13]

Thanks to these policies and efforts, in the 1960s the engineering departments of universities began to receive more financial support from relevant industries. Such donations allowed the University of Tokyo, for instance, to build many research facilities, and the Engineering School responded by reorganizing and expanding its departments to adapt to contemporary industrial needs.[14]

The movement toward closer ties between universities and industry was blocked by the student protests of the late 1960s: While American universities were excoriated for their military connections, Japanese students criticized the close relationship between the universities and private corporations. I will cite two statements responding to this protest movement, one by industrial leaders and the other by leaders at a university.

Industrial leaders responded to the student protests by emphasizing the social need for such collaboration and proposing to reform the university administration. The Keizai Dōyūkai group proposed a doc-

12. Chūō Kyōiku Shingikai, The Fourteenth Report, "Measures to Promote Scientific and Technological Education" (1957).

13. "On the industry and universities' collaboration of Keizai Dōyūkai," *Asahi Shimbun*, 10 July 1960. Quoted in Yokohama Kokuritsu Daigaku Gendai Kyōiku Kenkyūjo, ed., *Zōho Chūkyōshin to Kyōiku Kaikaku: Zaikai no Kyōiku Yōkyū to Chūkyōshin Tōshin* (*Zen*) (*The Central Educational Board and Educational Reform Policy: Pedagogical Requests from Industry and the Reports of the Board*) (Tokyo: Sanichi Shobō, 1973), pp. 201–2.

14. Tokyo Daigaku Hyakunenshi Henshū Iinkai, ed., *Tokyo Daigaku Hyakunenshi* (*The Centennial History of the University of Tokyo*) vol. 3 (Tokyo: University of Tokyo Press, 1987), pp. 648–49.

ument, "The Institution of Higher Education for the Advanced Welfare of Society," as their specific response to the student movement.[15] Concerning university-industrial cooperation, it stated:

> Keizai Dōyūkai have been proposing the urgent need to promote university-industry cooperation since 1959. We consider that such cooperation is necessary for universities to play a leading role in the coming advanced welfare society, and repeat our view below.
>
> University-industry collaboration coincides with modern educational thought to encourage the shift from "learning for the sake of learning" in an ivory tower to "academic research open for society." The history of the relationship between universities and industry in the United States, the USSR, and Japan, which accomplished rapid industrialization, would tell us that both grew and developed stimulating each other and that university-industry collaboration is a historical trend.
>
> Some delimit university-industry cooperation as a simple exchange of money and ideas between a specific researcher at a specific university and an individual corporation, and regard it as a wrong effort to make university researchers industrial subcontractors and to distort research freedom. But the functions of universities and industry interact with each other to drive social development, and their cooperation exists in various fields. Furthermore, the advancement of industrial research and development, the emergence of big science, the increasing social demand for adult education—all will increase the importance of their cooperation.
>
> The reason we dare to promote university-industry cooperation is that the institutional structures of universities do not respond to tendencies in real society. So-called academic freedom would be diminished, if applied research did not open new fields for basic research or if theoretical research did not relate to real processes. We oppose the attitude that criticizes a part of the university-industry collaboration and denies it altogether. We have to maintain the present state of collaboration and push forward a new organization and

15. Quoted in *Chūkyōshin to Kyōiku Kaikaku*, op.cit., pp. 246–64

> rule to correct present errors. The question will arise as to the financial distribution between technological areas relating to production and humanities areas relating to the national and traditional culture and values. This question will be solved by the redistribution of a specific proportion of funding from industry to the latter research areas or by establishing large multi-purpose foundations.[16]

After stating its view on university-industry cooperation, Keizai Dōyūkai proposed a plan to reform the university organization, including the recommendation to recruit on a contractual basis and reorganize all universities as non-profit corporations.

In contrast to the industrialists' statement, a statement from the university community clearly showed its more restrictive view on university-industry cooperation. The following is an excerpt from the first report of the Investigative Committee for the Preparation of University Reform at the University of Tokyo, concerned with the university-industry relationship. It told readers that universities were expected to distance themselves from industry, and probably contributed to the further alienation of university researchers from industrial needs:

> In relation to the research at the University of Tokyo, there is the problem of so-called "university-industry cooperation." Although the concept of "university-industry cooperation" is not necessarily clear, it would be defined here in the following relatively limited sense: that a university does research through official or unofficial contracts with private corporations, governmental agencies, foundations, and the like for certain commissioned researches and receives financial assistance for research.
>
> University-industry cooperation in this sense has been performed at the University of Tokyo, but the details are not clearly known and are to be duly investigated. At the discussion of the present special committee, the following points have been proposed for university-industry cooperation.

16. Ibid., p. 255.

First, the issues of university-industry cooperation lie in the danger that scholarly research would be subservient to the interest of the investor. It is felt, for instance, that the publication of data and research results might be restricted, and that the preconditions of research and, in an extreme case, the conclusion itself might be circumscribed. In other cases, the content of research is regarded as secondary, and the commissioned research is utilized for authorization under the name of the University of Tokyo. To avoid such misconduct, the plan and results of the research and its accounting data should be open for various commissioned research.

