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Chinese astronomy in the time of the Jesuits: Studies following *Science and Civilisation in China*

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Abstract

Viewing traditional Chinese science as one of the tributaries to be merged into the grand ocean of modern/universal science, Joseph Needham placed great importance on the period of the Jesuits in the 'Sciences of the Heavens' section in volume 3 of *Science and Civilisation in China*. He considered that period a turning point when Chinese astronomy – a representative field of Chinese science – changed from its traditional form into universal/modern astronomy. Among the work of other historians of Chinese science, Joseph Needham's work helped foster a growing interest in the astronomical work of the Jesuits in China. After more than 50 years, as many of the details in Needham's original work have been gradually clarified and enhanced, a new picture of the Jesuits' contribution to Chinese astronomy has taken shape. In some important respects, that picture is quite contrary to Needham's overall claim about the role and result of Jesuit works in the development of astronomy in China, which has led to new questions that invite further investigation.

Keywords

Joseph Needham, Chinese astronomy, time of the Jesuits, European astronomy in China

In volume 3 of *Science and Civilisation in China*, Joseph Needham (1959) devoted one section (section 20j) to 'The time of the Jesuits' (pp. 437–461). The section has only 20 pages, which is limited, compared to the 290 pages dedicated to the entire section on astronomy; however, by treating the period as a transitional stage leading to the final integration of Chinese astronomy into modern science, Needham attributed special importance to this section of the history of Chinese astronomy.

In his general view of the history of human science, Needham saw all traditional Chinese sciences as tributaries to be eventually merged into the grand ocean of the modern and universal science discovered and developed in Europe, but which was bound to be shared by people all over the world, including the Chinese. In the field of astronomy, he found a pertinent example that enabled him to analyse and illustrate such a process. From the voluminous but diffuse literature on the period, mostly created by sinologists, he told a succinct story that touched upon the most important aspects of the 'mutual impact of Chinese and Western thought' (Needham, 1959: 437) in the 17th and 18th centuries.

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All in all, Needham (1959) saw the transmission as 'an example of cultural relations at the highest level between the two civilizations theretofore sundered', one of which 'had the qualities of noble adventure' (p. 457). At the same time, however, he also emphasized that 'the coming of the Jesuits was by no means (as it has often been made to appear) an unmixed blessing for Chinese science' (Needham, 1959: 437). As an expression of this standpoint and an introduction to the whole section on the period, he drew up a balance sheet of the merits and demerits of the contribution made by the Jesuits to the development of Chinese astronomy.

The merits included the following:

1. European methods for the prediction of eclipses;
2. A clear exposition of the geometrical analysis of planetary motions, and the Euclidean geometry necessary for applying it;
3. The application of geometry in gnomonics and the stereographic projections of the astrolabe, and in surveying;
4. The doctrine of the spherical earth and its division into spaces separated by meridians and parallels;
5. The new 16th-century algebra of the time of Vieta, with new computing methods and, ultimately, mechanical devices such as the slide rule;
6. The most up-to-date European techniques of instrument-making, graduating of scales, micrometre screws, and so on, with increasing use of the telescope.

However, the demerits as seen by Needham included the following:

1. The imposition of the closed Ptolemaic–Aristotelian geocentric universe of solid concentric celestial spheres, which was dissipating in contemporary Europe, upon what Needham believed to be the indigenous *Xuan Ye*[1] doctrine of the floating of heavenly bodies in infinite space;
2. The obstruction of the spread of Copernican heliocentric doctrine in China;
3. The substitution of an erroneous theory of the precession of the equinoxes for the 'cautious Chinese' who refused to form any theory at all about it;
4. The complete failure in appreciating the equatorial and polar character of traditional Chinese astronomy, and therefore confusing the *xiu*[2] divisions with the zodiac, thereby equalizing the duodenary equatorial divisions when there was no need to do so;
5. The imposition of the less satisfactory Greek ecliptic coordinates upon Chinese astronomy.

Needham was more interested in the demerits and paid more attention to them. In section (e) on the 'polar and equatorial character of Chinese astronomy' and section (g) on the 'development of astronomical instruments' in the same chapter, he provided lengthy discussions on the issues related to demerits 3 and 4. In the section 'on the time of the Jesuits', he extended the discussion to demerits 1 and 2, which had obvious importance to a historian of science of his generation, who saw cosmology as the conceptual basis of science.

Through the story of how the celestial spheres were dissipating in Europe and its possible connection with China, Needham tried to show the absurdity of Matteo Ricci's enumeration of the disbelief in the solid heavens as one of the Chinese 'absurdities'. He then turned to 'the two most important features in European astronomy at the time the Jesuits began their work in China': '(a) the invention and use of the telescope, and (b) the acceptance of the heliocentric theory of Copernicus'. After a review of how 'the former they [the Jesuits] transmitted, but the latter, after some hesitations, they held back' in the wake of the papal condemnation of Galileo and Copernicanism in Europe, he characterized the Jesuit dissemination of European astronomy in China as an 'imperfect transmission' (Needham, 1959: 443–447).

Next, Needham tried to show how the limited motives of the Jesuits in China restricted their transmission of science: on the one hand, they introduced in the *Chongzhen lishu*[3] (*The Chongzhen Reign Treatises on Calendrical Astronomy*) an astronomical system that belonged to the new and universal

'modern' science; on the other hand, however, in order 'to support and commend "Western" religion by the prestige of the science from the West', they labelled the system 'Western science', which in his view was the name for a premodern and 'culture-rooted' science.

Finally, through a description of the refitting of the imperial observatory by Ferdinand Verbiest (1623–1688) and his Jesuit successors and their works on positional astronomy, as well as a survey of the responses to the Jesuit astronomical work of 'a number of Chinese scholars who were more or less outside their [the Jesuits and their followers'] circle', Needham sketched a picture of the integration of Chinese astronomy into modern science. According to his estimation, in about 1850, 'when Fêng Kuei-Fên gave tables of right ascensions and declinations of 100 stars in his *Hsien-Feng Yuan Nien Chung Hsing Piao*,[4] Chinese astronomical science might be said to have merged at last with that of the world as a whole' (Needham, 1959: 451–456).

Among historians of Chinese science, Needham's work helped foster a long-lasting interest in Jesuit astronomical work in China. Most of the points in his balance sheet have been studied further by later researchers. For example, following in the footsteps of demerit 1, Jiang Xiaoyuan reviewed the history of the celestial spheres and their fate in China. He found that Needham's accusation of the Jesuits 'did not reflect the fact in its entirety', because the Jesuits openly refuted the theory of the celestial spheres in the *Chongzhen lishu*, and the influence of the theory on Chinese astronomers was very little, if any (Jiang, 1987). In my study of Li Zhizao and Furtado's *Huanyou quan*[5] (*An Explanation of Things in the Cosmos*) – the Chinese translation and reception of the Coimbra commentaries on Aristotle's *De Caelo* – I examined the issue and confirmed Jiang's second impression (Shi, 1988). I found that the theory was thoroughly criticized by some Chinese astronomers of the time, such as Jie Xuan, who based his criticism not only on the Tychonic system of the world introduced into China through the *Chongzhen lishu*, but also on the traditional Chinese doctrine treating the heavens as a series of concentric whirlpools of *qi* moving at different speeds (Shi, 2004).

Demerit 2 has been keenly scrutinized further by historians of science in China. One point at issue was the reason for the Jesuits' failure in transmitting the heliocentric theory to China. Needham (1959) did not accept the contention that the reason was 'the resistance of the Chinese to any abandonment of the geocentric worldview', but at the same time he believed that 'this can have been only a part of the story', the other part being the condemnation of Galileo back in Europe (pp. 443–445).

On the occasion of the 500th anniversary of the birth of Copernicus, Nathan Sivin (1973) published a complete and contextualized article on the issue. Similarly to Needham, Sivin attributed the main reason to the direction taken by the Catholic Church on Copernicanism in 1616, but he did not believe that the Chinese had any intellectual or linguistic failings or any metaphysical disposition to reject the early fruits of modern science: 'To the contrary, those best prepared to judge were quite receptive'. In his opinion, the major hindrance came from two factors:

- In the beginning, the Jesuits characterized Copernicus' world system in a very misleading way so that 'when a Jesuit was free to correctly describe it in 1760, Chinese scientists rejected the heliocentric system because it contradicted the earlier statements about Copernicus'.
- 'To the very end of the Jesuit scientific effort in China, the rivalry between cosmologies was represented as between one astronomical innovator and another, for the most convenient and accurate methods of calculations, rather than between the scholastic philosopher and the mathematical and experimental scientist, for the most fruitful approach to the physical reality. The character of early modern science was concealed from Chinese scientists' (Sivin, 1973).

Twenty years later, in their studies of the manuscript *Lifa wenda*[6] (*Questions and Answers in Calendrical Astronomy*), written in the second decade of the 18th century at the request of Emperor Kangxi, Jean-Claude Martzloff, Hashimoto Keizo and Catherine Jami found that the French Jesuit

Jean-François Fouquet (1665–1741) had already provided a full and correct introduction to Copernicus' sun-centred model of the planetary motions (Hashimoto, 1999; Hashimoto and Jami, 1997; Martzloff, 1994). Soon after, Yang (1999) discovered a full and clear description of Copernicus' heliocentric system of the world in the writings of Huang Baijia (1643–1709). Those discoveries updated the date of the first clear introduction of the heliocentric system to China, but they did not change the second factor stressed by Sivin, because neither Fouquet nor Huang Baijia highlighted the cosmological significance of the system. Both of them presented it only as a pre-Tychonic scheme for the mathematical treatment of the planetary motions.

The first factor that Sivin stressed is also confirmed by the study of the astronomical section of *Tianbu zhenyuan*[7] (*True Principles of the Pacing of Heavens*) by Nikolaus Smogulecki (1611–1656) and Xue Fengzuo (1600–1680). It was found that the work was in fact an adaptation of the theory and tables of Philippe van Lansberge (1516–1632) based on heliocentric models of the planetary motions. However, the contents in *Tianbu zhenyuan* turn out to be very misleading, because the true face of Lansberge's models is deliberately veiled through simple changes and omissions of any words that might admit to the idea of the sun's centrality or the movability of the Earth, even though both Smogulecki and Xue Fengzuo openly claimed that the system was a treatment of the planetary motions that was far more precise than that of Tycho Brahe (Shi, 2000, 2007).

Other points in Needham's balance sheet also received considerable attention, but points 1 and 2 in the list of merits are studied much more than other points. Actually, these two points are related to one single topic – planetary astronomy, which was of central importance to Chinese astronomy at the time of the Jesuits. However, Needham did almost nothing on that topic. This limitation has been substantially remedied through the efforts of a number of scholars, and the most studied work on planetary astronomy produced in the period is the great astronomical encyclopaedia, the *Chongzhen lishu* compiled between 1629 and 1639. In the past three decades, we have seen at least four doctoral dissertations and several articles on this great Jesuit astronomical work in Chinese and its later editions (Hashimoto, 1988; Jiang, 1988; Ning, 2007b; Wong, 2004; Zhang, 2014).

A key issue is how the works of Tycho Brahe and other European astronomers from Ptolemy to Kepler are introduced, and which European sources were used by the Jesuit compilers. Starting with Hashimoto Keizo's pioneering work, clearer answers to these questions have been found (see Hashimoto, 1986, 1987, 1988, 1993; Jiang, 1988, 1989, 1992; Martzloff, 1998; Ning, 2007a, 2007b, 2011; Sun, 1995).

Another interesting issue is the history of the encyclopaedia itself, on which Pan Nai, Chu Pingyi, Chu Longfei and I have carried out very important surveys (Chu, 2008, 2009; Chu and Shi, 2018; Xu and Pan, 2009). A collective collation of the *Chongzhen lishu* has been completed on the basis of nearly 20 fragmentary copies of the work preserved in different libraries and archives across the world, which provide the clearest yet picture of how this encyclopaedic work evolved through a great number of additions, deletions and revisions made both before and after the compilation of the whole set of treatises was completed (Shi and Chu, 2017).

Other important works on planetary astronomy mentioned by Needham in section 20(j)—*Tianbu zhenyuan, Lifa wenda, Yuzhi lixiang kaocheng*[8] (*Thorough Investigation of Calendrical Astronomy Imperially Composed*) and *Yuzhi lixiang kaocheng houbian*[9] (*Later Volumes of the Thorough Investigation of Calendrical Astronomy Imperially Composed*)—have also been studied in unprecedented depth. Meanwhile, the works of Chinese astronomers of the time, such as Wang Xichan, Xue Fengzuo and Mei Wending, have also been more thoroughly analysed.

With all of these new studies, the picture of astronomical knowledge transmitted by the Jesuits to China has become even more complicated than Needham depicted in *Science and Civilisation in China*. For example, we now know that, in parallel with the Tychonic system introduced in the *Chongzhen lishu*, a complete Copernican system was introduced in *Tianbu zhenyuan* as a better system than that of Tycho Brahe (Shi, 2000, 2007) and

even Newton's theory of the moon was fully adopted in *Yuzhi lixiang kaocheng houbian* in addition to Kepler's first two laws, although their cosmological meanings were not mentioned (Han, 2001; Lu, 1997; Shi, 2008; Shi and Xing, 2006).

From these works, it is clear that what was introduced by the Jesuits to China was in fact much more 'modern' than in Needham's judgement. Moreover, Chinese astronomers in the generations of Wang Xichan and Mei Wending have been found to be more capable and active in their study of new astronomical knowledge from the West. For example, according to our recent study, they were able to find and fix all of the crucial knowledge gaps and mistakes left by the Jesuits in the *Chongzhen lishu*, and it might be their works, rather than those of the Jesuits as was previously believed, that form the very basis of *Yuzhi lixiang kaocheng* compiled at the order of Emperor Kangxi (Chu and Shi, 2012, 2013).

All of these new discoveries are accompanied by the results from the studies in another important dimension neglected by Needham: the social and cultural context of the transmission. This has been fruitfully explored by recent scholars, including Huang Yilong (1990, 1991a, 1991b, 1991c, 1992, 1993, 1996), Chu Pingyi (1997, 2002) and Catherine Jami (2015), on the basis of the controversies, conflicts and mutual accommodations involved in the transmission and adoption of new astronomical knowledge from Europe during this special period.

Putting all these new results of research together and turning back to the big picture of Chinese astronomy in the time of the Jesuits drawn by Needham more than 50 years ago, we may form a more or less different observation on that picture. According to Needham, the period was a transitional stage for the final integration of Chinese astronomy into modern science. Now, however, we need to reconsider that judgement in the light of the new discoveries.

Of course, with all the new knowledge introduced from Europe by the Jesuits, the methodology of astronomy in China witnessed a change so thorough and substantial that Hashimoto (1981) even characterized it as 'a process of scientific revolution', while Sivin (1982) called it 'a conceptual revolution in astronomy', or China's 'own scientific revolution'.

Just as Sivin (1982) had noticed, however, such a revolution turned out to be quite different from its counterpart in contemporary Europe, because

> . . . it did not generate the same level of tension as the one going on in Europe at the same time. It did not burst forth in as fundamental a reorientation of thought about Nature. It did not cast doubt on all the traditional ideas of what constitutes an astronomical problem. It did not narrow people's view of what meaning astronomical prediction can have for the ultimate understanding of Nature and of man's relation to it.

