A Historical Look at Technology and Society in Japan (1500-1900)

An essay based on a talk given by Dr. Eiichi Maruyama at the Japan-Sweden Science Club (JSSC) annual meeting, Tokyo, 31 October 1997.

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Introduction

Japanese industry today produces many technically advanced products of high quality. There may be a tendency to think that Japan has only recently set foot on the technological stage, but there are numerous records of highly innovative ideas as far back as the 16th century that have helped to lay the foundations for the technological prowess of modern day Japan. The aim of this essay is to shed light on some historical aspects of the technological development of Japan that might otherwise be overlooked, and in certain cases are not even well documented.

Table 1 is a list of important historical periods in Japan from AD 250 to the present day that will serve as a useful reference to this series of essays.

The first part of the essay discusses some early examples of Japanese biotechnology and microlithography; the second part relates to the organisation and management of people and the development of a highly sophisticated socio-technological infrastructure; the third and final part concerns changes in education and scientific thought following the Meiji Restoration in 1868.

Periods	Dates
Nara	710- 794
Heian	794-1185
Kamakura	1192-1333
Muromachi	1338-1573
Aduchi-Momoyama	1573-1600
Edo	1603-1867
Meiji	1868-1912
Taisho	1912-1926
Showa	1926-1989
Heisei	1989-

Table I Japanese Periods

PART 1

Gunpowder and Biotechnology - Ukiyo-e and Microlithography

In many parts of the world, and Japan was no exception, the 16th Century was a time of conflict and violence. In Japan, a number of feudal lords were embroiled in fierce battles for survival. The battles produced three victors who attempted, one after another, to unify Japan. The last of these was Ieyasu Tokugawa, who founded a "permanent" government which lasted for two and a half centuries before it was overthrown and replaced by the Meiji Government in 1868.

One particularly well documented battle was the Battle of Nagashino in 1575. This was a showdown between the organized gunmen of the Oda-Tokugawa Allies (two of the three unifiers) and the intrepid cavalry of Takeda, who was the most formidable barrier to unification under Nobunaga. Three groups of untrained infantry men with 3,000 match-lock guns completely defeated the troops of veteran horsemen by cyclical firing of their weapons. Historians regard this tactic as being Nobunaga's invention, occurring as it did about 30 years prior to its introduction on a European battle ground. The events leading to the victory date back to 1543 when a Portuguese ship was wrecked off a small island off the south-west of Kyushu called Tanegashima. The ship bore a pair of match-lock guns. The Lord of Tanegashima, a 15-year old youth named Tokitaka Tanegashima, cleverly recognized the benefit of possessing firearms and purchased the guns at a price of 2,000 ryo (equivalent to $1,000,000 at today's prices). He then ordered his retainers to copy the design and manufacture duplicates. Historical archives show that when the Portuguese returned to Tanegashima two years later, they were very surprised to find guns being manufactured there.

As a result of mass production at Kunitomo in Oumi (now Shiga), Negoro in Kishu (now Wakayama) and Sakai (presently Osaka), even before the start of the Battle of Nagashino in 1575 there were more than 100,000 guns in Japan. The gun-making technology was greatly facilitated by the presence of traditional iron-making and forging industries, known as tatara, which had been nurtured by the swordsmiths and provided a plentiful supply of high quality iron for the gunsmith.

Gunpowder

Another factor that contributed to the growth of the gun industry in Japan was the supply of gunpowder. Black gunpowder is made from charcoal, sulphur and potassium nitrate, known also as nitre. While charcoal and sulphur were abundantly available, nitre, which is readily soluble in water, did not exist naturally in Japan and had,

consequently, always been imported from China. However, by using an early form of biotechnology Japan managed to secure a stable supply of nitre from its own resources. The process used for making the nitre was as follows. A rain-proof hut was built with a one metre square fireplace in the centre around which several one metre deep holes were dug. Stacked layers of mugwort leaves, silkworms' excreta and chicken droppings were thrown alternately into the holes. The holes were then covered with earth and warmed by the heat from the fireplace.
Subsequently, human urine (a good source of nitrogen!) was added and the material in the holes was left for four to five years. During this time the various materials underwent a series of chemical reactions: the nitrogen compounds (urea and uric acid) in the excreta decomposed into ammonia, this was then converted by bacteria into nitric acid which reacted in turn with potassium in the mugwort leaves to form the potassium nitrate or nitre. Subsequently, the contents of the holes were dug out and put into a barrel with a perforated bottom. Water was then poured in from the top to leach or dissolve out the nitre. The resulting solution was then refined and dried to make a pure product.