Second, how to place emphasis among various topics during research (and education) at universities is clearly influenced by the prosecution of commissioned research and the like. But we should absolutely avoid the possibility that the selection of research planning be determined by the factor in conflict with the prerequisites of academic pursuits. It is certainly desirable that university research receive stimulation from the practical needs of society and play an active role as an intellectual center of society. … But if such factors as the interest of a specific corporation, which are in conflict with the prerequisites of academic research, influence the policy and planning of research and education, it would result that the autonomy of scholarship is lost. For university-industry cooperation, therefore, careful consideration and institutional regulation are needed to protect academic freedom. Furthermore, if university-industry cooperation is done over a long period and a close connection emerges between commissioned faculty and such investors as corporations and governments, the autonomy of researchers would be lost without their being aware. This is the problem of "the decadence of a researcher," and each faculty member must always be careful.

And third, one of the reasons large-scale university-industry cooperation is under way in certain specific departments is that the expenditures of the government for research and education are very low. It must be said, for instance, that because of extremely meager financial conditions at universities, it is necessary to rely on commissioned research fees and others from corporations in order to guide and educate graduate research. In other words, because university

> faculty are able to receive such commissioned research fees from industry, … the meager financial situation of the universities is covered up. It is necessary to improve the financial situation of the universities drastically in order for them to perform scholarly research and education in an autonomous way.[17]

The statement seems to have accurately represented the thinking of the faculty of national universities. It constituted the formal stance of a leading national university toward collaboration with industry. Despite the strong requests and demands from industry, Japanese universities tended toward restriction of collaboration with industry in the 1970s. These restrictions began to be moderated only in the 1980s; as the editors of an educational journal put it, in a special issue on university-industry collaboration, "the allergic response to the universities-and-industry collaboration is recently diminished."[18]

In this history of the hesitant relationship between universities and industry in postwar Japan, the role of university engineers in industrial development was in general rather implicit and indirect. Most of them did not commit themselves to making industrial innovations or selling their technological ideas. Perhaps one of their important roles was to mediate technological ideas between academic and industrial engineers or among industrial engineers. National and university research laboratories as well as annual meetings of academic societies provided occasions for such engineers to exchange important technical information. On a less formal level, university professors took the initiative in constructing a network of academic and industrial engineers, and made information on new technological ideas flow through that network.[19]

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17. "Daigaku Kaikaku Junbi Chōsakai Daiichiji Hōkokusho (The First Report of the Investigative Committee for the Preparation of the University Reform)" (October 1969), on pp. 99–100. It is an unpublished report preserved at the Centenary History Archival Center of the University of Tokyo. I am grateful to the late archivist Minoru Nakano of the Center for having informed me of this document.
18. *IDE*, no. 244, p. 5.
19. Nikkei Sangyo Shimbun, ed., *Nihon Gijutsu Jinmyaku* (*Human Networks of Technologies in Japan*) (Tokyo: Nihon Keizai Shimbunsha, 1989) recounts some fifty such networks in various technological and bio-medical fields.

The history of an instrument manufacturer shows the ways in which such networking worked in an almost ideal manner. This company, Murata Seisakusho, developed from being a small ceramics manufacturer into a leading high-tech electronics instrument company. In the process of its postwar development, its president, Akira Murata, received pivotal advice from Tetsurō Tanaka, a member of the engineering faculty at Kyoto University. Tanaka knew the interesting dielectric characteristic of a certain titanium alloy, and at a meeting of the *Kenkyū Tonarigumi* he recommended that Murata manufacture some products using this material. Murata followed advice and produced a titanium alloy condenser with the close collaboration of Tanaka's laboratory at Kyoto University.[20] When Murata was later at a loss as to what other products might use the piezo-electric characteristics of this titanium alloy, Tanaka again gave him the crucial advice that it could be used as a filter for radio waves; Murata Seisakusho became a leading manufacturer of radio wave filters, which eventually has led to their production for mobile telephones.[21] The history of Murata Seisakusho tells us that one of its managerial philosophies was "to borrow wisdom from experts," and that such a policy has worked throughout its history.[22]

The fruitful collaboration between Murata and Tanaka may not be a typical case in the history of university-industry collaboration in postwar Japan. But their give-and-take relationship seems to reflect well the postwar situation of university-industry cooperation.

8. Conclusion

The year 1945 marked a watershed in the history of university-industry cooperation in Japan. In prewar Japan, such a cooperative

20. Murata Seisakusho Gojūnenshi Hensan Iinkai, *Fushigi na Ishikoro no Hanseiki: Murata Seisakusho Gojūnenshi* (*A Half Century of Wonderful Stones: The Fifty Year History of Murata Seisakusho*) (Kyoto: Murata Seisakusho, 1996), pp. 15–20.

21. Ibid., p. 60. The professor and the manager had, however, conflict over whether the filter be applied to expensive high-performance receivers or economical radios.