In other words, it was different from its European counterpart in a very crucial dimension: the goal and basic value attached to the study of nature.

In fact, both the transmitter and the receiver of astronomical knowledge from Europe in that period shared the same goal, which was to serve a tradition that was thousands of years old at the time: the creation of a precise calendar that symbolized the authority of the emperor and the legitimacy of his power. In such a tradition, understanding nature and its works was not as important a task as in Europe. Within such a cultural milieu, both the Jesuits and Chinese astronomers could take a purely instrumentalist stance towards the different systems of planetary astronomy, no matter whether they were Copernican, Tychonic, Keplerian, or even Newtonian. As Xu Guangqi put it, their job was to cast new materials into a given mould serving a given goal.

Therefore, what happened to Chinese astronomy in the time of the Jesuits cannot be understood as a gradual integration of Chinese astronomy into modern science, but rather as an integration of early modern science into the traditional framework of native Chinese astronomy.

Bearing that in mind, it seems a little hard for us to believe that, as Needham (1959) claimed, when Chinese people called the systems introduced by the Jesuits 'new', they were united 'unknowingly with that group of men at the other end of the world who exactly at the same time were meeting in the Royal Society to work out the implication of the "new, or experimental, philosophy"' (p. 450).

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Notes

1. 宣夜说.
2. 宿.
3. 崇祯历书.
4. 咸丰元年中星表.
5. 寰有诠.
6. 历法问答.
7. 天步真原.
8. 御制历象考成.
9. 御制历象考成后编.

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Article

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Joseph Needham's inspiration for research on agricultural history in China

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Abstract

Ancient Chinese civilization was agricultural. To grasp the essence of science and civilization in China, Dr Joseph Needham drew attention to its agricultural development. He maintained close academic relations with Chinese historians of agriculture and obtained their help from time to time for the compilation of his *Science and Civilisation in China*. Needham also had a far-reaching influence on research on the agricultural history of China, both on its institutionalization and on transitions in the directions of research. The so-called 'Needham puzzle' was first proposed systematically in his address titled 'Science and agriculture in China and the West' at the annual conference of the China Agronomic Association in Chongqing in 1943. He believed that science is not isolated from society but is an indivisible part of civilization and that civilization has evolved as the result of the interactions of science, society and the environment.

Keywords

Joseph Needham, *Science and Civilisation in China*, agricultural history, agricultural heritage, history of science and technology

Research on China's agricultural history began as early as the 1920s. In 1920, in cooperation with the US Department of Agriculture and the Library of Congress, the University of Nanking (now Nanjing University), which was established by American missionaries, set up the Research Department of Agricultural Books. Ms Catherine Howes Wead of the Library of Congress was sent to Nanjing to systematically gather and collect ancient Chinese books on agriculture, which had been handed down to the Institution of Chinese Agricultural Civilization of Nanjing Agricultural University. In 1932, the Research Group on Agricultural History was set up within the Department of Agricultural Economics of the university, and a course on agricultural history was established for undergraduates. In general, however, research on agricultural history remained sparse and was sporadic during most of the Republican era (1911–1949). Circumstances changed from the 1940s onward, and one of the major instigators of that transformation was Dr Joseph Needham.

1. Falling in love with the history of science and technology in China

Dr Joseph Needham (1900–1995) was a well-known biochemist and founder of chemical embryology, for

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which he was elected as a Fellow of the British Royal Society in 1941. He became interested in the history of science and technology in the late 1920s. In 1931, he attended the second International Conference on the History of Science held in London and was deeply impressed by Marxist perspectives on the history of science. In 1936, he began delivering a series of lectures on the history of science at the University of Cambridge. He had no idea of Chinese attainments in science and technology until he became familiar with them in 1937 through Shen Shizhang, Wang Yinglai and Lu Guizhen (Lu Gwei-Djen, 1904–1991), who were pursuing their PhDs at Cambridge. He was amazed by the advanced accomplishments in science and technology in ancient Chinese times and devoted himself to the study of Chinese history.

In 1939, Needham published his first paper on the history of science in China in cooperation with Lu Guizhen,[1] who was the daughter of Lu Shiguo (Figure 1), a well-known physician of traditional Chinese medicine in Nanjing.

In February 1943, Needham was sent to China by the British Government. He later established the Sino-British Science Cooperation Office in Chongqing. During his 3-year stay in China, he had a number of opportunities to share ideas and knowledge with scholars from various institutions and universities and learned more about Chinese history and ancient China's accomplishments in science and technology. He had the idea of writing a book to introduce those remarkable achievements to the West.

In 1948, when he returned to Cambridge from Paris, Needham started a book project titled *Science and Civilisation in China* (*SCC*). Its first volume was published in 1954. By 1995, when Needham passed away, 16 volumes of *SCC* had been published and had earned him a worldwide reputation. *SCC* was awarded the First Prize for Natural Science in China, and Needham was elected as a member of the Chinese Academy of Sciences. For his accomplishments, Needham also won the George Sarton Medal in 1968.

2. Needham's circle of agricultural historians

Needham realized that ancient China was an agricultural society, and hence focused on its history of

Figure 1. Dr Joseph Needham and Mr Lu Shiguo in Nanjing (April 1946).
Source: Needham Research Institute (NRI) archives.

agricultural development and how that affected Chinese society and civilization. In February 1943, he delivered a famous speech titled 'Science and agriculture in China and the West' at the annual conference of the China Agronomic Association in Chongqing, proposing for the first time the well-known 'Needham puzzle': China had led the world in science and technology for two millennia, but why did it fail to do so in modern times? That question aroused worldwide interest and sparked heated debates for decades.

During his work on science and civilization in ancient China, Needham became acquainted with numerous scholars and established cooperative relationships with them that lasted decades. Among them there were a number of historians of agriculture, such as Professor Shi Shenghan (1907–1971)[2] of National Northwest College of Agriculture (now the Northwest Agriculture and Forestry University), Professor Wan Guoding of the University of Nanking, Mr Hu Daojing (1913–2003) of the China Press in Shanghai, Professor Wang Yuhu (1907–1980) of the Beijing Agricultural College (now China Agricultural University) and Professor Liang Jiamian (1908–1992) of the College of Agriculture of Zhongshan University (now South China Agricultural University).

Professor Shi Shenghan received his PhD in plant physiology from the University of London under the supervision of Professor F.F. Blackman. He served as a professor of biology at Tongji University, Wuhan University and National Northwest College of

Agriculture. From the 1950s on, he devoted all his efforts to studying Chinese agricultural history.

Needham first met Shi at Sichuan University in Leshan. As Needham was a biochemist and Shi was a biologist who spoke excellent English, Shi soon became an ideal companion for Needham's academic investigations and they became good friends.

Shi was erudite in both Chinese and Western scholarship and gave Needham considerable assistance. Needham benefitted a great deal from Shi's work, especially his *Annotations of Qi Min Yao Shu* (Shi, 1957) and many other works. While initiating the *SCC* project, Needham had hoped initially to have Shi as his collaborator for the volume on biology and agriculture. He wrote to the Chinese Government about it but failed owing to Shi's politically precarious situation in China at the time. Needham did not forget their friendship and the enlightening help he had received from Shi. He dedicated the *SCC* volume on botany to Shi (Needham, 1986).

Needham also wished to help Shi in any way Shi needed. In the late 1950s, when the Science Press prepared for the publication of English translations of Shi's books *A Preliminary Survey of the Book Chi Min Yao Shu* (Shi, 1958) and *On Fan Sheng-chih Shu* (Shi, 1959), Needham offered his help on collation and annotation. Shi expressed his gratitude to Needham in the prefaces of the books.

Needham also had contact and academic exchanges with Professor Chou Io (Zhou Yao) of the National Northwest College of Agriculture.[3] Chou was a distinguished entomologist who had graduated from the Universita degli studi di Napoli Federico II in Italy under the supervision of world-renowned entomologist Filippo Silvestri. Chou (1957) published the first treatise of *A History of Chinese Entomology in Early Times*, and was a pioneer in the history of biology in China. Needham attached importance to Chou's research and cited a number of his results in *SCC*.

Mr Hu Daojing was a well-known editor and bibliographer (Figure 2).[4] He graduated from Chizhi University in Shanghai (now the Shanghai International Studies University) and wrote numerous articles and books on ancient Chinese classics; the most famous ones are *Annotations of Shen Kuo's Meng Xi Bi Tan* (Hu, 1956) and *Ancient Agronomic Books and Essays on Agricultural History* (Hu, 1985). Because of his

Figure 2. Needham and Hu Daojing in Shanghai.
Source: Needham Research Institute (NRI) archives.

experience in collection and publication, he became an important source for Needham's research materials for *SCC*. They corresponded frequently (there are 14 folders of their correspondence in the Needham Research Institute (NRI) archives). In 1964 alone, Hu sent Needham more than 30 books on science and technology in ancient China.

In 1980, Hu gathered Chinese scholars distinguished in the history of science and edited a book titled *Explorations in the History of Science and Technology in China* (Hu, 1981) as a gift to celebrate Needham's 80th birthday. It was published by Shanghai Classics publishing house. Needham appreciated Hu's contribution to the bibliography of ancient science and technology and agricultural history, and wrote a dedication to Hu in his book *Meng Xi Bi Tan Bu Zheng*. Needham was also an important advocate for Hu's membership of the International Academy of the History of Science in 1981.

Professor Wang Yuhu was a distinguished scholar in agricultural history and ancient agricultural bibliography.[5] He studied economics at the Technische Universität München (Germany) and the Université de Paris (France) and initiated world agricultural history and comparative agricultural history studies in China. He returned to China in 1933 to serve as curator of the university library of the Beijing College of Agriculture for nearly 30 years. His best known work is *A Collection of Agronomic Books in Ancient China* (Wang, 1957). Needham drew attention to his

Figure 3. Needham and Liang Jiamian at South China Agricultural College.
Source: Needham Research Institute (NRI) archives.

works and had them listed as important reference works for *SCC*. When the *SCC* biology volume was published, Needham wrote on the title page in memory of Wang Yuhu, Shi Shenghan and Amano Motonosuke and stated that, without their pioneering work in agricultural history, the volume on agriculture could not have been completed (Needham, 1984).

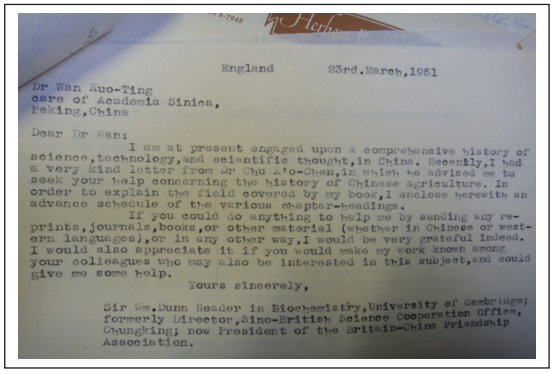
Professor Liang Jiamian studied at the College of Agriculture of Zhongshan University and became interested in agricultural history under the influence of Professor Ding Ying, the dean of the college.[6] In 1941, he was engaged to work in the university library and made agricultural history studies as his lifelong career. Needham first met Liang in May 1944 in the company of Dr Huang Xingzong. Because of the war with Japan, Zhongshan University moved to Zhangyi in Hunan Province. As Liang was in charge of the university library and had accumulated much knowledge of the history of agriculture, Needham spoke to him twice in detail regarding Chinese agricultural history (Figure 3). From then on, they maintained a close academic relationship. Because Liang acted as director of the university library for decades and was familiar with ancient sources, he offered Needham considerable assistance by sending books or providing valuable duplicates of ancient Chinese texts on farming and biology.

Professor Wan Guoding was the first scholar to research the agricultural history of China.[7] He was born in Wujin (Jiangsu Province) in 1897 and graduated from the University of Nanking in 1920. Wan fell in love with agricultural history in the early years of his university education and wrote his first paper on the history of sericulture in ancient China. In 1924, he was appointed director of the Research Department on Agricultural Books and, in 1932, head of the Agricultural History Research Office of the Department of Agricultural Economics in the university. In 1955, he was appointed as the first director of the National Institute of Chinese Agricultural Heritage under the dual leadership of the Chinese Academy of Agricultural Sciences and Nanjing Agricultural College (now Nanjing Agricultural University).

Needham made three visits to Professor Wan and his research team, in 1943, 1958 and 1964. When Needham first visited the University of Nanking in 1943, he became acquainted with Wan through Zhang Zhiwen (1900–1982).[8] Zhang graduated from Cornell University and was a well-known agronomist specializing in cotton. He was dean of the College of Agriculture at the University of Nanking from 1931 to 1948. During the war with Japan, along with other universities, the University of Nanking was moved to Chengdu. In June 1943, Needham was told that Wan and his colleagues had been involved in a major project called *A Complete Collection of Ancient Agricultural Works* since 1920, and Needham hoped that Wan could provide him with the academic materials he needed. Before long, Needham received a piece on the outline of the project and Professor Zhang Zhiwen's treatise, *Plan of Post-war Agricultural Construction in China*.

On 17 October 1948, Needham wrote again to Zhang, requesting more academic resources for the compilation of *SCC* and expressed hope that he would get two copies of *A Complete Collection of Ancient Agricultural Works*. In 1951, Needham also tried to communicate with Wan Guoding through their old friend Zhu Kezhen (1890–1974), a former president of Zhejiang University and then vice president of the Chinese Academy of Sciences. In a letter, he told Wan about his grand project and enclosed 'an advance schedule of the various chapter-headings' (Figure 4).

The archives show that Needham not only received a lot of academic resources from Chinese



England 23rd.March,1951

Dr Wan Kuo-Ting
care of Academia Sinica,
Peking,China

Dear Dr Wan:

I am at present engaged upon a comprehensive history of science,technology,and scientific thought,in China. Recently,I had a very kind letter from Dr Chu Ko-Chen,in which he advised me to seek your help concerning the history of Chinese agriculture. In order to explain the field covered by my book,I enclose herewith an advance schedule of the various chapter-headings.

If you could do anything to help me by sending any reprints,journals,books,or other material (whether in Chinese or western languages),or in any other way,I would be very grateful indeed. I would also appreciate it if you would make my work known among your colleagues who may also be interested in this subject,and could give me some help.

Yours sincerely,

Sir Wm.Dunn Reader in Biochemistry,University of Cambridge; formerly Director,Sino-British Science Cooperation Office, Chungking; now President of the Britain-China Friendship Association.

Figure 4. Needham's letter to Wan Guoding, 23 March 1951.
Source: Needham Research Institute (NRI) archives.