Ukiyo-e and Imaging Technology

The introduction of Ukiyo-e to Paris in 1850 created enormous enthusiasm for this form of Japanese art. Its fresh and simple use of colour together with its bold and clear designs was highly appreciated. Indeed, many impressionist and post-impressionist artists such as Monet, van Gogh and Degas were so deeply affected by Ukiyo-e art that they used its concepts in their own works. Ukiyo-e is a multi-coloured wooden block print which can be thought of as a high-precision colour printing technology. A painter creates an original picture design and a team of wood cutters engrave that picture into a number of wooden blocks, one for each of the different colours.Finally, a print is made using the seven or eight wooden blocks in accurate registration. Extreme care is required to prevent misalignment. A deluxe version of this technique called Nishiki-e also exists in which each print is made with 50 or 60 blocks, using a powder of gold and silver foil as well as the ordinary dyes on embossed paper. These prints are treasured by connoisseurs worldwide.

Techniques analogous to those of Ukiyo-e are used in the microlithography industry in Japan today. For example, the fabrication of microelectronic circuits such as the 256-megabit DRAM, where l0 to 15 separate exposures are required, employs multiple masks that have to be aligned with submicron accuracy.

PART 2
Socio-Technological Infrastructure

During the Edo Period the practice of "sankin kotai" (1) contributed to the establishment of a very efficient socio-technological infrastructure in Japan. This was because if approximately 260 daimyos spread over Japan travel back and forth between Edo and their respective domains once every other year, it is necessary to establish an extensive traffic management system, including chains of relay stations to provide lodgings, horses, labourers, food and other provisions, distributed along major paths. For instance, about 130 daimyos having domains in the western part of Japan had to pass through a sekisho (checkpoint) at Hakone. Since most of the jounrneys involved during sankin kotai were scheduled in Spring, the relay station at Hakone had to accept daimyo processions everyday. This required a systemmatic operation based on a precise timetable, flexible adjustment to cope with unexpected accidents such as storms and flooding, and effective information gathering on the part of the relay stations. The money spent by the Daimyo during this biennial journey was mostly used for maintenance of the traffic infrastructure. There is a byobu (folding screen) portraying a view of daimyo gyoretsu (procession) of the Kaga-han involving more than 2,000 people. They shuttled between Kanazawa, home city of the Maeda, and Edo, walking 600 kilometers in a fortnight every other year. The Maeda spent about 200 million Yen per single journey at current prices. The establishment of a traffic infrastructure stimulated tourism among the general public. They enjoyed travelling in groups to Ise Shrine. According to statistics, nearly 3 million people, about 10 % of the total population of the nation at the time, visited Ise each year. The Japanese fondness for teamed tourism seems to have been inherited from this period.

The long distance travel of a daimyo on sankin kotai required frequent communication between his home and Edo by hikyaku or courier system. At that time, a courier ran from Edo to Kyoto in about 10 days, while an express courier on relayed horses covered the distance in 2 days. This speed is comparable to that of the current mailing system.

Centralized Economy

The feudalism of Japan in the Edo Period was somewhat different from that in Medieval Europe. Feudal lords or daimyos were given autonomous political authority for their domains, but the economy was fully centralized.

Edo, with one-million inhabitants, was one of the largest cities in the world. Samurai and their employees accounted for about half of the Edo population. They were all consumers. Most commodi-

ties were transported to Edo from other parts of Japan, mainly via sea. A number of kaiser, or coastal trading companies, with fleets of merchant vessels, flourished with bases at Osaka, such as Higaki Kaisen and Taru Kaisen. For example, sake (rice wine) produced at Nada near Osaka and sent down to Edo was more highly evaluated than that locally brewed. From this, a Japanese adjective "kudaranai" evolved for lower quality, literally meaning "not sent down".