22. Ibid., p. 47.

relationship was encouraged by the government and enhanced by the nationalistic environment. Not only those corporations that had made fortunes through war-related transactions but also those beneficent industrialists who succeeded in business were potential sources for prewar Japanese universities in expanding their research facilities and organizations. Large corporations donated money to establish foundations whose mission was to promote academic research activities, but did not establish their own research laboratories. As Barkhausen noted, there was no industrial laboratories at firms under Mitsubishi or Sumitomo. Many research efforts necessary for industrial innovation were, consequently, conducted at university laboratories.

The close prewar relationship between universities and industry was broken in 1945, and a new relationship was constructed. GHQ, most of whose influential members were Americans, attempted to disband the old university system and to implement a more democratic one. Although there were some discrepancies in their views of the role of the university in postwar Japanese society, university researchers lost their corporate patrons and had to continue their scientific investigations in extremely poor facilities for more than a decade. During that period, Japanese industrial corporations vigorously imported foreign technologies, bypassing Japanese university researchers. Large corporations began to establish their own central research laboratories and even recruited competent engineers from universities.

In the decade after Sputnik, the need for university-industry cooperation was increasingly recognized and budgets for scientific and engineering departments were greatly increased in order to remedy the material and institutional deficiencies at universities. University faculty began to receive financial support from industrial firms through the conduit of nonprofit organizations. However, the university reform caused by student protests in the late 1960s again restricted the cooperative relationship between university faculty and industry. It was only in the 1980s that the close cooperation between the universities and industries was generally encouraged by government agencies, including the Ministry of Education.

Behind this formal history of weak university-industry collaboration, there seems to have existed informal collaborations between university faculty and corporation in postwar Japan. Industrial firms offer experimental equipment or research funds to university faculty, who in return offer industry crucial technical information which may eventually lead to marketable products. Such symbiosis based on an informal give-and-take relationship seems to have existed and worked fairly well in at least at some quarters of postwar Japanese industry. The informal but nonetheless significant give-and-take relationship of Japanese universities and industrial firms are certainly worth for a more extensive investigation.

10

Technological Research Associations and University-Industry Cooperation

Reprint with revisions of the paper "Technological Research Associations and Industry and University Collaboration in Postwar Japan" presented at the symposium "Governing University Research: Historical and Comparative Perspectives" held at Glasgow University, 10–11 September 2004.

The need for more active collaboration between universities and industry has been claimed increasingly in Japan recently. The Japanese version of the Bayh-Dole act was enacted and TLOs were organized at many universities. Such an active promotion of the collaboration today conversely implies the relative inactiveness of their collaboration in the past. The previous chapter discussed a brief history of university-industry collaboration in Japan before and after the war. It has shown that despite an active collaboration between the two sectors in prewar Japan, it was set back after the war, and further subdued by the student protests in the late 1960s. It was only in the early 1980s that perspective regarding their relationship evolved and was actively encouraged from both sides.

In studying the history of this hesitant relationship, a curious question has remained. If the collaboration between universities and industries had been weak and subdued, what kinds of research were academic professors engaged in during the postwar period of Japan? What were the aims and content of academic research up to around 1980? The previous chapter pointed to academic meetings as a forum for both university and corporate engineers as well as to an informal relationship they had that enabled the exchange of technical information. This chapter will call attention to another important forum for their possible collaboration, that is, the technological research associations promoted mainly by MITI, the Ministry of International Trade and Industry.

1. The Ōkōchi Award

For the technological rise of postwar Japan, many crucial technologies were imported from abroad. Corporate engineers created many other important innovations. Academic engineers, on the other hand, rarely appear in postwar stories of Japanese industrial miracles. To examine the contribution of both academic and corporate engineers, it would be convenient to have an overview of major technological achievements in postwar Japan, and for that purpose, a list of awards given to important engineering innovations has been investigated. A list of such awards could possibly serve as an index for major technical innovations in the period. The author has consulted for this purpose the Ōkōchi Award, which was established in 1954 in honor of Masatoshi Ōkōchi, the former director of the Institute of Physical and Chemical Research. The awards were given for the most significant industrial innovations, both basic and practical.

According to the official history of Ōkōchi Award, only about seventeen out of 281 innovations were the outcome of industry and university collaborations.[1] Of these seventeen awarded innovations, some originated from research done by university faculty members, and others from that done by corporate engineers. Several other examples show that the awarded innovations were the outcome of fruitful collaboration from within cooperative research groups, both formal and informal.

2. Technological Research Associations

Of these formal and informal meetings, I have been particularly interested in the group called "kenkyū kumiai" or the Technological Research Association. In 1975, an Ōkōchi award was given for the

1. Ōkōchishō Sanjusshūnen Kinen Shuppan Henshū Iinkai, ed., *Ōkōchishō Sanjūnen no Ayumi: Jushōgo no Tenkai to Hakyū Kōka* (*The Course of Thirty Years of the Ōkōchi Award: Developments and Effects after the Award*) (Tokyo: Ōkōchi Kinenkai, 1987).

development of a measuring device for optical response functions, which was the result of the collaboration between a university professor, corporate engineers, and researchers at a national laboratory as the activity of the Optical Industry Technological Research Association.