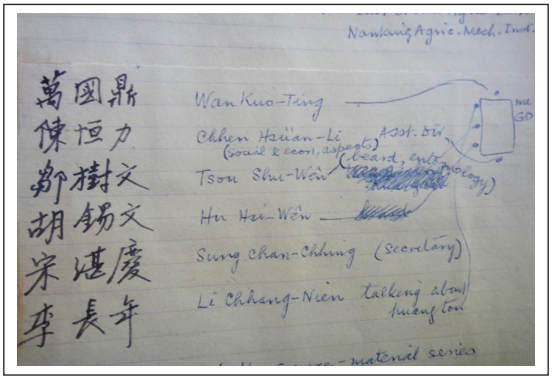


Figure 5. Needham's diary entry on his visit to the Institute of Chinese Agricultural Heritage in 1958.
Source: Needham Research Institute (NRI) archives.

scholars but also arrived at important findings through discussions with his Chinese colleagues. For instance, on 25 June 1958, Needham and Lu Guizhen visited the Institute of Chinese Agricultural Heritage and had a long discussion with professors Wan Guoding, Chen Hengli, Zou Shuwen, Hu Xiwen, Song Zhanqing and Li Changnian and other researchers at the institute. Needham's diary contains a detailed description of the event (Figure 5). The topics they dealt with were extensive: the origin of the soybean and its use; comparisons of economic and political institutions in China and the West; the reasons why farming practices in ancient China had been more advanced than those in Western countries; and special histories of various crops, pest control and hydraulic engineering. Some of those discussions are reflected in *SCC*. During his visit to the institute on 27 August 1964, Needham discussed with Professor Hu Xiwen the use of green manure in ancient China. He believed that Chinese civilization could have developed over thousands of years because of this perfect combination of the use and nurturing of farmland.[9]

Later in the same year, Needham had another long exchange in Beijing with Professor Zou Shuwen, who visited the Science Press to prepare his book *The History of Chinese Entomology* (Zou, 1981) for publication.[10] They discussed in detail ways of using beneficial insects, such as silkworms, honeybees, white wax insects and the like, as well as ways of controlling various pests in ancient China. Some of their discussions are recorded in the volume on agriculture in *SCC* (Needham, 1984).

3. Needham and the institutionalization of the history of science in China

Although China had a long history of achievements in science and technology, no effort had been made to study them before the 20th century. Needham's *SCC* inspired and stimulated work on the history of science and technology as an independent discipline in China.

After the publication of the first volume of *SCC* in 1954, systematic research on the history of science in China flourished. One of the leading figures in the field was Zhu Kezhen, who was a distinguished meteorologist. Zhu was born in Shaoxing (Zhejiang Province) in 1890. He obtained his PhD from Harvard University in 1918 and became the first chairman of the Department of Geography of Southeast University in 1921. He became the founding figure of modern geography and meteorology in China. In 1934, together with Weng Wenhao and others, he set up the China Geography Association. From 1936, Zhu served as president of Zhejiang University for 13 years. In 1948, he was elected as a member of the Chinese Academy of Sciences and, in 1949, he was appointed vice president of the academy.

Zhu was not only an outstanding meteorologist and leader in scientific activities but also a historian of science. He conducted pioneering work in a number of fields, such as historical meteorology, historical phenology and historical seismology. His magnum opus is 'A preliminary survey of climate change in China for five thousand years' (Zhu, 1972). Needham became acquainted with Zhu as early as March 1943, when he met him at a welcoming banquet held by Zhu Jiahua, the Minister of Education, in Chongqing. In April and October 1944, Needham visited Zhejiang University at Zunyi (Guizhou Province) and established a lifelong friendship with Zhu.

Zhu was also a constant supporter of Needham's research. He sent dozens of boxes of ancient Chinese academic materials to Needham, including a set of the *Gu Jin Tu Shu Ji Cheng* (*Complete Collection of Illustrations and Writings from Past to Present*). From their correspondence, one notes that Zhu even drew up a list of leading Chinese scholars in different fields of the history of science and technology for Needham's reference, including Li Yan and Qian Baocong for the history of mathematics, Liu Zhaoyang for the history of astronomy, Liu Xianzhou for mechanical history, Wan Guoding for agricultural history, Li Tao for the history of traditional Chinese medicine, Liu Dunzhen for the history of architecture, Zhang Hanying for the history of hydraulic engineering and others.[11] Because there was no stable funding for Needham's *SCC* project early on, Zhu even persuaded the Chinese Government to give Needham some financial support for 3 years and entrusted Wang Ling to assist Needham with the compilation of *SCC*. Needham expressed his gratitude to Zhu in the preface of the first volume of *SCC*, describing him as the most generous and persistent donor and supporter of Needham's huge, lengthy project.

Needham's ideas and his *SCC* have had a far-reaching impact on the institutionalization of the history of science in China. Inspired by the first volume of *SCC*, Zhu published an article in the *People's Daily* on 26 July 1954 titled 'Why should we study the history of science and technology in ancient China?' drawing people's attention to Needham's work and stressing the importance of the history of science. In 1956, with Needham's help, Zhu led a group of historians of science to Italy to take part for the first time in the International Conference on the History of Science (Figure 6).

Figure 6. Zhu Kezhen and Needham in Italy at the 8th International Conference on the History of Science. Source: Needham Research Institute (NRI) archives.

After returning home, Zhu and some other well-known scholars asked the Chinese Government to set up a special institute for the history of science. In 1957, the Chinese Academy of Sciences established the Institute for the History of Natural Science and started the publication of *The Collection for the History of Science*, with Qian Baocong as chief editor. Before long, a number of universities and institutions in other parts of China established special institutes or research offices in this field, including the Institute for the History of Science at the University of Science and Technology of China in Hefei (Anhui Province).

In 1954, the Ministry of Agriculture held a symposium on investigating the agricultural heritage of ancient China. In 1955, with the support of Jin Shanbao,[12] the president of Nanjing Agricultural College, the national Institute of Chinese Agricultural Heritage was formally established in Nanjing, with Professor Wan Guoding as its first director.

In 1957, the institute was reorganized and affiliated under the dual leadership of the newly established Chinese Academy of Agricultural Sciences in Beijing and Nanjing Agricultural College (where the institute was located). Similar research units were

later set up in other agricultural universities, such as the Research Office on Ancient Agronomy of the National Northwest College of Agriculture at Wugong (Shaanxi Province), led by Professor Shi Shenghan; the Research Office on Agricultural History of Beijing Agricultural College, led by Professor Wang Yuhu; and the Special Collection of Ancient Agricultural Classics of South China Agricultural College in Guangzhou, led by Professor Liang Jiamian. Although there was no special unit for agricultural history, similar research was conducted by scholars at Zhejiang Agricultural College (now Zhejiang University), the Chinese Academy of Forestry Sciences and the Chinese Academy of Hydraulic Science and Technology.

In the early decades of the People's Republic of China, the nation was isolated, but Needham was one of a few scholars to maintain a friendly relationship with the country. He was the founder and first chairman of the Sino-British Friendship Association. As early as in 1943, Needham met with Zhou Enlai, one of the leaders of the Communist Party of China, in Chongqing. In 1964, on the 15th anniversary of the People's Republic of China, Needham met Chairman Mao Zedong. Mao praised Needham's wonderful work on the history of science and technology in China and sought his suggestions on the development of modern industry.

With the encouragement of China's leaders, Needham gained some privileges in China. Not only did he have opportunities to visit many academic institutions, but he also made series of rural field trips throughout China and collected much firsthand material on rural areas and traditional Chinese farming practices.

4. Needham's influence on research into the agricultural history of China

In the late 19th century, China was invaded by a succession of imperialist powers. To survive, the country was forced to learn from the West. During the Westernization Movement and later periods, a number of talented people were sent to Western Europe and the United States to study advanced science and technology. Under the influence of a Eurocentric ideology, it was widely believed that science was derived from the West and that there had been no natural science in ancient China. Ren Hongjun (1915), the founder of the China Science Society, wrote a paper titled 'Why was there no science in ancient China?' for the first issue of *Science*. Needham and Zhu Kezhen disagreed with Ren and claimed that a clear distinction should be made between traditional science and modern experimental science.

Many thought that Needham first raised the Needham puzzle in the first volume of *SCC* in 1954, but he had already posed the question at the annual conference of the China Agronomic Association in Chongqing in February 1944 in his lecture on 'Science and Agriculture in China and the West'.

In that lecture, Needham refuted the argument that there had been no science in ancient China and claimed that a large number of inventions and advances in science and technology had been made in that period, including the compass, gunpowder, paper-making and printing.[13] In agriculture, the ancient Chinese began raising silkworms and using their cocoons as early as thousands of years ago. China was the motherland of tea planting and tea making, which later spread throughout the world. The ancient Chinese were also the first to invent biological controls of pests in fruit production.

Western scholars had focused on contributions made by the Egyptians, Babylonians and Arabs, ignoring achievements by China and India. In Needham's view, China had been far superior to the West in science and technology, at least until the 15th century. Chinese civilization was rooted in agriculture, and Chinese farming technology had been a model for European countries, exerting a deep influence on the agricultural revolution in Western Europe in the 17th and 18th centuries. Yet, a stunning reversion had occurred in the past 100 years.

Chinese farmers began using the iron plough extensively as early as 2000 years ago, while European farmers used wooden ones. However, by the time Europeans started using steel ploughs, Chinese farmers were still using iron ones. Hence, Needham raised the question, 'Why did these great beginnings of agricultural science not arise in China,

one of the greatest agricultural countries in the world?' (Needham, 1948).

It is not an easy question, and Needham tried to give a brief answer from geographical, environmental, economic and social perspectives. He was deeply influenced by Karl Marx's philosophy and Karl Wittfogel's (1957) *Oriental Despotism*.[14] Their different natural environments and cultural traditions meant that China and European countries had followed different paths of development. The ancient Chinese had invented gunpowder but failed to make advances in gun-making and military technology.

Modern agriculture was based on the engineering and chemical industries, so, to improve Chinese agriculture, China would have to accelerate the development of modern science and technology. The Needham puzzle stimulated generations of Chinese scholars to examine traditional China's culture, its national strategy and shortcomings, and encouraged people to carry out social and cultural reforms.

What is most important is not whether Needham's argument is correct, but rather his broader vision of exploration and the ways he suggested engaging with the history of science and technology. His intellectual heritage had a profound influence on the direction and content of agricultural history in China. According to Hu Daojing's recollection, Needham sent an outline of the *SCC* volume on agriculture to Chinese historians of agriculture for comments and suggestions in 1979. Inspired by Needham and his *SCC*, Chinese historians of agriculture discussed the possibility of compiling what became *A History of Agricultural Science and Technology in China* (Liang, 1989) at a conference in Zhengzhou (Henan Province). With financial support from the Ministry of Agriculture and the joint efforts of scholars from dozens of institutions, the work was published in 1986 and won the National Prize for the Advancement of Science and Technology.

The true intellectual legacy of Needham and his *SCC* is not only the series of books and records he brought together on the history of science and technology in ancient China (Chinese scholars may well be more familiar with the academic resources). The real value of his work lies in his ideas, his theoretical analysis, his comparative view of cultural development and his probing of interactions among civilizations. I suspect that is why he gave his book the name '*Science and Civilisation in China*', placing technology in a certain historical context, and exploring the interactions between technology and civilization.

At the beginning of the compilation of *A History of Agricultural Science and Technology in China*, Chinese agronomists and historians of agriculture had planned to deal exclusively with the historical development of agricultural science and technology, without considering other factors related to agriculture. However, inspired by Needham's *SCC*, they realized that farming is a complex socio-economic activity involving not only tools and technology but also productive activities such as land ownership, marketing and distribution. They had previously limited the scope of the research to a narrative concept of the history of planting, but they realized that ancient Chinese agriculture had been an organic combination of cropping, forestry, husbandry, fishing and sideline production; hence, the concept of 'comprehensive agriculture' was adopted to guide the compilation. The effort proved to be a great success.

From the 1920s to the 1980s, nearly all efforts by historians of agriculture in China were focused on collating and annotating ancient agronomic works and the history of agricultural technology, especially in the fields of crop breeding, fruit, vegetables, pest control, farming implements and husbandry. Needham's vision of comparative history encouraged Chinese scholars to explore the broader background of agricultural development and the social and economic settings for the transformation from the traditional to the modern. Inspired by Needham and *SCC*, they came to recognize that technology never develops in isolation, and that technology alone cannot explain the development of Chinese agriculture; every technique has its own historical and cultural background. From the 1980s onward, Chinese historians of agriculture began to pay more attention to comprehensive research on Chinese agricultural developments and the interactions among civilizations.

Civilizations are interconnected, and Needham drew attention to the spread and interactions of the world's civilizations. He listed 26 important Chinese inventions and probed their far-reaching influence. In

recent decades, increasing attention has been devoted to research on agricultural diffusion and communication between China and other parts of the world. Examples include the National Social Science Foundation's 'Agricultural Communications between China and Abroad through the Silk Road' and 'The Introduction and Extension of American-originated Crops and Their Long-term Impacts in China' projects. In October 2012, the first International Conference on Agricultural Origination and Diffusion in the World, sponsored by Nanjing Agricultural University and the University of Reading in the United Kingdom, was held in Nanjing. In addition, the Series on Crop Introduction and Localization in China has been in progress at the Institute of Chinese Agricultural Civilization of Nanjing Agricultural University, and dozens of books have been published.

Needham shifted to study the history of science, but he was not pedantic about history. He believed that people could learn from historical enlightenment and was thus concerned about ongoing developments, showing his passion for economic and rural development. As early as in the 1940s, he made rural field trips to different parts of China, especially Sichuan, Guizhou, Shaanxi, Gansu and Jiangxi, to investigate agricultural production, the daily lives of farmers and irrigation systems. After the founding of the People's Republic of China, when he returned to China, he also chose to visit Nanyuan People's Commune in Beijing; Jiajiazhuang People's Commune in Taiyuan; and the national model in agriculture, Dazhai in Xiyang County (Shanxi Province).

Needham paid great attention to traditional Chinese farming and its achievements. He collected a set of documents and pictures of the National Exhibition of Agricultural Implements in 1956. Based on those materials, he wrote a paper on the development of steel technology in modern China and had it published in a special issue of *Newcomen Society*. In his position as chairman of the Sino-British Friendship Association, he wrote to the leaders of China, helped the London Science Museum duplicate some agricultural implements from the China National History Museum and held a special exhibition in London.[15]

When he visited the South China Institute of Tropical Crops in Hainan, he revealed a great interest in rubber technology and production. During his visit to the Chongqing Institute of Citrus and Tangerines of the Chinese Academy of Agricultural Sciences, he held detailed discussions with researchers there and took 18 pages of notes about citrus varieties and related technologies.

Chinese historians of agriculture also recognize the importance of historical studies on agricultural and rural development. Several studies have been published in recent decades. The inaugural rotating workshop of the Joint Conference of Purdue and Nanjing for China Studies was held at Nanjing Agricultural University in October 2015. Scholars from China and the United States got together to explore economic and social transformations in modern times.

Needham valued the traditions of Chinese agriculture and thought they could play an important role in sustainable development in the future. In line with that view, there have been two core areas of research on the agriculture of China since the 1990s.

The first is research on the interactions between agricultural development and environmental change. The second is ways of preserving the excellent Chinese agricultural heritage and making it better serve rural development.

In 2014, the Expert Committee on Globally Important Agricultural Heritage was set up in Beijing under the Ministry of Agriculture to steer the conservation of Chinese agricultural heritage. At present, 11 sites in China have been selected and nominated by the Food and Agriculture Organization of the United Nations as 'globally important agricultural heritage system' sites, and more than 100 have been selected as 'nationally important agricultural heritage system' sites. In cooperation with the Institution of Chinese Agricultural Civilization of Nanjing Agricultural University, the China Agricultural Science and Technology Press has published a series on Chinese agricultural heritage studies. Dozens of books have been published as part of the series, including *A Directory of Agricultural Heritage in China* (two volumes), *On Agricultural Heritage, On the Conservation of Agricultural Heritage in China*, and *Memories of Traditional Villages in China*. The first Forum on Chinese Agricultural Heritage Conservation and the Symposium on the Protection of Traditional

Villages were held in Nanjing in 2010 and 2012, respectively.