The centralized economy was based not on barter but on exchange of bill notes. This required merchants to be able not only to keep accounts by using a fore runner of the digital calculator, soroban (abacus), but also to read and write. In this way, merchants' children were forcibly educated.

At that time there were a large number of ronin, or unemployed samurai, who were well educated but not paid well. They opened juku or private schools in every corner of the nation's towns and villages. Popularised education improved the literacy of the Japanese to the highest level in the world, as high as 50 % (80 % for male and 20 % for female).

Another merit of sankin kotai was to distribute the metropolitan culture of Edo to remote towns and villages. Samurai returning home from Edo brought a variety of souvenirs, including Ukiyo-e prints, which served as sight-seeing guides of Edo, and fashion books to show portraits of Kabuki players, new hair styles and kimono patterns. The active cultural exchanges between the centre and remote areas are illustrated by the presence of old dolls manufactured in Kyoto in a remote village of Tohoku District.

The taxation in this period is said to be go-kou go-min, meaning 50 % of the harvest for the government and 50 % for peasants' consumption. In view of the population ratio among four classes at that time: peasants 84 % and the other three (samurai, artisans and merchants combined) 16 %, the government was taking much more rice than they consumed. Samurais discharged excess rice to the rice market at Osaka to obtain cash to buy extravagant goods. The tax rate was variable depending upon the financial conditions of each of the hens (feudal clans) or the state of harvest. In the year of a poor harvest, the tax rate was reduced, but unchanged or raised in others so as to secure fixed income for the samurai, while letting peasants suffer from starvation.

Prosperity in Genroku and Yoshimune's Reform

Peace and prosperity enjoyed a peak in the middle of the Edo Period, or Genroku Period (1688-1706). This period is characterised by the climactic development of consumer technologies, consolidation of traffic and transportation networks, urban infra-structure, and education. All these conditions have some resemblance to the phase of rapid economic growth of Japan in 1970-80s. Hence, this phase is often called "ShowaGenroku".

Engelbert Kampfer, a German surgeon-naturalist, was sent to Japan by the Dutch East India Company and stayed in Nagasaki between 1690-91. He introduced history, politics, religion and the geography of Japan to Europe in his book "Historia Japonica". Kampfer wrote about the Japanese as following: "All the people of Japan live in full harmony and cooperation, respect their own gods, observe laws, follow the superior's instructions, and exert politeness and friendliness to their colleagues. They are superior to any nation of the world in respect to habits, morals, arts and behaviors. They have thriving domestic trade, fertile farmland, good health and brave spirits. Daily commodities are available in surplus, and the political peace has been held for a long span of time. Thus, the Japanese are the happiest nation which is rarely encountered in the world."

Every peak is accompanied with a trough. The Genroku prosperity was followed by a serious depression. Here stepped in the eighth Shogun, Yoshimune Tokugawa. Kiyonobu Itakura, a historian, described the situation as following in his book "Nihonshi Saihakken (Rediscovered History of Japan)": Yoshimune issued in 1720 "Prohibition of Production of New Articles" stating that since everything is now in adequate supply, any new designs should not be produced. Production of new cakes, new kimonos, or anything new was bannned. This situation is closely analogous to the present day Japan where the domestic market is saturated by the collapse of the so-called "bubble" economy. From this time on there was technological stagnation throughout the Edo Period. The Prohibition Law is heavily criticized by historians including Mr.Itakura, for retarding technological progress in Japan. However, Yoshimune tried to strengthen the economic power of the Tokugawa Government by encouraging local industries and promoting expansion of new arable land.

The general populace of Edo responded to Yoshimune's Prohibition Law with extensive recycling of resources: used paper was collected to be used as raw materials for new paper, ash from ovens was gathered for use as fertiliser, and people were enthusiastically absorbed in low cost hobbies and entertain

ments such as haiku (making short poems), cultivation of asagao (morning glory), joruri (a sort of ballad sung to the accompaniment of shamisen, a 3-string instrument), bonsai (growing miniature trees as old as hundreds of years in a small pot), ikebana (the art of flower arrangement), chano-yu (tea ceremony), hana-mi (going to admire cherry blossom), momiji-gari (going to admire autumn col-

ors) and o-matsuri (a parading and dancing festival).