The system of technological research associations was formally established with the enactment of the Law on Technological Research Association in Mining and Manufacturing in 1961 with MITI's initiative. According to the law, these research associations could only consist of corporate members, and excluded academic universities, presumably reflecting the discord between the two ministries supervising them. However, its actual procedure permitted active participation of academic engineers as consultants or subcontractors.

The 30 Year History of Technological Research Associations tells us about the origin of the idea of research associations. After the war, Masao Sugimoto, Director of the Mechanical Testing Laboratory under MITI's Agency of Industrial Science and Technology, became interested in the system of research associations created in Britain in 1917. Sugimoto visited and investigated British research associations and wrote a report on it in the mid 1950s.[2] He concluded the report with the necessity to establish such organizations in Japan to promote the R&D activities of smaller companies. Soon after the publication of his paper, several research associations were organized to work on automobile technologies: filters (1956), radiators (1957), air springs (1958), and engine parts (1961), although they did not in fact become formal research associations under the 1961 law, because large automobile corporations were reluctant to follow the rule that required a democratic process of decision-making by all member companies. Behind the establishment of these research associations, there was a large amount of funding for industrial research provided by the Agency of Industrial Science and Technology at MITI. Research associations were considered suitable outlets to receive such public funds. Starting at three million yen in 1949, it grew to 30 mil-

2. Masao Sugimoto, "Eikoku no Kenkyū Seido nitsuite (On the System of Research Associations in Britain)," *Nihon Kikai Gakkaishi* (*Journal of the J.S.M.E.*), 59 (1956): 589–593.

lion yen in 1950 and half a billion yen around 1959.

The 30 Year History of Technological Research Associations lists 94 technological research associations, of which 52 were still active in 1990. [3] The number of associations established during these three decades is as follows: 13 during the first decade from 1961 to 1970; 34 during the second decade from 1971 to 1980; and 47 during the last decade from 1981 to 1990. The areas of technology covered by the associations and the numbers of established associations in respective areas are as follows: machine and electronics industries, 35; chemistry, 24; non iron material, 10; textiles and paper, 6; electric power, 6; steel, 4; others, 9. The tables of technological associations list their member companies and, if any, the universities or university professor who were intended to serve as technical consultants or leaders. Of the 94 research associations, only twelve or so associations explicitly refer to the participation of university faculty.

Among others, the above cited Optical Industrial Technology Research Association particularly fostered active collaboration between industrial and university researchers. It originated in the informal Camera Technology Meeting, which had been organized after the war by engineers of the Machine Testing Laboratory. An Optical Informal Meeting of the Society of Applied Physics followed up on part of the activities of the meeting, and the Industrial Technology Committee of the Japanese Society of the Camera Industry followed up on the more technical part. The latter committee was reorganized as the Technological Research Association of the Camera Industry in 1956 at the initiative of the engineer of the Machine Testing Laboratory and a MITI bureaucrat modeling the system after British research associations, specifically the Scientific Instrument Research Association. This research association tackled several technological topics including a method to prevent lenses from tarnishing, improvements in grinding and polishing techniques, and the development of a measuring method for the response function of lenses. With the enactment of the above Law of Technological Research

3. Kōkōgyō Gijutsu Kenkyūkumiai Kondankai, ed., *Kōkōgyō Gijutsu Kenkyūkumiai 30 Nenno Ayumi* (*30 Year History of Technological Research Associations of Mining and Industry*) (Tokyo: Japan Society for the Promotion of Industrial Technology, 1991).

Associations, it was finally reorganized as the Optical Industrial Technology Research Association, and previous research themes continued to be studied. At all phases of reorganization, it consistently encouraged close and active collaboration among engineers from industry, universities, and government laboratories.

One of the first topics pursued at the Association was on the problem of lenses tarnishing. The problem was originally assigned from the Society of the Camera Industry, and duly studied by members of the Association. Koreo Kinoshita's interim report captured quite well the nature and function of the research association and of university-industry collaboration using this organization. According to Kinoshita, they at first had attempted to find one single best method to prevent the problem, but soon found that the variety of manufacturing procedures of different member companies made it inappropriate to provide only one method. They investigated the causes of tarnish, searched exhaustively for conditions to prevent it, and gave practical preventive advice to the engineers of each participant company. By the time of the publication of the interim report, most companies had already solved the problem of tarnish, aided by research outcomes of this group. The report was therefore intended to provide basic knowledge and techniques to those not attending the committee. In it, he even used single-underlines and double-underlines in order to clarify that experimental findings were "fairly certain" and "definitely certain," respectively. Kinoshita's pedagogical stance was consistent with his formal position as a physics professor at a private university, and his reservation from providing specific and practical advice somehow reflected the role of the technological association. In another case, a university professor who had studied a new technology at an American university played a crucial role in stimulating another research activity at this association.

Although it is not certain that the active collaboration between corporate and academic engineers at the Optical Technology Research Association was a typical case, the authors of the history of these research associations state that it was so. Their statement on the industry and university collaboration in relation to this institutional system is worth full quotation:

We cannot escape to observe that Technological Research Associations became a forum to combine universities and industry, and contributed to promote industry and university collaboration.