To summarize, Joseph Needham was an outstanding scholar with a profound vision of the world. His wide-ranging knowledge of science and history, in both the West and China, helped him create his great work, *SCC*, which brought him world renown. Because of his peculiar status as an 'old friend of the Chinese people' and a famous scholar, he and his *SCC* became an important impetus for the institutionalization of the history of science and agriculture. Given that Chinese civilization was agricultural, Needham paid attention to its agricultural development. In his compilation of *SCC*, he received a lot of assistance from Chinese historians of agriculture and established close relationships with them.

Needham and *SCC* had a far-reaching influence on the institutionalization of research into agricultural history in China and on transitions in the direction of that research. Chinese historians of agriculture have drawn on comprehensive and comparative studies in their academic research to learn about history and better serve rural and agricultural development.

Needham taught us that science is not isolated from society and other parts of the world, but is an indivisible part of civilization, and that civilization evolves as a result of the interactions of science, society and the environment.

He probably posed the Needham puzzle not as a real question with a real answer, but as a way to inspire us to think of world civilization and humankind's future from a more balanced and sustainable perspective.

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Notes

1. Lu Guizhen was born in 1904 and obtained her PhD in nutritional science from Cambridge University. She had an important impact on Needham's lifelong interest in the history of science and technology in China, acting not only as his cooperator, but also as his translator and teacher of Chinese. Allegedly, Needham's Chinese name, Li Yuese, was coined by Lu Guizhen. Needham dedicated the first volume of *SCC* to her father, Lu Shiguo. Lu married Needham at the age of 85.
2. Shi Shenghan was born in Kunming (Yunnan Province) on 19 November 1907 and received his bachelor's degree from Zhongshan University. He was a pioneer in plant physiology in modern China and a major leader in agricultural history. He founded the Office of Ancient Agronomy at Northwest College of Agriculture and served as the first director. He died on 28 June 1971.
3. Chou Io was born in Yin County (Zhejiang Province) on 8 June 1912. He was a pioneer of entomology in modern China and founder of the history of Chinese entomology. His book *History of Chinese Entomology* won the First Prize for Excellent Books of Science and Technology and has been translated into five languages. He also setup the first museum of entomology in China. Chou died on 15 December 2008.
4. Hu Daojing was born in Shanghai in February 1913. He was a distinguished scholar in bibliography. In addition to editorial work, he also served as part-time professor at Fudan University, East China Normal University and Shanghai Normal University. He was one of the founding members of the China Agricultural History Association and a corresponding member of the International Academy of the History of Science.
5. Wang Yuhu was born in Gaoyang County (Hebei Province) on 16 April 1907. He was a well-known historian of agriculture; was the founder of the Research Office of Agricultural History at the Beijing Agricultural College; and made pioneering contributions to the comparative history of agriculture, agricultural thought and world agricultural history. He died on 27 November 1980.
6. Liang Jiamian was born in Nanhai County (Guangdong Province) on 25 April 1908. He was a distinguished historian of agriculture who wrote more than 90 papers on agricultural history. He was the founder of the Special Collection of Agricultural Classics and the Research Office of Agricultural History and Heritage of South China Agricultural College, and the first president of the Agricultural History Society of Guangdong Province. He died on 12 March 1992.

7. Wan Guoding was born in Wujin County (Jiangsu Province) on 26 December 1897. He was the initiator of research on agricultural history in China and the first director of the National Institute of Chinese Agricultural Heritage in Nanjing. He published the *Series of Chinese Agricultural Heritage* and *Collections of Agricultural History Research*, which were the first journals in this field. He authored 10 books and more than 130 papers, and his magnum opus – *History of Chinese Agronomy* – won the First Prize of the Ministry of Agriculture in 1987. Wan died on 15 November 1963.
8. Zhang Zhiwen (1900–1982) was born in Lai'an County (Anhui Province) and graduated from the University of Nanking in 1922. In 1930, he went to Cornell University to pursue further studies in agronomy and received his master's degree in 1931. In 1949, Zhang was engaged as adviser to and executive secretary of the World Rice Association. On 5 January 1982, he passed away in the United States.
9. This is similar to the view expressed by Franklin King, who was the director of the Soil Bureau of the US Department of Agriculture and wrote the famous book *Farmers of Forty Centuries: Or Permanent Agriculture in China, Korea, and Japan* after researching in those countries in 1911.
10. Zou Shuwen (1884–1980) graduated from Peking University in 1907 and obtained his bachelor's degree from Cornell University and a master's degree from the University of Illinois. He was one of the founders of entomology in modern China. He served as dean of the College of Agriculture at the University of Nanking and as an adviser to the Institute of Chinese Agricultural Heritage of the Chinese Academy of Agricultural Sciences.
11. From Zhu Kezhen's letter to Needham on 16 February 1958, SCC2/2/36-44 in the Needham Research Institute (NRI) archive.
12. Jin Shanbao was born in Zhuji County (Zhejiang Province) on 2 July 1895. He was the founder of wheat science in modern China and an outstanding leader in agricultural education and research. He obtained his bachelor's degree from Southeast China University in 1926 and a master's degree from the University of Minnesota in the United States in 1932. In 1952, the colleges of agriculture of Central University and the University of Nanking merged into the independent Nanjing Agricultural College. Jin was appointed its first president. In 1957, he moved to work in the Chinese Academy of Agricultural Sciences and served as its president for decades.
13. In *Science and Civilisation in China*, Needham lists 26 Chinese inventions that had a significant impact on the world.
14. Karl A Wittfogel, born in Germany on 6 September 1896, was a well-known scholar of China studies and a professor at Washington State University in the United States. He believed that any culture having an agricultural system dependent on large-scale government-managed waterworks for irrigation and water control was by nature a 'hydraulic' civilization, and advanced that term in his book *Oriental Despotism* (Wittfogel, 1957).
15. From Huan Xiang's letter to Needham on 17 December 1958, SCC2/238/1/17 in the NRI archives. Huan was chargé d'affaires at the Chinese Embassy to the United Kingdom. After the exhibition, Needham and the Sino-British Friendship Association donated duplicates of ancient agricultural implements to the London Science Museum.

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Science, society and planning: Joseph Needham's report to Chiang Kai-shek in 1946

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Abstract

Based on historical materials in the United Kingdom and China, this article analyses Joseph Needham's 1946 report to the national government's then leader, Chiang Kai-shek, on the state and prospects of modern science in China, and discusses its background, main content, characteristics, influences and significance. Needham completed the report at the end of 1945, and kept in mind the rich Eastern and Western contexts while writing it. The report revealed a series of institutional problems to do with science in China and provided a framework for scientific development. It also provided specific measures and essentially formed a plan for the scientific development of China at the institutional level. The report had an impact in China at the time, and the Ministry of Education engaged its content to formulate six specific measures for scientific development. Moreover, the Supreme Council for National Defence promoted China's first 10-year plan for applied science. Needham's report had universal significance for the development of science – not only in China at the time, but even globally today. The report also played an important role in the formation of Needham's monumental book series, *Science and Civilisation in China*.

Keywords

Chinese modern science, science and society, planning of science, Needham puzzle

In recent years, research on Joseph Needham has focused on his personal experience on the one hand, and a discussion of the 'Needham puzzle' on the other. In both cases, the basis of the discussion is Needham's understanding of ancient Chinese science and technology. In the 1940s, Needham also expressed at length his views on modern Chinese science and culture.

In the winter of 1945, before his departure from China, Needham wrote a 63-page secret report at the invitation of Chiang Kai-shek to discuss the state and prospects of science and technology in China at the time. The report was submitted to Chiang in February 1946. It not only exposed problems in the development of science and technology in China, but also proposed a series of suggestions for improvement, fully reflecting Needham's thoughts on contemporary Chinese society and culture from the perspective of a foreign scientist. Some of those recommendations had an impact on China's subsequent policies.

This article is based on the report titled *Report to His Excellency President and Generalissimo Chiang Kai-shek on the Position and Prospects of Science*

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and Technology in China (Needham, 1945)[1] and analyses its background, content, characteristics, significance and impact.

1. The historical context of the report

Joseph Needham's visit to China during World War II might have seemed to be on the spur of the moment but had been planned for a long time. The historical background provided here explains his reasons for coming to China, why Chiang Kai-shek asked him for advice on science and technology, and why Needham was able to provide such a detailed report.

1.1. The science and society movement in Britain

The global economic crisis from 1929 to 1933 affected every country with the exception of the Soviet Union. This was because of the implementation of the Soviet model of a planned economic system, which, as a result, received considerable attention.

The planned economic system of the Soviet Union was initiated in the 1920s, and Nikolai Bukharin played an important role in it. In 1930, after being out-manoeuvred by Stalin, he was sidelined from the Politburo onto the Supreme National Economic Council of the Soviet Union as head of planning research (Gao, 2000). In that position, he began developing scientific research institutions over the next 5 years and, in April 1931, hosted the first Soviet all-union conference on the planning of scientific research, with a view to studying the methodology of 'planning science' (Fu, 2012). It was in that period that, guided by dialectical materialism, he began to organize scientists at the Soviet Academy of Sciences to study historical issues in science. He himself focused in the meanwhile on theoretically expounding the social functions of science and demonstrating the superiority of a science planning system based on socialism. He proposed five aspects of scientific planning that needed to be determined:

- The share of the country's budgetary resources that should be devoted to science;
- The subjects of scientific research;
- Support for scientific research institutions;
- The geographical placement of scientific research institutions;
- The supply of personnel or 'cadres' (Graham, 1964).

From 29 June to 4 July 1931, the Second International Congress on the History of Science was held in London and was attended by Bukharin and his research group. Coincidentally, Needham was one of its main organizers. Presentations by the Soviet delegation, especially the one by Boris Hessen, greatly impressed the participants. Subsequently, the attention of some British scientists was drawn to research on the relationship between science and society. Some activists, such as Solly Zucherman and JD Bernal, organized clubs to discuss the social application of science (Brown, 2005). As a friend of Bernal, Needham was one of those activists.

In 1968, when Gary Werskey interviewed Joseph Needham for his doctoral thesis, 'The visible college: A study of left-wing scientists in Britain, 1918–1939', Needham first asked Gary to relate to two Chinese scholars with him some of Werskey's own ideas about the social relations of British science in the 1930s (Werskey, 1976: 25). The social relationship of science that Needham was referring to can easily be found in publications at the time. Throughout the 1930s, *Nature* and similar natural science journals published many articles on such topics as government and science, science and politics, the social relations of science, and science and national services. The articles reflected how scientists were thinking broadly about the relationship between science and society.

Specialized organizations were established, one of which was the Committee on Science and its Social Relations (CSSR), initiated by the Royal Society and formed by left-wing British scientists in 1937. Its function was to conduct surveys of scientific work in certain fields in order to understand science and its impact on human society and the response of scientific research to the social environment (Anonymous, 1938a).

The CSSR designed a special questionnaire and distributed it to various research institutions and

organizations. The survey received such an enthusiastic response that the Royal Society even set up a special committee to deal with it (Anonymous, 1938b). The CSSR also appointed correspondents and established branches in countries around the world. Liu Xian,[2] the editor-in-chief of *Science*, sponsored by the Science Society of China, was the Chinese correspondent of the CSSR. Other members of the Chinese branch were as follows (Liu, 1938):

Dr Li Heng李珩, a professor at Sichuan University

Dr Yan Jici严济慈, director of the Institute of Physics of the Peiping Academy

Dr Zeng Zhaolun曾昭抡, president of the Chinese Chemical Association and a professor at Southwest Associated University

Wang Jiaji王家楫, director of the Animal and Plant Institute of the Academia Sinica

Dr Li Liangqing李良庆, director of the Specimen Room of the Peiping Jingshen Bio-investigation Institute

Dr Wu Dingliang吴定良, director of the Anthropology Group of the Institute of History and Languages, Academia Sinica

Dr Lu Yudao卢于道, a technician at the Institute of Psychology, Academia Sinica

Professor Zhang Qiyun张其昀, director of the Department of History and Geography, Zhejiang University

Dr Lyu Jiong吕炯, acting director of the Institute of Meteorology, Academia Sinica

Dr Yang Zhongjian杨钟健, a technician at the Geological Survey

Dr Feng Fang冯芳, head of the Central Agricultural Laboratory

Zhang Yanxiang张延祥, an engineer in Hong Kong

Dr Zhu Hengbi朱恒璧, dean of Shanghai National Medical College.

Thus, the areas of research pursued by the members covered mathematics, astronomy, physics, chemistry, zoology, botany, anthropology, archaeology, psychology, geography, meteorology, geology, agriculture, engineering and medical science.

In 1938, to further research the social relationship of science, the Council of the British Association proposed the establishment of a new division – the Division for Social and International Relations of Science – to explore the influence of scientific progress on social welfare and that of social conditions on scientific progress by means of inquiry, publication, and meetings (Anonymous, 1938c). The division formed a committee of 40 people, including Richard Gregory, the editor of *Nature*, and the well-known scientists JD Bernal, PMS Blackett, AV Hill, L Hogben, JS Huxley and FC Bartlett (Anonymous, 1938d).

After the Second International Conference on the History of Science, discussions on the relationship between science and society intensified. Alongside international research by left-wing scientists, enthusiasm for the history of science flourished in Cambridge. In 1936, due in part to efforts by Joseph Needham, Cambridge established a committee of 11 people to lecture on the history of science. Those activities eventually led to the birth of the Department of the History and Philosophy of Science at the university.

The committee invited Ernest Rutherford, Arthur Eddington and other scientists to lecture on the history of their areas of expertise, creating unprecedented grand occasions in Cambridge. At times, audiences were so large that many people had to stand in the aisles or sit on the floor of the lecture room (Needham and Pagel, 1938). Needham himself was an active participant and delivered two lectures: 'Biology from Galen to Harvey' and 'Biology and the social background in the 17th century' (Needham and Pagel, 1938).

These events show that, well before the establishment of specific investigative and research institutions, Needham not only regarded the history of science as an important field of study but had also begun to study the histories of disciplines from the perspective of the relationship between science and

society. Through these discussions and research on the history of science, prior to the arrival of Dr Lu Gwei-djen[3] at Cambridge, Needham and his left-wing friends had already formed a consensus on a specific question – Why did science originate only in Europe? (Fu, 2011).

The arrival of three Chinese students at the biochemistry laboratories in Cambridge in 1937 naturally attracted Needham's attention to China. He developed a strong interest in Chinese culture, learned Chinese from one of the students, Lu Gwei-djen, and later resolved to write a history of science, technology and medicine in Chinese culture (Wangqian, 1999).

As early as in 1939, he began to plan a visit to China, developing extensive contacts with the British Council and other institutions in Britain and China. In 1942, prompted by a marked improvement in Sino-British relations, the British Government decided to send representatives of the scientific and humanities research communities to China to promote academic relations. Needham, who had a preliminary understanding of Chinese and had been seeking an opportunity to visit China, was the first choice.

In March 1943, Needham arrived in Chongqing, the wartime capital (Needham and Needham, 1948). In June, he established the Sino-British Science Cooperation Office there, with the mission of providing China with assistance in wartime scientific research (Wangqian, 2007). In August, he led some colleagues to the north-west to inspect wartime scientific and technological work in Gansu. This was followed by several other long-distance trips by him and his colleagues, covering the western, north-western, south-eastern and south-western parts of China, all described in the book *Science Outpost* (Needham and Needham, 1948).