Another undertaking Yoshimune emphatically promoted was education. He allowed learning of Dutch things except for Christianity. He allowed town people to attend lectures at Shoheiko, a government operated school for young samurai. Furthermore, Yoshimune encouraged daimyo to establish their own government and private schools. This contributed to raising the literacy of the Japanese to the highest level in the world at that time.

In the area of science and technology, a mathematician, Takakazu Seki invented the calculation of determinants, and a surgeon, Seishu Hanaoka prepared an anaesthetising agent called "Tsusen-San", with which he anaesthetised a female patient and successfully removed breast cancer, 37 years prior to general anaesthetision with ether by the American surgeon, Crawford W. Long. Tadataka Ino, who was a merchant until the age of 50 years, started to learn astronomy and the art of surveying and made a highly accurate map of the entirity of Japan in 17 years, walking through all the areas of Japan. Errors in Tadataka's map are said to be within 1/1000.

Towards the end of the Edo Period, a number of private schools were active in teaching young people. Among them were: Kaitokudo; Tekijuku, founded by Koan Ogata in Osaka for teaching science and medicine in the Dutch language, and Shoka-sonjuku in Yamaguchi presided over by Shoin Yoshida. Many of the young samurai, who greatly contributed to the Meiji Restoration, were trained and educated at these schools: Yukichi Fukuzawa and Masujiro Omura at Tekijuku; and Takayoshi Kido, Shinsaku Takasugi and Hirobumi Ito at Shoka sonjuku.

By the 19th century, the old socio-economic structures were beginning to collapse. Peasant uprisings had become common place, the samurai and even the daimyo were badly indebted to the merchant class, and the Tokugawa Government's repeated attempts to improve the economic situation failed. The leadership of Shogun was questioned, and further deteriorated by the arrival of Perry's ships, forcing Japan to accept unequal commercial treaties with the United States and several European countries. In l867, the Shogun was forced to resign and the imperial government was restored under the young Meiji Emperor.

PART 3

Meiji Restoration

Meiji Ishin or Restoration was a coup d 'etat initiated and brought to completion by a group of young samurai of Choshu (present Yamaguchi Prefecture) and Satsuma (present Kagoshima Prefecture). Choshu is located at the extreme west of Honshu Island, and Satsuma at the extreme south of Kyushu Island. Both were least affected by, and the least attached to, the cultures of Edo and Kyoto.

Education in Early Meiji

A number of Japanese scientists achieved world-wide fame in the Meiji Period. For instance, Shibazaburo Kitazato developed the serum therapy for tetanus under Dr. Robert Koch of Germany; Jokichi Takamine discovered adrenaline (or epinephrine), a hormone which causes emergency reactions in the body and is produced in the adrenal gland; Kikunae Ikeda discovered the seasoning effect of kelp extract, identified its main ingredient (sodium glutamate) and commercialized it as ajinomoto; Hantaro Nagaoka proposed an atomic model based on the Saturn ring system; Kumagusu Minakata pioneered the study of slime molds and plants in ever-green, broad-leaved tree forests; Kiyoshi Shiga identified the pathogen of dysentery, Bacillusdysenteriae, which was later renamed as Shigella dysenteriae after him; Umetaro Suzuki discovered that vitamin B1 (or thiamine) prevented beriberi, and Hideyo Noguchi succeeded in culturing the pathogen of syphilis, Treponema (formerly called-Spirochaeta) and was nominated for a Nobel Prize in physiology or medicine several times.

Alas ! Subsequently, no renowned scholars emerged from Japan until Hideki Yukawa was awarded with the Nobel Prize in physics in 1949. It may be said, that under the Seclusion in the Edo Period, the intellectual potential of the Japanese had been fully realised, and, after the Restoration, a lot of ambitious young men went abroad to boost their scientific capability. I think that the education system established in the Meiji Period is responsible for reducing the vigor of Japanese scientists in the early part of the 20th century.

The Government established a schooling system in 1872, by combining elementary schools operated by feudal lords with privately owned terakoya, to provide equal opportunity for education to children of all classes under a centrally controlled system. In 1879 the Law of Education was enacted to reform the primary school system, transferring educational control to local communities. The Government, suffering from a financial crisis, was attempting to reduce its financial burden.

In 1886 the Education Ordinance was issued to centralize educa-