After the war, Japanese universities showed a strong refusal to collaborate with industries because it only profits private companies. But university departments of science and engineering recognized the great importance of university and industry collaboration for the improvement of technological standards and industrial development, and both sides have closely collaborated. Therefore, the need for university and industry collaboration was consistently emphasized in postwar Japan.

Technological Associations, being organizations of collaborative research of private companies, were not public organizations like foundations, but *they were regarded to possess a public character, and university researchers were able to cooperate relatively easily on research and development of technological research associations.* When technological research associations received grants-in-aid or money-in-trust from the government, in particular, they were well justified to cooperate with the government and participate in the association, easily and actively. Those from universities took positions as consultants or engineering members, and played important roles in making research plans, leading the execution of plans, and assessing research outcomes.

University researchers were also able to obtain knowledge of advanced technologies through the participation in research and development of cutting-edge technologies. They thankfully recounted that they acquired condensed technological knowledge usually unobtainable by routine attendance at academic meetings.

What is particularly important is the creation of a human network among university and corporate engineers. It seems that these human networks will play an important role for the exchange of technological information after the end of research and development. By the R&D activities of technological research associations, the climate for university and industry collaboration has been created and reluctance of universities to collaborate with private

> corporations has been gradually alleviated. [emphasis added] [4]

Their reference to a sociological reason particularly caught my attention. Since they possessed a public character, university researchers could collaborate relatively easily with engineers. As stated above, only 13% of the research associations explicitly refer to the involvement of university professors. But it might be possible that university professors actually worked for research associations that did not explicitly record their participation.

3. Concluding Remarks

In this history of the hesitant relationship between universities and industry in postwar Japan, the role of university engineers for industrial R&D was considered generally rather implicit and indirect. Most of them did not commit themselves to making industrial innovations or selling their technological ideas as they now actively attempt to do. National and university research laboratories, annual meetings and investigative committees of academic societies, and technological research associations—all provided occasions for academic and corporate engineers to exchange important technical information. Such forums for information exchange, in turn, helped construct various forms of a human network. And this human network, all-important in the Japanese cultural context, sometimes played a significant role in charting the technological course of industrial corporations, and cannot be ignored when discussing the present theme.

4. Ibid., pp. 34–35.

11

The Roles of Corporations, Universities, and the Government before and after 1990

Reprint with an additional postscript of "Japanese Innovation System Reconsidered: The Roles of Corporations, Universities, and the Government before and after 1990," *International Journal of Contemporary Sociology*, vol. 42, no. 1(2005): 44–50.

In 1992, the economist Richard Nelson edited the book, *The National System of Innovation.*[1] It provided a comprehensive and comparative survey of the system and characteristics of innovation activities in various countries. In the chapter on the Japanese innovation system, Goto and Odagiri traced the history of technological innovation in Japan, and discussed the important actors involved in such innovation activities.[2] They specifically discussed the strength of the industrial sector and the relative insignificance of the academic governmental sectors. According to Goto, their argument was partly a counter-response to the prevalent view on the Japanese innovation system at the time, which placed greater emphasis on the strong initiatives taken by the government, especially MITI, as was discussed in Chalmers Johnson's *MITI and the Japanese Miracle.*[3] It was certainly true that corporations played a crucial role in producing much of the industrial innovation in Japan's recent past.

Since it was published in 1992, such a system of innovation like Japan portrayed via Goto and other scholars has, at least in some respects, experienced a significant change. Despite, perhaps partly due to, economic decline and financial problems in Japan, the govern-

1. Richard R. Nelson, ed., *National Innovation Systems: A Comparative Study* (Oxford and New York: Oxford University Press, 1993).
2. Hiroyuki Odagiri and Akira Goto, "The Japanese System of Innovations: Past, Present, and Future," in ibid.: 76–114
3. Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925–1975* (Stanford: Stanford University Press, 1982).

ment has taken new initiatives to strengthen the innovative activities in academic and industrial sectors. This chapter attempts to analyze and reconsider the views prevalent before 1990. It first introduces new historical research on cases of innovations by corporations and discusses the nature of the innovations. It will then show the new initiatives taken by the government especially through the establishment of the Science and Technology Basic Law in 1995.

1. Corporate Initiatives in Postwar Japanese Innovation

The recent popular TV program in Japan, "Project X," introduces a number of case stories for the efforts of postwar Japanese engineers to make technological accomplishment through the production of new products or solving difficult social problems. The examples are numerous—video recorders, the YS11 airplane, an endoscopic camera, the bullet train, Honda's CVCC engine, Seiko's quartz watch, and so on. The emphasis of the program director is to disclose the difficulties the engineers together with their fellow assistants or family members encountered in their struggle to achieve a goal and how they finally overcame such difficulties. In presenting the drama in that way, university engineers are occasionally depicted as armchair scholars who only criticize the unfeasibility of the proposed innovation project. The key actors in these historical stories are all engineers who acted at construction or production sites rather than university laboratories.

Whether it is real or not, this image of engineers and the evaluation of the contrastive roles of corporate and university engineers seem to be prevalent in Japanese society. In comparison to engineers at corporations, it is considered that those at universities played a relatively insignificant role with regard to the rapid technological development in postwar Japan. As traced in the previous chapters, university faculty members in engineering and science were not encouraged to have close ties with industrial corporations until around the 1980s.