In addition, several articles were published in *Nature* in 1943 and 1944, such as 'Science in south-west China', 'Science in Chongqing' and 'Science and technology in southeastern China' (Needham and Needham, 1948), reporting to the Western world on the status of science in unoccupied China. These activities involved both performing the task assigned to him by the British Government and fulfilling the scientific investigative functions of the CSSR.

Meanwhile, the science and society movement that Needham had been involved in before he came to China progressed further. In 1939, the publication of Bernal's book *The Social Function of Science* gave rise to a hotly debated controversy: Should science be planned or free? This is usually referred to as the Bernal–Polanyi dispute (Brookman, 1979). The 'planning of science' group, represented by Needham's friend, Bernal, and the 'freedom of science' group, represented by M Polanyi, debated the question fiercely on the radio, in newspapers and magazines, and at gatherings (Fu, 2012). The dispute was continuing on the eve of Needham's arrival in China, but the 'planners' had achieved notable success (Polanyi, 2002). The Soviet-style system of management of science advocated by Bernal was widely circulated (Fu, 2008). In 1942, Needham joined the Society for Freedom in Science founded in 1941 by Polanyi, although he was in fact a believer in Bernal's 'planning of science'.

1.2. The planning movement in China from the 1930s to the 1940s

In China, the exigencies of the war against Japan motivated the government to look for international aid and undertake efforts for the country's prosperity. In 1940, China's military situation deteriorated further. The national government's fiscal revenue fell to less than one-fifth of that before 1937, whereas fiscal expenditure increased several times (Dong, 1997). In those circumstances, to enable the government to continue functioning and support the front line, the government sought foreign aid.

At that time, however, countries such as the United States and Britain had adopted an appeasement policy. Chinese endeavours to borrow money from both were thus unsuccessful (Wang, 2013).[4] Chiang Kai-shek (2015 [1940]) wrote in his diary: 'The British attitude is despicable, the United States is waiting and seeing; this is the fateful day when we must depend on ourselves. If not, how can we succeed in adversity?'. With foreign aid unreliable, Chiang believed that only by girding themselves for the great task could the Chinese people succeed in defeating Japan, and that the first thing to accomplish was to effectively organize the human, material

and financial resources of the country and to strengthen unified organization and control at the national level. This had been the agenda of the national government since the Mukden Incident (September 18 Incident) of 1931.

Since the 1930s, the national government had embarked on a series of measures for economic and cultural construction, such as the New Life Movement and the National Economic Construction Movement. Economic construction was prioritized in both. In this area, the national government adopted an attitude of open learning. At the time, although the United States adopted Roosevelt's New Deal and implemented state intervention in the economy in response to the Great Depression, Japan and Germany adopted state capitalism. Keynesianism also matured during this process to become one of the most important economic theories of the time. However, the scandals associated with Stalin's 'Great Purge' in the Soviet Union had not yet leaked out, and the positive international reputation of the early stages of the planned economy there had not yet been affected. Thus, the national government's natural choice was to learn from the Soviet model.

In 1933, the Chinese intellectual community initiated a discussion on how to build a modern national economy. Yang Duanliu,[5] Tao Mengru[6] and 26 other intellectuals reached a consensus that China should implement a planned economic system (Yang et al., 1933). Prior to this theoretical exploration, the national government had practised some degree of economic planning to strengthen national defence and cope with a possible full-scale Japanese invasion of China.

In November 1932, a secret organization of the Kuomintang (KMT), the National Defence Design Committee (NDDC),[7] was established. The agency was composed of three parts and was divided into 8 groups employing 39 experts and scholars to formulate a national defence plan, map out a national defence-centred construction project and prepare for the emergency organization of national defence (Wu, 1988). After the establishment of the NDDC, based on statistical investigations of the national defence economy and its resources, a number of important programmes were formulated, such as the National Defence Industry Initial Plan, the Five-year Plan for Heavy Industry Construction, the Wartime Fuel and Petroleum Control Plan, the Preliminary Plan for Mobilization and Control of Transportation and the Food Storage and Control Plan (Wang, 2004). All were gradually implemented.

In April 1935, the NDDC was reorganized into the Resource Committee.[8] In the same period, Chiang Kai-shek launched a national economic construction campaign in Guiyang (National Economic Planning Commission of the Central Committee of KMT Congress (NEPCCCKMTC), 1976). The campaign expanded rapidly, and various 'national economic construction committees' were established from the central government down to the local government level. Their objective was to 'concentrate on the power of various parts of national society' and to use the 'cooperative system', 'military organization', 'academic institutions', 'academic groups', 'industrial institutions', 'production organs' and all the forces of agriculture, industry and commerce to build a sound national economy. The role of the government in this was 'to forcefully expedite the removal of obstacles, and provide all kinds of help and convenience' (Chiang, 1935). Academic institutions such as the Academia Sinica were one of the focuses of the campaign.

In November 1935, the Fifth National Congress of the KMT decided to set up the National Economic Planning Committee to discuss construction projects and collect materials (NEPCCCKMTC, 1976). With the further development of the National Economic Construction Movement, a growing number of people came to believe that, in the face of the turbulent international political situation, the implementation of a planned and controlled economic policy that unified the national economic sectors and was driven by the will of national unity was important (Xu, 1936). By the 1940s, the implementation of the planned economy had become an important principle of the wartime nation-building programme (Fu, 2015).

In addition to promoting economic planning theory and practice in the 1930s, the national government promoted administrative procedure theory.[9] A group of intellectuals in the administrative field, represented by Gan Naiguang,[10] initiated an administrative efficiency movement in the Ministry of the

Interior. They proposed that the ultimate goal of administration could be achieved through five steps: using materials, making plans, implementing decrees, guiding supervision, and assessing rewards and punishments. In this way, fruitless discussions and ineffective measures could be avoided. The most effective way to guide and supervise was to have the right to appoint and remove personnel and to carry out budget and plan reviews of lower-level organizations (Yu, 2019). Gan's theory was widely implemented in the KMT Central Department, and Chiang Kai-shek considered it significant (Chiang, 2015 [1939]).[11]

Faced with the political reality of national poverty, social turbulence and a lack of foreign aid, the dissemination of foreign-planned economic practices and theories as well as China's own pre-war control of economic and administrative efficiency enabled Chiang Kai-shek to develop a strong belief in the need to use centralized planning methods to manage the country.

In 1940, Chiang proposed a planned administrative management model: the Triple System of Administration (TSA).[12] This new system divided various types of work into three parts: planning, execution and assessment. The Central Design Bureau (CDB)[13] of the KMT Central Committee established a plan based on the budget, the practicability of implementation and the results of assessments. Central and local KMT party and government executive organs implemented the plan layer by layer. An assessment committee was later established to evaluate the work of the party and the government. The results of the assessment were provided to the CDB as a reference for the next round of planning (Chiang, 1941).

The national government intended to improve administrative efficiency and achieve state control over a variety of resources, and the TSA was essentially the implementation of a planning system. Chiang Kai-shek (1941) noted that the system was designed to lay the foundation for 'planning politics' and a 'planned economy'. The Academia Sinica and the Ministry of Education, both of which dealt with science, were included in this design and evaluation system. Chiang Kai-shek, as the chief proponent, promoted the theory of the TSA. He placed two TSA institutions – the CDB and the Party and Government Work Evaluation Committee – under the direct leadership of the Supreme Council for National Defence,[14] which was the highest institution during wartime. He also personally selected the leaders of the two agencies, who reported directly to him, and personally supervised the relevant seminars (Yu, 2019).

When Joseph Needham arrived in China, the TSA was at the peak of its implementation. China's war against Japan had shifted from a stalemate to a counter-attack. Under the framework of the TSA, the national government planned the reconstruction of the country after demobilization. In 1942, the National Council of the Academia Sinica drafted a plan of scientific research for China after the war (Fu, 2008). As the head of government, Chiang Kai-shek emphasized the development of science in China. In the same year, he issued a statement – 'The way of science and the spirit of science' – that required that all scientific workers understand the content of science, embrace the spirit of science, and use scientific methods to exert 10 times their own strength for the rejuvenation of the nation (Needham, 1952). The article was posted in various national laboratories and workshops.

In March 1943, Chiang's (1943) book *The Destiny of China* was published and, by December, had been reprinted more than 200 times. According to the archives in Nanjing, the Academia Sinica and the Peiping Academy were commissioned to study the book and accordingly draw up plans for future research and development.[15] There were indications that Chiang also intended to apply his system of administrative planning to the scientific field. It was against this backdrop that he asked Needham to provide criticism and suggestions on Chinese science and technology.

2. The main content, features and essence of the report

Joseph Needham's report is rich in content, documenting many aspects that he had observed and reflected on in China. There are praise, criticism and suggestions; there are also many comparisons with the Western world, reflecting some distinctive features of science in China.

2.1. Overview of the report

The report is divided into nine parts, in which 10 recommendations are made. The first page contains an outline, in which the headings of each part are listed:

- The necessity for increased government support for science;
- The necessity for increasing the prestige of Chinese science;
- The necessity for finding political leaders with an understanding of the function and importance of science in the national welfare;
- A special ministry for science and technology;
- The Ministry of Education and the overseas study programme;
- Scientific societies and other organisations;
- Industrial organisations and industrial welfare;
- Wartime science of China and Britain in retrospect;
- International scientific relations.

There are minor differences between the English and Chinese versions of the report with respect to the recommendations. In the Chinese version, the recommendations are placed at the end of the report and, as a result of the translation, differ slightly in meaning from the original text, although that does not affect the overall meaning.[16] In the English version, the 10 suggestions, which precede the main text of the report, are as follows:

1. That the government should embark on a great investment policy by subsidising the Chinese scientific institutions (pure as well as applied) on a scale very much greater than heretofore.
2. That means should be developed for increasing the prestige of science and technology in China, perhaps by the foundation of new orders and decorations, accompanied by suitable publicity, by stricter registration of qualified men, or other methods as may be found good.
3. That great efforts be made to encourage political leaders with a real knowledge and understanding of science and technology in order to reduce the inhibiting factors which retard the industrialisation and modernisation of the country.
4. That the Ministry of Education be strengthened on the scientific side.
5. That since science cannot flourish except in a democratic and liberal atmosphere, steps be taken to ensure variety and freedom of thought and expression in the universities.
6. That the policy of sending the maximum number possible of scholars, students, and foreman-apprentices abroad for study, in the interests of the industrialisation and modernisation of the country, be vigorously proceeded with, and that western scholars and students be invited to China also.
7. That careful thought be given to the ways in which China's industrialisation might profitably differ from that which was historically gone through by the western countries, for example, in the use of non-ferrous metals, plastics, plant products and chemurgic processes.
8. That special care be taken to ensure sound workers' welfare practice during industrialisation, insofar as the situation permits approximation to western standards.
9. That thought be given to the problem of the provision of scientific advisory bodies at all levels of and to the participation of scientific men in the foreign relations of the country.
10. That China continue her policy of demanding a United Nations Cultural Organisation capable of fulfilling the functions of an international science cooperation service, and that the Chinese scientific movement be strengthened as soon as possible by the arranging of one or more international scientific congresses in China.

2.2. The characteristics and essence of the report

Some notable characteristics come to the fore when we consider an overall view of the report.

First of all, Joseph Needham praised the science and technology of China during the war, especially

the work of Chinese scientists. However, most of his observations pertain to criticisms of the environment in which China's science and technology had been developing.

He pointed out that, in circumstances that would have left European and American scientists depressed, the achievements of Chinese education and industrial technology merited sympathy and admiration. China had a group of scientists who had made important contributions to the pure sciences, but the environment that the Chinese Government provided for them had not been sufficiently suitable. The government's investment in science was too low, and resources and personnel were in short supply in many Chinese research institutions. Furthermore, the eagerness for rapid scientific success in China had led to an overemphasis on the applied sciences and the neglect of the pure sciences.

Needham repeatedly referred to the atomic bomb – the most compelling scientific achievement of the time – as an example to illustrate the importance of increasing investment in and attaching importance to the pure sciences. He proposed that the amount of funding for scientific and technological research be increased to 0.5% of national income. In addition, he sharply criticized several aspects: political leaders lacked a modern mind-set and had neglected science or even hindered its development; the Ministry of Education was weak in science, restricted freedom of thought in universities and neglected students' health; the military had destroyed some research institutions.

Needham considered almost all aspects and made appropriate suggestions, from the construction of institutions and the choice of organizational models to the staffing of organizations and the livelihoods of the people. He even analysed the problem of corruption in China. His comments thus included pungent criticisms of prevalent ills at the time and did not avoid sensitive topics. For example, he noted that political leaders lacked scientific literacy, that the Ministry of Education had not performed well in defending freedom of thought, and that the behaviour of the police in 'disappearing professor'[17] incidents was problematic. Some criticisms and suggestions are thought-provoking even today.

Second, Needham paid special attention to the relationship between science and politics. He devoted more than one section to a discussion of this issue. He claimed that politics was the biggest problem facing science in China at the time, commenting, 'If science in China has any shortcomings it is that it is too readily subject to interference by politicians who, however well-intentioned, have neither knowledge of, nor interest in, science'. He highlighted a series of abnormal relations between politics and science, such as

- The restriction of democracy and the freedom of science;
- The lack of understanding of science among political leaders;
- The setting up of scientific positions based solely on the interests of a political group;
- Scientific work completely interrupted by a change of director in an organization;
- The erosion of pharmacological research due to national sentiment;
- The destruction of scientific research facilities by the military;
- Hesitation in implementing science and technology in the education of the masses for fear of their enthusiasm;
- A lack of understanding in the Ministry of Education of the scientific needs of universities, and so on.

He added that most Chinese politicians had accepted only those people with a classical education, had narrow views on nationalism, lacked a modern mind-set, and could not understand the modern world, so it was difficult for them to lead China's industrialization. He cited psychological reasons for politicians and others not appreciating science: the influence of Confucian philosophy, which led them to think of science as a luxury; economic considerations whereby they did not require science to gain wealth; and 2,000 years of bureaucratic influence. In short, the contemporary state of Chinese politics had hindered and damaged the growth of science in China. His references to Sun Yat-sen's political philosophy regarding national construction – the 'Three Principles of the People' and Chiang Kai-shek's

book *The Destiny of China* – showed that Needham had not only paid attention to real political issues, but had also studied the KMT's political programme as well as the interaction between political opinions and science.

Third, when analysing Chinese science, beyond politics, Needham also considered such factors as economics and culture. In terms of the economy, besides industry, he focused on agriculture, forestry, and soil and water conservation. For industry, he made specific proposals for improving the railway transportation network and developing water resources in western China. He even proposed ideas and suggestions on the model to be followed for China's industrialization. Needham believed that China should establish its own model of industrialization based on its own advantages in natural resources, instead of following the old model of the West based on the steel industry. The term 'industrialization' appears 17 times in the report.