While the university and industry collaboration was apparently inactive, university engineers certainly contributed to the postwar development of Japanese technology. Aside from producing young engineers, they played a role in distributing and circulating technological information from outside and inside Japan. In some cases, they introduced foreign technical knowledge in a widely intelligible form to various engineers in Japan, and circulated knowledge of cutting-edge technology through some form of research group that they organized, bringing in engineers from different corporations.

The MITI is often said to have had an important role in implementing powerful industrial policy regarding the orientation of postwar Japanese industry, and MITI successfully fulfilled its role in catching up to the more advanced industrial and technological level of other countries. However, it is also said that MITI did not play any significant role in assisting with any specific innovations and technological development of corporations.

The innovative activities in corporations in postwar Japan are well documented and analyzed in a recent historical work edited by the historian of technology Tetsuro Nakaoka.[4] The book is the outcome of a research project done by a group of historians of technology that was conducted from 1993 to 1996. The project was to trace the trajectories of technological innovations at various corporations in the 1970s and 1980s when some Japanese corporations produced innovative products that could truly compete with foreign companies on the international market. Of roughly thirty historical cases, Nakaoka selected five to characterize the nature of innovative activities of postwar Japanese corporate engineers: the development of PAN carbon fibers, liquid crystal display, a stepper for lithographic alignment of semiconductors, turbines, and the pressing of steel plates.

As the book's subtitle, *Creation or Imitation,* indicates, Nakaoka poses a question about the originality of Japanese innovation in these years. After World War II, the Japanese made every effort to introduce foreign technologies from the Untied States and Europe in order to catch up to their technological level. They succeeded in doing so in

4. Tetsuro Nakaoka, ed., *Sengo Nihon no Gijutsu Keisei: Mohō kara Sōzō e* (*The Formation of Technology in Postwar Japan: From Imitation to Creation*) (Tokyo Nihon Hyoronsha, 2002).

the 1960s, attaining a high rate of economic growth. In the 1970s, however, Japanese industry started to experience economic competition on world market, and had to produce innovative products of a less expensive but still better quality. The five cases selected here examine the nature of the creativity of the products of Japanese innovation in this period.

All these products—carbon fibers, LCD, etc.—are original technology and competitive in the world market. The reason for the accomplishment in producing such original products was the accumulation of relevant technologies in corporations. However, Nakaoka emphatically denies the once-often-quoted statement that Japan became No. 1. He aptly analyzes that the degree of originality of these products was not as high as some produced in other leading countries.

They are certainly original in comparison to those produced when Japanese corporations were competing to catch up with the technological levels of U.S. and European companies. The Fuji Film Company attempted to produce its own film qualitatively equivalent to Kodak's by 1971 when the government lifted the ban of the import of foreign film. In a way, Fuji created its own process and product, but in the sense that the goal was clearly fixed, its innovation effort was not conducted in an environment of uncertainty. Tore, Sharp, Nikon, Canon, and Mitsubishi, the companies that produced the products analyzed by Nakaoka's group, did work in an environment different from Fuji. No company around the world achieved the goal of their innovation effort. It was uncertain whether the expected products could be made by the new technologies in hand. It was so uncertain, in fact, that RCA and Rolls Royce failed to produce a television set with LCD and a turbine blade strengthened with carbon fiber. They failed because their estimation of time for successful development was too optimistic. Nakaoka's emphasis on this uncertainty in developing new technologies and products led him to conclude that part of the reason for the success of Japanese companies was their luck in retrospectively selecting the right technology to attain their goal. Sharp was lucky, Nakaoka points out, firstly because RCA was on the wrong track, and secondly because RCA declined for Sharp to develop its product and so it was forced to develop the product by itself. Thirdly, unlike RCA, it did not select the wrong technology to use to make the product.

But Nakaoka also states that the degree of uncertainty that these Japanese companies overcame was not as high as the truly original accomplishment that no other company even attempted to produce similar products. While they tried to produce new products, the original scientific idea of the production technology had been found elsewhere and other companies were trying to make similar products using similar technologies. Based on this historical and economic analysis, Nakaoka points out that Japan entered an entirely different stage of technological innovation where technological uncertainty prevailed.

2. The New Initiative by the Government

In their paper on Japanese innovation systems, Goto and Odagiri posed the idea that "the weight of government policies will further decline, particularly because the government is losing most of its control tools through deregulation and liberalization." As they suggested, the government industrial policy of the postwar MITI style certainly seems to be losing its influence for the reasons mentioned by the authors. They stated, "MITI's role in the collection and diffusion of information may have been significant, as it could obtain information on overseas markets through its Japan External Trade Organization (JETRO)," but "this role has also declined as firms themselves accumulated international experiences and technological knowledge."[5] Goto, in his recent paper, refers to the achievement of the government-initiated large-scale technological development programs, such as "Next Generation Projects," as well as "research consortia."[6] Although he acknowledges the accomplishments made through these programs in the 1980s, he casts doubt on the feasibility of this policy to promote technological innovation that is not in "catch up" phase and

5. Odagiri and Goto, "The Japanese System of Innovation," op.cit., p. 103.
6. Akira Goto, "Japan's National Innovation System: Current Status and Problems," *Oxford Review of Economic Policy*, vol. 16, no. 2 (2000): 103–113.

also of new technologies such as IT and genome engineering, in which small venture capital firms can play important roles.