Although Needham thought that economic structure – a critical issue – was beyond the scope of the report, he nevertheless discussed several aspects related to it, such as where to establish a natural nitrogen fertilizer plant, where to carry out dairy farming, where to build a canned fruit base, and how to plan water and soil conservation. He even considered the issue of China's economic path:

> I often question, however, whether it is necessary for China to retrace all the steps in the weary road of the development of capitalism in Western Europe. The proposals of Sun Chung-shan [Sun Yat-sen] that heavy industry, mining, power production and all communications should be owned and operated by the state, while light industry should be left for individual enterprise, seem to be an excellent compromise.

This supported the implementation of the 'planned economy' model, which was still being hotly debated at the time.

Needham also realized that inflation had had a serious effect on the development of China's industrial technology, and that there would be little hope for Chinese industry in the future unless it was controlled by people possessed of a modern outlook and an industrial mind. At the same time, he emphasized that culture is closely linked to science. China emphasized only the material culture of the West while abandoning its intellectual and spiritual culture; this was as unreasonable as the West's disregard of China's four inventions and the contribution of Mencius' thought to the French Revolution: 'Modern science cannot be fully understood without understanding the social setting of European civilization in which it took its rise'. Therefore, when analysing Chinese science, he not only observed social phenomena but also made significant efforts to trace the social and historical roots of those phenomena. This method was in line with the Science and Society Movement and 'externalism theory' after the Second International Conference on the History of Science.

Fourth, the report shows Needham's special feelings for ancient Chinese cultural heritage. Needham was disheartened at seeing that the Thousand Buddha Caves at Dunhuang[18] had not been protected by any formal measures, and that the Confucian temples in rural towns were neglected by people or destroyed by the army. He suggested that a special agency – a monuments protection committee – should be set up to work closely with the Academia Sinica and to encourage all politicians to remedy this problem.

In addition, he emphasized that China had already gained international prestige for its art and archaeology, and that the government should provide strong support for archaeologists. Large investments should also be made in the construction of national museums to help retrieve Chinese cultural relics taken abroad. China could easily play an important role in the United Nations Science and Culture Organization, he added, because 'her age-old and famous respect for scholars enables her particularly readily to push forward this public work in the comity of nations, which incidentally may be a source of much prestige for herself'.

Needham also felt that Chinese could be used as a scientific language and could become a language of world communication. Such content, although seemingly not closely related to the subject he was discussing, was expressed in a naturally heartfelt way. An unofficial purpose of his travels in China had been to collect information about China's historical and cultural heritage to deepen his personal academic research (Winchester, 2008), and what he had seen must have stirred him deeply.

Fifth, the purpose of the main body of Needham's suggestions was to establish an orderly system of science and technology in China. To promote the development of China's science and technology after the war, Needham's suggestions included increasing investment in research on science, establishing a reward system, improving the scientific literacy of leaders, improving the Ministry of Education, creating an atmosphere of democracy and freedom, promoting foreign exchange, and establishing a ministry of science and technology.

Regarding the Ministry of Education, he opined that it should be improved by increasing the number of scientists serving in it, ending the censorship of academic works, liberalizing control of universities, caring about the health of students, promoting academic exchanges with foreign countries, improving foreign language teaching, liberalizing Russian studies, changing narrow concepts of nationalism, and learning about Western culture alongside Western science and technology.

The ministry of science and technology should be designed to help Chinese science programmes. Its responsibilities should include managing all research conducted by government organizations; leading national agricultural research bureaus and overseeing provincial agricultural activities; leading industrial research bureaus, national geological survey bureaus, national medical research institutes and national compilation institutions; and maintaining a close relationship with universities and the two national research academies. An important feature of the ministry was that it should be independent of other ministries and should have nothing to do with basic administrative departments so that its long-term programmes would not be at risk of being interrupted by political changes. Needham's suggestion for such a ministry clearly showed his hope that China should have a department responsible for the top-level design of science while ensuring academic autonomy.

Needham's proposals covered multiple facets of the construction of the science and technology system in China. Setting up a ministry of science and technology and improving the Ministry of Education involved both the establishment of a new agency and improvements in the organizational system. Increasing investment, establishing incentive systems, improving the scientific and technical literacy of leaders, creating a democratic and unfettered research environment and promoting foreign academic exchange were the measures suggested for optimizing the mechanism of operation of the science and technology system (Fang, 1994). Those suggestions were in line with Bernal's 'planning of science' proposed in *The Social Function of Science* – that the national academy of sciences should carry out the planning and management functions of scientific and technological development (Bernal, 1982 [1939]).

Finally, from Needham's criticisms and suggestions, the answer to the famous question of why Chinese science had fallen behind in modern times can also be inferred. During his tenure as head of the Sino-British Science Cooperation Office, he discussed this question with many scholars and made detailed notes. It is clear that solving this problem was a consistent motif throughout his investigations (Liu and Wang, 2002).

In this report, in which Needham summarized the work of the Sino-British Science Cooperation Office, we can easily find his embryonic answer to the 'Needham puzzle'. His views, presented in the article titled 'Science and society in the East and West' in 1964, were already present in this report. He analysed not only reasons why Chinese society failed to develop commercial and industrial capitalism, but also the bureaucratic ideology of Chinese society and the psychological reasons why Chinese politicians had not attached importance to science. He noted how politics had interfered with, and sometimes caused the destruction of, Chinese scientific endeavours in many places (Needham, 2002).

He argued that the psychological reason why scholars, the gentry and bankers had not attached importance to science was that they thought that its purpose was to contribute to comfort and luxury. He added that, in the traditional economy, they could become wealthy as long as they held a high official position or invested in land and banks; they did not consider the investment of capital in industrial production and the country's scientific modernization as a means to personal prosperity.

Needham mentioned all the necessary conditions for the rise of modern science, such as social forces

interested in technological progress, an atmosphere for free debate and people engaged in both mental and physical labour (Graham, 2002). He claimed, however, that China still lacked those conditions, especially that of a democratic and free environment. Aside from deriving Needham's solution to his puzzle solely on the basis of this report, his subtext on science in the Republic of China can be summarized by saying that China's political, economic and technological systems at the time were not conducive to the development of modern science.

3. The impact and significance of the report

Needham's report was not intended for Chiang Kai-shek alone. There were many follow-up initiatives as a consequence of it.

3.1. Subsequent distribution and impact of the report

Once the report had been completed, on 28 February 1946, Needham sent it, together with the translated Chinese version, to the British Embassy in Chongqing and requested that the embassy pass it on to Chiang Kai-shek. At the same time, he asked the embassy to send out copies marked 'confidential' a week later to leaders and key personnel of 14 institutions:

Dr Wang Ching-Hsi汪敬熙, acting secretary-general of the Academia Sinica

Dr Li Shu-Hua李书华, secretary-general of the Peking Academy

Dr Chu Chia-Hua朱家骅, Minister of Education

Dr Wong Wen-Hao翁文灏, Minister of Economic Affairs and vice president of the Executive Yuan

General Yu Ta-Wei余大维, Army Ordnance Administration

Dr TV Sung宋子文, chairman, Executive Yuan

Dr Sun Ko孙科, chairman, the Legislative Yuan

Dr Fu Ssu-Nien傅斯年, Academia Sinica

President Wu Yo-Hsun吴有训, National Central University

Dr Tseng Chao-Lun曾昭抡, Peiching[19] University

Dr Li Sse-Kuang李四光, Academia Sinica

Dr Chiang Mon-Lin蒋梦麟, secretary-general, Executive Yuan

General Ling Ko-Hsing林可胜, Army Medical Administration

Dr Hou Teh-Pang侯德榜, Yungli Chemical Corporation (Needham, 1946).

Needham also requested that, once the copies had been sent, more copies be printed as soon as possible. They were then secretly issued in his personal name and sent to another group of people:

Dr Hu Shih胡适, Peiching University

Dr Wang Chia-Chi王家楫, Academia Sinica

Dr Wu Shioh-Chou吴学周, Academia Sinica

Dr Yeh Chi-Sun叶企孙, Nat. [National] SW [Southwest] Associated University西南联大

Dr Rjen[20] Hung-Chang任鸿隽, China Foundation

Dr Shen Chih-I沈其益, Biological Laboratories, National Central University

President Mei Yi-Chi梅贻琦, Nat. SW Associated University

Dr Chang His-Man张西曼, Ed[itor], *Democracy and Science*

Mr Mao Tze-Tung毛泽东, care [of] Kungchangtang[21] Secretariat

Dr Shen Tsung-Han沈宗瀚, Nat. Agricultural Research Bureau

Dr Chin Bao-Shan金宝善, National Health Administration

Mr Mao I-Sheng茅以升, China Bridge Company

Mr Ling Hung-Hsun凌鸿勋, Vice Minister of Communications

Dr Han Li-Wu杭立武, Vice Minister of Education (Needham, 1946).

Thus, in addition to Chiang Kai-shek, this report, which Joseph Needham had repeatedly emphasized was confidential, was sent to 28 important figures in the fields of science, technology, culture and politics, including Mao Zedong, the leader of the Communist Party of China (Needham, 1946).

Needham's report was distributed in 1946, just after the war, when travel in China was difficult. The Minister of Education and acting director of the Academia Sinica, Zhu Jiahua, should have received it in early April but did not read it carefully. He simply hurriedly wrote to Needham confirming receipt of the report, placed it in his personal files and sent them to Nanjing (Chu, 1946).

Due to travel restrictions at the time, Zhu did not receive his files in Nanjing until the beginning of 1947 (Chu, 1947). Before then, however, the report had been read by others who were not on the two lists. The most notable of them was Zhu Kezhen. Although Needham did not send him a copy, Zhu read the report on 11 April, only a few days after Zhu Jiahua had received it. He even made an English excerpt and a Chinese summary of the report in his diary for that day (Zhu, 2006). The first sentence of his excerpt was that 'in the United Kingdom, research and organizations are independent of the corresponding ministry'. After quoting in English the democratic university system in the United Kingdom, Needham's promise to help Chinese educationalists to go there to study, and elements that paved the way for the French Revolution, he went on summarizing in Chinese as follows:

> Needham narrates the achievements of Chinese science in the past. At present, Blackett's student Hu Qianshan, Max Born's student Peng Huanwu, AV Hill's student Tang Peisong and Tong Dizhou's experimental morphology, and Wu Xian's invention of protein denaturalization are all considered rare achievements. It is necessary to increase funding for the Academia Sinica and Peiping Academy by 100 times . . . Furthermore, too many employees are used in institutions . . . The report also mentions that universities control ideas and professors go missing. As for academic society, [Needham] insists that scientific journals should be maintained and praises the *Chinese Journal of Psychology, Sinensia*,[22] *Science Record*, the *Journal of Meteorology*, and the *Journal of Chemistry*. (Zhu, 2006: 93)

Zhu Kezhen's diary shows that he had read the full text and noted what had impressed him the most. Although it is difficult to verify how individuals felt after receiving and reading the report, we can infer from Zhu's reflection that the report was widely disseminated among scientists, despite Needham's emphasis that it be marked as 'confidential' and only discreetly transmitted.

Chiang Kai-shek should have received the report transmitted by Wang Shijie in March, since Needham had given it to the ambassador on 28 February 1946. On 8 April, Wang told him that he had forwarded it to Chiang a few days before (Wang, 1946). Due to a lack of evidence, any specific steps taken by Chiang after he received the report cannot be verified, but we can find some clues.

In October 1946, the Supreme Council for National Defence (the highest decision-making body at the time) reported good news: the government had decided to 'return science to the scientists' and would increase investment, stating that 'scientific research funds should account for a percentage of the country's entire budget', or 1% of military spending (Hu, 1946). Even more suggestive is the fact that, at the beginning of 1946, Chiang ordered the CDB, the hub of the Triple System, to formulate a Science and Technology Guidance Programme (STGP). In the process of its formulation, Chiang sent a secret order to Zhu Jiahua on 20 January 1946, stating, 'For developing applied science, I hope that the Ministry of Education and the Academia Sinica can propose a 10 year plan, including year by year progress' (Chiang, 1946).

Both orders were issued before Needham's report had been delivered. Afterwards, the two cases were merged. The CDB drafted the STGP. The Academia Sinica and the Ministry of Education convened experts from various institutions to discuss the contents of the report in detail and finally produced a draft – *A Ten-Year Plan for Applied Science Development* (Anonymous, 1946). The STGP

proposed establishing a science and technology steering committee responsible for

- Developing scientific and technological guidelines;
- Preparing a scientific and technological work plan in the national construction programme, and prioritizing procedures for the formulation of scientific and technological work;
- Distributing key work projects to various scientific and technological institutions;
- Reviewing the progress of their work and promoting contact and cooperation among them;
- Gathering information needed for scientific and technological work;
- Investigating technical issues relating to the industrial, mining, agricultural and medical industries, conducting professional or special group research, and implementing it after conference review (Anonymous, 1946).

Overall, the responsibilities of this supreme institution were not different from what Needham had proposed as 'taking care of all governmentally organized research'. The 10-year plan was proposed under the framework of the STGP. In it, the proposed institution was called the 'Applied Science Promotion Committee'. The plan proposed that the committee be funded with at least 1% of annual gross national income – twice the 0.5% recommended by Needham. This plan, which was under discussion for a long time, was undoubtedly influenced by his report. The principles in the guidance programme of the Science and Technology Steering Committee, such as the allocation of decision-making power to the scientists, avoiding the duplication of institutional functions and decentralizing the power of the government, were in line with the principles of academic independence that Needham had proposed and Zhu Kezhen had emphasized.

One may conclude that the plan was influenced by Needham's report for two reasons. One is that the plan was jointly discussed by scientists of the Ministry of Education and the Academia Sinica and was submitted in only December 1946, while a third group of reports had been sent out by Needham well before that, on 3 April 1946 (Bolton, 1946). The other is that the Ministry of Education had carried out serious deliberations on the report.

Interestingly, Needham did not send the report separately to the then secretary-general of the Academia Sinica, Sa Bendong. Although the report can be found in the archives of the Academia Sinica, its precise origin is unclear. The archives contain neither a record of receipt at the main office nor any record of the processing of the document, and the copy is missing the 'confidential' stamp that Needham had emphasized.[23]

Probably because there was no specific criticism of or suggestion to the Academia Sinica in the report, but a number of criticisms aimed at the Ministry of Education, it was treated seriously by the latter, although only a long time after its receipt. The earliest signature by Minister Zhu Jiahua is dated 10 November 1946, on the day he instructed that 'the two reports, Needham's scientific research of China and Pound's report on China's legal and education systems, should be printed, translated and dealt with rapidly'. A symbol indicating emphasis was added to the word 'rapidly'.[24]

The instruction shows that Zhu initially had read only the English version, that he had not known that there was a Chinese version, and that he was anxious to solicit the opinions of the Ministry of Education on how to handle it. This shows that, even 6 months after its first circulation, no one in the Ministry of Education had opened and read the report or had known anything about the criticisms of the ministry raised by Needham. It was likely that they got news of this in discussions between the Academia Sinica and the Ministry of Education on the 10-year plan because, at that time, the report to Zhu was still on its way back to Nanjing from Chongqing.

The Department of Higher Education would have obtained the Chinese version not long after. Zhou Hongjing,[25] the director of the department, sorted out the content of the report according to the original text in only three days and presented a preliminary treatment of the relevant parts for the Ministry of Education. In response to the material prepared by Zhou, Zhu Jiahua offered two opinions: 'First, present detailed methods and an implementation plan for checking and approving promptly. Second, draft a reply to Needham for verification'. Zhou Hongjing

and the executive vice-president of the Ministry of Education, Tian Peilin,[26] contributed to the following detailed measures and an implementation plan, in which they finally formulated eight recommendations and six specific measures.[27]

First, on enhancing facilities for science and research in educational institutions above the college level, they wrote,

> It seems that we should actively enrich it in the future . . . We should invite experts from both inside and outside the department to set up a permanent organization working on the research plan (proposed to be called the Science and Technology Education Research Committee (STERC) of the Ministry of Education) to inspect the science and technology teaching and research at each institution. To guarantee that the funds raised are distributed in the most reasonable way . . . The equipment of each institution (学校) should be self-contained.

To this, Zhu added his instructions in the margin: 'This matter is important; let Mr Zhou discuss with Mr Sa Bendong[28] and Mr Wu Zhengzhi[29] immediately, and formulate an appropriate approach according to Executive Vice-President Tian's recommendation. As for research equipment, it must be purchased by each institution'.

Second, on enhancing the relationship between the Ministry of Education and various scientific societies, they wrote,

> In the past, there was not enough contact. In future, we will learn more about the situation of each society and raise a batch of funds to subsidize the publishing expenses of the societies.

Zhu instructed that 'the headquarters must pay special attention to this on a regular basis. This should be discussed by Director Zhou and Mr Sa Bendong'.

Third, on the issue of excessive staff members in each institution, Zhou and Tian wrote,

> This is a very unreasonable phenomenon, and the number of appointments for each institution should be limited in the future. The abuse of having redundant staff and the waste of expenses thus can be avoided.

On this, Zhu commented, 'This is the biggest shortcoming of China's education. This kind of phenomenon has intensified during the war of resistance. When I was in Zhongzheng and Zhongyang universities, I was deeply affected by the fact that it was not easy to get rid of this. The results at Sun Yat-Sen University were better and more thorough; however, at Zhongyang University, it was even more difficult'.

Fourth, concerning the government's interference with academics, they wrote,

> The government has never interfered with the research work of institutions. The examination of faculty members' qualifications by the Academic Review Committee is equal to the rigorous registration of the qualified personnel needed, as pointed out by Needham. There has never been a problem with the contents of the faculty's work.[30] Academic awards organized by the Academic Review Committee have encouraged academic research and have been recognized by the academic community. Needham's comments that 'in universities, scientists are often disturbed by political activities' and 'academic papers for professors should be allowed to develop freely, and the Ministry of Education should not examine them' are a misunderstanding. In addition to the examination of the qualifications of the faculty members, it seems that our department should increase the number of academic prizes, and those who have made special contributions should be given medals or honours, and if necessary, receive further praise.

Zhu instructed, 'Explain to Needham. As for reward, Mr Sa, Mr Wu and Director Zhou should discuss effective measures and an increase in the annual budget'.

Fifth, it was recommended that the department determine incentives and encourage the rich to set up research institutes in universities to conduct specialized research. Zhu added the instruction: 'Do as Vice-President Tian advises'.

Sixth, on sending students abroad, Zhou and Tian wrote,

> In the thirty-sixth year [i.e. 1947], students are to be sent abroad as usual and a request is to be submitted to the Executive Yuan to continue sending them.

Concerning the professors who had been sent abroad for further study, they noted,

> It seems that the system for sending professors to study abroad in the past was too lax. In the future, they should be strictly examined. They will not be sent if they do not have suitable achievements and research plans, or do not need to do research abroad. In particular, faculty members being sent overseas for inspections should be restricted further. Inviting Western scholars to give lectures in China fulfils an advocacy role for scientific research . . . each subject should have one first-class scholar of physics, chemistry, biology and medicine invited in the thirty-sixth year.

Zhu commented, 'Formulate a detailed plan with the Department of Culture and Education'.

Seventh, on setting up science museums, Zhou and Tian wrote,

> Gansu Science Museum was greatly praised by Needham. In the future, it should continue to be funded, and such museums should be set up in various provincial capitals.

Zhu added his approval: 'Sure'.

Eighth, on international scientific cooperation, they wrote,

> The International Culture and Education Division has been established in our ministry. When it can be actively promoted in the future, its cultural commissioner should be from among those who majored in science and engineering.

Zhu instructed, 'The Office of Culture and Education should pay special attention to this. The establishment of the commissioner cannot be delayed any longer. Please check and act urgently on it'.

To help execute the plan, the Ministry of Education separately formulated instructions on six main points related to these recommendations.

First, on the set-up of the STERC, in accordance with the opinions of the Ministry of Education, it was decided that a scientific and technological research committee with from 7 to 11 members should be established. It would be divided into two groups: one to investigate the scientific equipment and state of teaching and research in each university, and another to design ways to enhance teachers and teaching equipment and carry out research work. Furthermore, a regular meeting would be held at the end of each semester.

Second, to strengthen the relationship between the Ministry of Education and various scientific societies, each society would be required to submit reports on time. Those that had not yet been put on record should be recorded as soon as possible. Special funds should be set up to subsidize research and enrich the societies' collections of books and equipment. The Ministry of Education should help them overcome difficulties in scientific research, assist personnel from various groups to conduct research in China and abroad, and hold an annual national science and technology meeting with the Academia Sinica.

Third, for controlling the personnel, standards for the number of teachers in schools for professional training should be worked out by class; standards for the number of teachers in universities and private colleges should be determined by department, and the maximum and minimum number of employees for each department should be clearly stipulated. Flexibility should be reduced as much as possible: 'Firmly restrict the appointment of work staff; each institution should submit a roster of all personnel and strictly prohibit part-time jobs and part-time salaries for faculty and staff'.

Fourth, a reward system for research in each institution should be implemented. National university research institutes should be subsidized according to their needs and results. Depending on the academic value of publications, printing expenses could be subsidized. University professors conducting valuable research would receive a special subsidy, and a bonus would be given to master's graduates whose theses had special value. In addition to the subsidy, a variety of medals would be awarded for exceptional research. Other than these measures, the ministry proposed that 'The research subsidy for the faculty members of national university research institutes should be double that of the general faculty' and that 'in addition to fees and bonuses, graduate students should receive subsidies of half of the minimum salary of a teaching assistant', but both those suggestions were turned down by Zhu Jiahua.

Fifth, wealthy patrons should be encouraged to set up research institutes in universities and rewarded for it. Those making private donations to set up an institute would be commended and given an award according to the amount of the donation, which would be calculated cumulatively, and donations of equipment or real estate would be calculated according to their monetary value at the time.

Finally, to strengthen international cooperation, outstanding scientists would be selected to participate in the United Nations Educational, Scientific and Cultural Organization (UNESCO) Science Committee, establish contacts and collect news and publications, and thus strengthen the role of the STERC of the Ministry of Education as the external contact centre of China.

The processing procedure and outcomes of Needham's report show that the Ministry of Education focused on the recommendations relevant to it and proposed measures mainly concerning universities and colleges, but the ministry's measures lacked the macroscopic design required at the national strategic level. From the outset, the top cadres of the Ministry of Education paid special attention to Needham's accusation that the ministry interfered with academic freedom. Needham's report noted that science in China was often subject to political interference and that, because of the direct connection between science and the ideals of democracy and freedom, the government should allow universities a considerable degree of freedom of thought. On this point, Tian commented, 'The Ministry of Education has paid great attention to this in the past two years. It is also guaranteed in the Constitution'. He countered Needham's criticism that 'professors should be free to develop academic papers, and should not be examined' with a terse '[we] never did this'. Concerning the 'monitoring of the political thought of foreign students', he instructed that 'this will no longer occur'.

Although the Ministry of Education had developed preliminary measures for providing research subsidies and incentives, controlling the redundancy of personnel and encouraging private investment in scientific research, it finished drafting the relevant measures only in April 1947. This coincided with major changes in the domestic political and economic situation. The national government itself had entered a critical stage in its fight for survival and had lost the ability to realize this new vision for science and technology.

3.2. The significance of the report

Although Needham's proposals were not substantially implemented during the period of the Republic of China, their significance is clear. First, the report established a model for expert consultation, which was valued by the government authorities. Needham had been asked by Chiang Kai-shek to prepare the report, and would have benefitted from Chiang's commission as it would have helped facilitate his subsequent visits to almost all important institutions related to science and technology in the KMT's territory over his 3 years in China, including military enterprises. Once the report had been submitted, the Ministry of Education, led by the minister, organized personnel to consider it, and the minister deliberated on it himself. The STERC proposed by the Ministry of Education to support university research and the plan to control the number of administrative staff were all practical measures suggested in the report.

Second, the report is an exemplar of academic freedom in the way that it was disseminated. Needham's distribution list included the chiefs of various ministries and the most influential figures in science, technology and culture in China at the time. The report dedicates several paragraphs to highlighting the interference that Chinese academic institutions had faced from the ministry. From the reaction of both the Ministry of Education and Zhu Kezhen, we can infer that both the government's administrative staff and the scientists involved in education were impressed by the report. The rapport felt by scientists and the defensiveness of the politicians highlight the social acceptance of freedom in academic thought at the time.

Third, Needham's interpretation of the relationship between basic and applied science gave Chinese scientists a boost. Throughout the period of the Republic of China, there were disagreements between politicians and scientists on how to deal with the relative importance of basic and applied sciences. A large number of scientists insisted on the

importance of developing basic science, while politicians were always trying to direct resources towards applied science. According to the scientists, applied science could not be developed in isolation; it depended not only on pure science but also on the humanities (Fu, 2015). In times of war, scientists should serve the practical needs of the hour, but, in times of peace, science needs to return to the path of pure science, they claimed.

In 1946, when Chiang Kai-shek asked the Academia Sinica and the Ministry of Education to draw up a 10-year plan for the development of applied science, the two parties proposed a plan only for nurturing talent. This indicates that, even after World War II, reconciling the fundamentally conflicting concepts of the two groups was still a big problem. Perhaps it was Needham's influence that led to the setting up in Taiwan of the Long-term Scientific Development Board in 1959, with three special committees in mathematical sciences, biological sciences, and humanities and social sciences, and the establishment of the Centre for Mathematics and Theoretical Physics for pure scientific research (Academia Sinica's Eighty Years History Compilation Committee, 2007).

The idea of attaching greater importance to basic science was also reflected on the Chinese mainland in the formulation of a 12-year plan for science in the 1950s. Once the principle of 'Tasks Leading Disciplines'[31] had been established, scientists argued for the importance of basic science and gained the support of Premier Zhou Enlai. In the end, to the 56 major tasks in the original plan, 'research on some basic theoretical issues in modern natural science' was added, for a total of 57. Furthermore, a separate plan covering all basic scientific research fields was formulated (Central Committee of the Communist Party of China and Sichuan Provincial Party Committee, 2005).

Fourth, the further dissemination of ideas on planned science and science and technology policy was significant. Needham's report embodied several aspects of Bukharin's theory on the planning of science. For example, he championed dedicating at least 0.5% of national income to scientific and technological research. Other important ideas included the following:

- A study on soil erosion in the Loess Plateau;
- A survey of forest resources in Fujian Province;
- The construction of large-scale reservoirs and irrigation projects at the foot of the Nanshan Mountains;
- A hundred-fold increase in funds for the Academia Sinica and the Peiping Academy;
- The sending abroad of students and the introduction of experts to China to nurture talent at all levels.

Needham also stressed the importance of a reliable supply of funds and talented people to scientific research institutions, their geographical layout, the training of talented researchers and cadres, and project design. Furthermore, he introduced his experience of British national science and technology policy to China. In 1916, the United Kingdom had established the first special department – the Department of Scientific and Industrial Research – which marked the birth of modern British national science and technology policy and coordinated British scientific efforts during the two world wars (Wu, 1998). Needham strongly recommended that China establish a department specializing in the planning of science and industry – a ministry of science and technology – which should not be affiliated with the Executive Yuan and thus should be immune to changes in political leadership.

In modern times, science and technology policy is defined as a collection of measures taken by governments to support the development of science and technology and their use to promote economic and social development. Needham's design contained not only measures that the Chinese Government should have taken to support the development of science and technology, but also measures that used science and technology to promote economic and social development in China. Thus, the report conveyed a clear concept of science and technology policy to the Chinese social elite. All this advice had been offered by the time the secretary-general of the Academia Sinica, Sa Bendong, wrote to V Bush and asked for advice on science and technology policy in post-war China (Sa, 1945) and is commendable.

The content of the report also shows that Needham was being frank about the state of science in China. In the report, he talked about the scientific organizations and individuals that should be heavily funded, management and support that should be given to universities, methods that should be adopted in agriculture and industry, and rewards that the state should offer to science. He even pointed out a number of problems in various areas. In the main, he adopted a broad comparative approach to make his points. For example, on the independence of researchers, he noted, 'In the United Kingdom, the principal research organizations of the government are independent of their corresponding ministries . . . In the United States, the government research organizations have to a large extent been safeguarded from the "spoils system"'. Yet, there were instances when he went very directly to the crux of the matter, such as

> Science in China . . . is too readily subject to interference by politicians who, however well-intentioned, have neither the knowledge of, nor interest in, science.
>
> Unless modern-minded and industrially minded men are placed in control, the large industrial accessions, which the circumstances of the ending of the war have mercifully brought intact into Chinese hands, will not be properly exploited.
>
> During the war I've noticed a lot of instances which indicated a failure of the government to appreciate the needs of technology.
>
> All Chinese organizations are overstaffed with bureaucratic personnel, unskilled laborers, business staff and the like.
>
> Party politicians seem unduly nervous of mass education.
>
> Within the universities also, there is undesirable political interference with science.
>
> A contemptuous attitude towards science is found in the army as well as among politicians.
>
> [In Xi'an] The professor of a physics laboratory had to have a hand-turned dynamo supplying current, while the bacteriologists were unable to use their centrifuge and incubator, although every petty merchant's store and teashop in the city had electric light . . . This is not a way to make China a great nation.
>
> On the part of most British scholars who have visited China in recent years has been one of thankfulness that no such organization is necessary in England.
>
> It would be very worthwhile for a small group of Chinese educationalists to go to England specifically to study our democratic university system, and consider carefully what steps could be taken in China towards the freeing of the Chinese universities from bureaucratic dead weight.
>
> The Confucian temple has been wrecked by the quartering of soldiers, and the terraces of the central shrine of the sage itself, with all its beautiful carving, are today polluted with ordure. This is a disgrace to the nation.

All these comments were heartfelt. It was surely impossible for the authorities to read them with complete indifference.

4. Conclusion

In preparing his report to the leader of the KMT, Needham conducted a comprehensive survey of the situation of China's science, technology and society. From the perspective of a scientist, he carried out a comparison between science in China and that in the West, paying special attention to the historical background and social situation at that time. The breadth and depth of his understanding were unprecedented among Western scholars. This work, therefore, was one of the most important foundations for Joseph Needham's great work, *Science and Civilisation in China*.

In the report, Needham noted the many problems China was facing or would face and showed foresight in the many questions and plans that he proposed. For example, he noticed the shortage of skilled workers in China and pointed out that, to educate people about science and technology, workshop foremen were more urgently needed than well-trained engineers. In view of language problems, he suggested that foreign technical training experts be

invited to China so that foremen could receive intensive training at home. On industrialization, he warned that 'the Chinese government must ensure that industrialization does not proceed on an unfettered path at the expense of hurting the working people'. On the connection between China's traditional agrarian society and modern industrial society, he proposed that China's industrial cooperatives be given a certain amount of space to carry out their activities for a long time. In this way, industrial life and the local family system could gradually be connected. On Chinese culture, he pointed out that the country's respect for scholars had a long history and was well known around the world. This perhaps also constituted a source of international prestige – one that made it particularly suitable for China to promote international scientific cooperation.