In the paper, Goto re-examines the possible roles of three sectors: industries, universities, and the government. In particular, he emphasizes the prospect of Japanese universities. Although the role of the university has been low key in postwar years and it seemed to remain so due to the financial stringency of the government, he points out that the situation surrounding the university is rapidly and vastly changing and the government is increasing its role in supporting basic research. As he states:

> This trend has changed significantly in recent years. In accordance with the 1996 Basic Science and Technology Plan, which was based on the provisions of the Science Technology Act of 1995, the target budgetary funding for research was doubled to about 1 per cent of GDP, a figure on par with the allocations in Europe and the United States. Government spending on research has since grown faster than other public expenditure items, and the 1 per cent target is being achieved, as planned, this year. [7]

The Science and Technology Basic Law (Act) originated from an idea of a Liberal Democratic Party politician, Koji Omi, who worked for science and technology policy in the party.[8] The Act itself had once experienced total refusal as a law in 1967, when the proposed act was rejected because it included the promotion of human and social as well as natural sciences. Omi started to investigate the content of the act to be proposed in 1994, and the act was passed in congress the next year. Behind the establishment of the act, there prevailed a public opinion to improve the deteriorated research conditions at university laboratories, and there was also a new policy to construct a Center of Excellence.[9]

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7. Ibid., p. 107.
8. This Japanese act, "Kagaku Gijutsu Kihon Hō," is now officially more often translated as "Science and Technology Basic Law."
9. Shuichi Tsukahara, "Science and Technology Policy towards Basic Research," *Journal of Science and Technology Studies*, 24 (1994): 12–36.

With the establishment of the Science and Technology Basic Law and Plan, the Council for Science and Technology Policy at the Science and Technology Agency increased the importance to implementing science and technology policy. The Council for Science and Technology Policy (CSTP) was established in 1959. Because the function of the Science and Technology Agency was decided not to cover research conducted at universities as well as human science research, the role of the CSTP was limited. In the early 1980s, a new fund was established and enhanced its power. It was the Special Coordination Fund for Science and Technology (SCFST), established in 1981, which aimed at enhancing the coordinating function of the Council for Science and Technology Policy at the Science and Technology Agency. The SCFST was to "promote cutting-edge and basic research, to promote research and development requiring more than one institution, and to enhance the cooperation between academia, government, and industry."

The numbers of SCFST steadily grew in the 1980s and its growth rate further increased in the 1990s. The establishment of the Science and Technology Basic Plan further enhanced it despite the government and Japanese society suffering from devastating financial problems.

In January 2001, the Japanese government experienced a massive reorganization, and the Ministry of Education and the Science and Technology Agency merged together into the new Ministry of Education, Culture, Sports, Science, and Technology (officially abbreviated as MEXT). As a result of this substantial reorganization, the Council of Science and Technology was transferred from the Science and Technology Agency to the Cabinet Office under the Prime Minister. Its objectives were "basic/comprehensive policy planning of science and technology and general coordination, taking the initiative among the ministries concerned, with an overall and panoramic view."[10]

At the eve of the merger of the Ministry of Education and the Sci-

10. Council for Science and Technology Policy, "Council for Science and Technology Policy," February 2002. As accessed in 2002 at the website of the Council of Science and Technology Policy. The document has been, however, subsequently deleted from the website.

ence and Technology Agency, a private group of experts in science and technology policy presented a report on the significance of the Council of Science and Technology Policy. The report was based on the investigation of a special committee at the Society of Science, Technology, and Economy, whose members included industrial leaders, journalists, and scholars in innovation policy. The investigation, which took place in 1999 and 2000, consisted of research about published materials, including the reports of the Council for Science and Technology Policy, as well as interviews with those concerned with the research and development of science and technology in some way or another. At the meeting of those interviewed, experts in science and technology policy provided an insightful and well-summarized view about the significance of the Council of Science and Technology Policy. In conclusion, the report summarized the points of both positive and negative evaluations. Of them, the positively evaluated points are:

(1) Leadership in the promotion of science and technology as an important national policy;
(2) The education of scientists and engineers;
(3) The emphasis on basic research;
(4) The presentation of goals of research investment;
(5) The promotion of life sciences;
(6) The promotion of earth and environmental sciences and engineering;
(7) Planning of the general policy on the evaluation of national research and development;
(8) The promotion of national experimental and research laboratories.

On the other hand, rather negatively evaluated points are:

(1) It could not hold enough discussion at the Council;
(2) The strong tendency to approve the plan of each ministry;
(3) The lack of the follow-ups of the execution of basic policies recommended by the Council;

(4) The partial selection of members of the Council;
(5) The lack of the function of analysis and investigation at the Council;
(6) Problems of the function and organization of the administrative office of the Council;
(7) The delay in the engagement of scientific and technological education;
(8) The lack of emphasis on the utilization of achievements through technology transfer by the cooperation of academe, industry, and government.

From these analyses, the report proposes to emphasize five points of "syntheses (sōgō)" to be attained by the new science and technology policy:

(1) The synthesis between private and public sectors;
(2) The synthesis between the center and the local;
(3) The synthesis between society and scientific and technological communities;
(4) The synthesis among separate academic and bureaucratic structures;
(5) The synthesis between Japan and the world.

The "synthesis" means here putting emphasis on the relatively neglected domains, such as S&T research activities in local regions and at private universities, as well as constructing a productive relationship between relatively separate domains. Notably, item four proposed to bridge the gap between separate academic disciplines as well as between separate bureaucratic offices under different ministries. And item three stated the need to bridge the gap between researchers who create scientific ideas and technological products and people in the public who are supposed to receive the benefits from these products. After the report was presented, the Council for Science and Technology Policy was reorganized. Whereas its English name was not changed, its original Japanese name notably added "sōgō (synthesis)" at the top of its name. Its new Japanese name "Sōgō Kagaku Gijutsu

Kaigi" initially meant "Synthetic," "Comprehensive," or "General" Science-and-Technology Council.

The renewed Council, which started in the new century, incorporated several characteristics requested by the above report. First, the new Council moved from the Science and Technology Agency to the Cabinet Office under the Prime Minister, thus greatly enhancing its power in the bureaucratic structure of the Japanese government. The newly established Cabinet Office itself has had a function to plan the basic and strategic policy and to generally coordinate separate bureaucratic branches. Strategy and coordination are the two key words of the function of the Cabinet Office and its branches. In addition, the Minister of State for Science, Technology and Innovation Policy was appointed to empower the Council.

Second, the Special Coordination Fund for Science and Technology, which has worked as an effective funding tool to implement the policies proposed by the previous and present Council, put emphasis on synthesis—the problems relating both to natural and social sciences or to more than one bureaucratic branch. Beginning in 2001, the ScoFST was allocated not only to national laboratories but also to universities to emphasize the lens of research encouraged by the basic policy proposed by the Council.

The outcome of the new science and technology policy encouraging various "synthesis" is yet to be seen. Whether this renewed emphasis on the university and industry cooperation will contribute to the Japanese economic growth of is also yet to be seen.

3. Postscript

In the last three chapters, I have discussed the postwar history of university-industry cooperative relationship in Japan. I did so to explore direct and indirect contributions of academic engineers to the creation of new industrial technologies or to the efficient importation and assimilation of new Western technologies. It should be remembered, however, that the relative autonomy of university engineers from corporations should have provided institutional merits to them.

First, the relative aloofness from urgent corporate needs permitted academic and government engineers to be engaged in basic and fundamental research on important technological subjects. Their research would not produce economically viable results within a short length of time, but would bring in the long run useful and profitable outcome to the public. There are successful cases of such long-term research whose decades-long consistent pursuit of a specific engineering subject brought about fruitful technological outcome only many years after its initiation.

Second, it should also be remembered that the role of engineers in present society is not limited to the creation of industrial technologies and technical know-how. They not only educate future engineers, but also often assume positions to control and orientate technologies to be used and created in society. Academic engineers, together with corporate and government engineers, joined committees to search for the cause of accidents and malfunctions of technological systems when they happened, to set standards to protect safety and environment, and to lay out policies and plans to allocate government financial supports among various engineering topics to attain a better society. For these increasingly important purposes, the relative autonomy of academic engineers is considered to provide indispensable merits and conditions allowing them to make sound judgments at increasingly complicated circumstances. And making such reasonable, considerate, and far-sighted judgments on complex and grave problems in the current changing world is becoming an increasingly important task for today's engineering experts.

Note about the author

Takehiko Hashimoto received his B.A. in 1980 and M.S. in 1982, both in the history of science, from the University of Tokyo. In 1984, he enrolled at the Department of History of Science at Johns Hopkins University in the United States, and received his Ph.D. on the early history of aerodynamics and aeronautics in 1991. Since 1991, he has been a faculty member at the University of Tokyo. From 1996 to 2006, he was affiliated with the Research Center for Advanced Science and Technology (RCAST), engaged in research on the history and social studies of science and technology. He is now a Professor at the Department of History and Philosophy of Science of the University of Tokyo. His main publications include *Butsuri Kagaku Tsūshi* (*A General History of Physics and Chemistry*) (Tokyo: Hoso Daigaku Kyoiku Shinkokai, 1999), *Chikoku no Tanjō* (*The Birth of Tardiness*) (co-edited with Shigehisa Kuriyama) (Tokyo: Sangensha, 2001), *Hyōjun no Tetsugaku* (*A Philosophy of Standards*) (Tokyo: Kodansha, 2002), and *Egakareta Gijutsu Kagaku no Katachi* (*An Iconographic History of Science and Technology*) (Tokyo: University of Tokyo Press, 2008). He has written papers on multiple topics in the history of science and technology, such as histories of time, clocks, standardization, physics, aeronautics, engineering education, and Japanese science and technology.