Nowadays, the super-community business model of the direct docking of commerce with farmers and herdsmen, the capacious investment and guidance of the nation in occupational education, and the success of Confucius Institutes, which provide windows into Chinese culture for the world, all remind us that Needham's proposal from the mid-20th century is still worthy of serious consideration today.

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Notes

1. A copy of the report is housed in the East Asian History of Science Library of Cambridge, Classmark: JN: C/2. All references to the English version of the report in this article are from that copy. A PDF file is also available on the Needham Research Institute website: http://www.nri.cam.ac.uk/wartime_extras/Wartime_report_to_Chiang_Kai-shek.pdf. When quoting from the report, Dr Needham's spelling of Chinese personal names and institutions is retained.
2. 刘咸.
3. 鲁桂珍.
4. There are more than 80 records in Wang Shijie's diary discussing loans from Britain and the United States.
5. 杨端六.
6. 陶孟如.
7. 国防设计委员会.
8. 资源委员会.
9. 行政程序论.
10. 甘乃光.
11. On 30 November or 1 December in the chronology of major events scheduled for December, Chiang Kai-shek wrote: 'First, the party and government efficiency organization (design, implementation, assessment) of the Trinity organization. Gan'. Here, 'Gan' should be 'Gan Naiguang'.
12. 行政三联制.
13. 中央设计局.
14. 国防最高委员会.
15. In the Second Historical Archives of China, there are files in the archive of the Academia Sinica (Issue 393) and Peiping Academy (Issue 394) containing study notes on this book and drawing up research plans according to it.
16. See archive: 'The position and prospects of science and technology in China' written by Joseph Needham and translated by Sino-British Science Cooperation Office and signed verification opinions of various institutions. Issue 5, no. 42. Nanjing: The Second Historical Archives of China.
17. What Needham referred to was high-ranking scholars being arrested and held incommunicado for long periods by the police on quite inadequate grounds. He criticized this in a footnote to his report and named it the 'disappearing professor' phenomenon.
18. 敦煌千佛洞.
19. This was Needham's special spelling; it should be 'Peking'.
20. This was Needham's special spelling; it should be 'Ren'.
21. The Communist Party of China.
22. *The Journal of Zoology*, sponsored by the Academia Sinica in the Republic of China period.
23. From the *Daily Information Bulletin* of the Information Office of the Government, *Daily News Bulletin* of the Nanjing American News Agency, etc. (in English). Issue 393, no. 2360(3), Nanjing: The Second Historical Archives of China.

24. See Zhu Jiahua's (1946) instructions. In archive: 'The position and prospects of science and technology in China' written by Joseph Needham and translated by Sino-British Science Cooperation Office and signed verification opinions of various institutions. Issue 5, no. 42. Nanjing: The Second Historical Archives of China.
25. 周鸿经.
26. 田培林.
27. All the following citations are from the archive: 'The position and prospects of science and technology in China' written by Joseph Needham and translated by Sino-British Science Cooperation Office and signed verification opinions of various institutions. Issue 5, no. 42. Nanjing: The Second Historical Archives of China.
28. 萨本栋.
29. 吴正之.
30. This means that the Ministry of Education had never prevented a book from being published due to its content.
31. 以任务带学科.

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Report to His Excellency President and Generalissimo Chiang Kai-Shek on the Position and Prospects of Science and Technology in China[1]

Joseph Needham

Chungking
Winter, 1945

Summary of Recommendations

It is recommended:

(1) That the Government should embark on a great investment policy by subsidising the leading Chinese scientific institutions (pure as well as applied) on a scale very much greater than heretofore. These include:
Academia Sinica
The Peiping Academy
The Fukien and other Provincial Academies, if any
National Geological Survey and Provincial Geological and Meteorological Surveys
National Industrial Research Bureau and other research activities of the Ministry of Economics
National Agricultural Research Bureau and other research activities of the Ministry of Agriculture and Forestry
National Institute of Health, National Epidemics Prevention Bureau and other research activities of the National Health Administration

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Army Ordnance Administration research activities
Army Medical Administration research activities
Air Force Research Bureau
The Provincial Science Institutes
The Science Departments of the Universities, including the University of Communications Huanghai Research Institute and similar institutes.

There are special reasons for greatly increasing support given to the:
National Institute of Compilation and Translation

Substantial government grants should also be given to:
Science Society of China
Natural Science Society of China
and all the specialised scientific societies.

This list is in no way exclusive or exhaustive, but only indicative.

(2) That means should be developed for increasing the prestige of Science and Technology in China, perhaps by the foundation of new Orders and Decorations, accompanied by suitable publicity; by stricter registration of qualified men; or other methods as may be found good.
(3) That great efforts be made to encourage political leaders with a real knowledge and understanding of Science and Technology in order to reduce the inhibiting factors which retard the industrialisation and modernisation of the country.
(4) That the Ministry of Education be strengthened on the scientific side.
(5) That since science cannot flourish except in a democratic and liberal atmosphere, steps be taken to ensure variety and freedom of thought and expression in the universities.
(6) That the policy of sending the maximum number possible of scholars, students and foreman-apprentices abroad for study, in the interests of the industrialisation and modernisation of the country, be vigorously proceeded with, and that Western scholars and students be invited to China also.
(7) That careful thought be given to the ways in which China's industrialisation might profitably differ from that which was historically gone through by the Western countries, for example, in the use of non-ferrous metals, plastics, plant products and chemurgic processes.
(8) That special care be taken to ensure sound workers' welfare practice during industrialisation, in so far as the situation permits approximation to Western standards.
(9) That thought be given to the problem of the provision of scientific advisory bodies at all levels of and to the participation of scientific men in the foreign relations of the country.
(10) That China continue her policy of demanding a United Nations Cultural Organisation capable of fulfilling the functions of an international science cooperation service, and that the Chinese scientific movement be strengthened as soon as possible by the arranging of one or more International Scientific Congresses in China.

Your Excellency:

When we met in the summer of 1943, you did me the honour of asking me to prepare for you, before I finally left China on completion of my wartime assignment, a Report on the Position and Prospects of Chinese Science and Technology. This I now submit in the form of a letter.[1] During the intervening period, I have travelled widely through the country, from the borders of Sinkiang in the Northwest to Fukien and Fuchow in the Southeast and the Salween in the Southwest, visiting nearly every university and scientific laboratory in Free China, and a large number of factories and arsenals. At the conclusion of this letter, I shall have a few words to say about the Sino-British Science Cooperation Office, which I organised and which is now continuing in slightly modified form in peacetime.

1. It emanates from me, of course, in my private capacity as a scientist, irrespective of any position I held under the British Government, which naturally has no responsibility for my views. My opinions are also not necessarily identical with those of any other persons who have been or may be concerned with Sino-British cultural interchanges.

I remember that at our interview, you asked me for my criticisms on the shortcomings of Chinese science and technology. These I shall summarise below, but first of all, I want to express my genuinely felt and truly unfeigned admiration for what the main body of Chinese scientists and technologists have accomplished during the war period, under the inspired leadership of such men as Dr Won Wên-Hao and Gen. Yu Ta-Wei. Chinese scientists have kept university training in the sciences going under conditions which would have daunted any European or American scientist; Chinese technologists have created new factories in West China where before there was nothing but wild land or rice fields. I well remember one plant in Szechwan (under the National Resources Commission) for the dry distillation of wood, where the chief engineer told me that the whole thing had been set up by men of no specialised experience, having no blueprints and depending entirely on textbook descriptions. This required initiative and talent for improvisation of a very high order, and my experience is that Chinese engineers are second to none in possessing it. Evidence is available from many sources as to the excellence of Chinese construction works, such as the Hsiang-Kuei Railway Bridges, built by graduates of Tangshan Engineering College, and found very difficult to destroy by those who had to blow them up during the Japanese advance into Kuangsi at the end of 1944.

Again, on the purely scientific side, Ting Wên-Chiang and Li Sse-Kuang have been world-famous. The eminent physicists P.M.S. Blackett and Max Born considered Hu Chien-Shan and H.H. Pêng, respectively, among their most brilliant collaborators; the famous mathematician G.H. Hardy holds Hua Lo-Kêng in similar esteem. The world-renowned physiologists A.V. Hill and R.W. Gerard have likewise a very high opinion of their colleagues Fêng Teh-Pei and Tang Pei-Sung. The industrial chemist Hou Teh-Pang achieved classical improvements on the Solvay process; Tung Ti-Chou and Chuang Hsiao-Hui have done outstanding work in experimental morphology. Wu Hsien produced the now generally accepted theory of protein denaturation 7 years before his colleagues in the West, and Chen Ko-Kuei isolated ephedrine from the traditional drug *ma huang*. Great advances in our knowledge of pneumonic plague came from the work of Wu Nien-Teh, and Li Chen-Pin (with Goodpasture) was the first to cultivate viruses in tissue-culture, a method which is still the only one by which yellow-fever vaccine can be prepared. Lim Boon-Kêng, the father of the eminent Edinburgh and Peiping physiologist Ling Ko-Hsing (Robert Lim) collaborated 50 years ago with W.B. Hardy in pioneer work on the physical chemistry of the proteins. But I need not multiply examples, I could give hundreds of them, and the public statements I have frequently made concerning the high quality of Chinese scientific and technical work have been in no way flattering propaganda but real statements of observed fact.

The Necessity of Increased Government Support for Science

If then, firm foundations for future Chinese science and technology have been laid, as I believe they have, and quantity rather than quality is lacking, what is the most important thing required for building up science in China? It is, in a word, financial support on the part of the government. The proper attitude of government towards science is to realise that science, pure and applied, is the most important single factor in the raising of the standard of life of the people, the 'people's livelihood' of Sun Chung-Shan, up from the mediaeval standards of the present, to the modern standards of the most advanced parts of the world. Government must absolutely avoid the 'miraculous' attitude towards science, in which science is regarded as something magic which can produce miracles. Government officials, having systematically starved scientific institutions of research funds for years, suddenly hear of something new and important, such as synthetic rubber, and immediately order the scientists to produce this within a few months. When they cannot do so, they are considered no good. Not in this way have the powerful modern countries built up their scientific organisations. It was recently estimated that the United Kingdom spends a 10th of 1% of the whole national income on scientific research, the United States about half of 1% and the Soviet Union just under 1%. The point is that these are investments which bring enormous returns. The crowning example of the release of intra-atomic energy over Hiroshima and Nagasaki, which shortened the agony

of China perhaps by several years, and which has such enormous possibilities for peaceful use in the future, should suffice to indicate whether profound investment in science is worthwhile or not.

Moreover, it is most important that no distinction should be made between pure and applied science. The former is the life-blood of the latter. To take the atomic bomb again, nothing would have been possible without the purely academic researches of Becquerel and the Curies in France at the beginning of the present century, and of Rutherford, Cockcroft and Walton at Cambridge in the years after the First World War. The only distinction between pure and applied science is that the latter is likely to have applications for human welfare in the near future, while the former may not do so for perhaps a hundred years. But, as I shall point out later, since there may be in China a tendency on the part of thoughtless people to wish to adopt the technology of the West without the science, 'pure' science should be strongly emphasised henceforward in China.

I recommend, therefore, that the post-war budget of both Academia Sinica and the Peiping Academy of Sciences should be raised to at least one hundred times what it was before the war.[2] If science in China is supported on this scale, there is nothing to prevent her becoming a leading scientific country in 25 years. Such a budget would allow of the encouragement of special sciences, such as biophysics, nuclear physics and experimental medicine, which have in recent years made great strides but are as yet little represented in China. The same very great increases in endowments should be made with respect to the scientific laboratories of the universities, and it should be understood (as it has long been in England) that every science professor and lecturer should carry out individual researches in addition to his teaching as a matter of course.

The Academia Sinica, which follows the pattern of the Soviet Academy of Sciences rather than that of the Royal Society or the National Academy at Washington in having a series of laboratories of its own, is, in my opinion, well-planned. There is no reason, when a country is of continental size, as China is, why there should not be two Academies, and the Peiping Academy's standards are in most cases equally high. The Academia Sinica should be expected to expand – it could take over, for example, if necessary, the excellent Sericultural Institute at Tsunyi and the Geographical Institute at Beipei (hitherto supported by the British Indemnity Board of Trustees). It might well also have some closer connections with the National Institute of Industrial Research, with its 17 departments just as the Royal Society is connected with the British National Chemical and Physical Laboratories. This Institute, too, needs very great financial strengthening.

The same applies to (1) the National Institute of Health (Medical Research) and all research activities of the National Health Administration and (2) the National Institute of Agricultural Research, which is doing excellent work, and to all the research activities of the Ministry of Agriculture and Forestry. Here in particular I should like to mention certain enterprises. The Chinling Mountains Forest Preservation Service, centred in Chouchih-hsien, Shensi, is doing an excellent work of protection, afforestation and education. In many other regions such as Fukien, the great natural wealth of China's forests should be scientifically exploited and not allowed to go to waste. Even more important is the problem of preventing soil erosion, in the loess country, for instance. Daily the great rivers carry away millions of tons of good land to the sea. At Tienshui, Kansu, a Soil Conservation Experiment Station has been set up and it is doing excellent work. This is the kind of institution which should receive a thousand (rather than a hundred) times the financial support which it is actually getting, if China's welfare is, as it must be, the first consideration.

I shall return later to the question of the ordinary universities; here I would like to refer to some other institutions which deserve support on a lavish scale. I have been much impressed by the work of all the sections of the University of Communications, in both its Tangshan and Shanghai sections, which for more than 40 years have been training engineers for China, and every financial support should be given to them. In the field of technological research again, the Huanghai Industrial Research Institute, though not a government organisation, has done and is doing excellent work, and there is no reason why it should

2. I refer, of course, to actual purchasing power, irrespective of monetary denominations.

not be aided by substantial government grants. I would also like to mention as especially needing support the National Institute of Compilation and Translation. This institute has long been responsible for the preparation of glossaries of standard equivalents for the technical terms used by Western scientists and technologists. Such standard technical terms are an absolute necessity for a vigorous development of science in China. But owing to lack of funds, the time taken in their preparation has been rather long, so that in some cases, the terms have already been obsolete by the time the glossary was published – it is therefore essential to increase the budget of this institute also by a very large amount.

I hope I shall not be expected, in this brief account, to mention all the scientific organisations which urgently need greatly increased national support. But one is indeed obvious enough, the National Geological Survey, founded by Dr V.K. Ting, and perhaps China's most internationally well-known scientific body. Although support for it has hitherto been fairly reasonable by ordinary standards, one has only to compare it with the wonderful effort made by the Soviet Union to see that the Chinese Geological Survey has really been starved. The Soviet Union embarked upon a training programme which provided no less than 2000 geologists. Working in hundreds of expeditions, they have scoured the vast expanse of the Soviet Union for new minerals and previously unknown sources of old minerals, with the result that the Union has been enriched a millionfold in wealth. Indeed, it is now able to boast that it contains within its borders economic sources of every element in the Periodic Table. I think it would be a great mistake if confidence were reposed in the sometimes pessimistic estimate of China's mineral wealth. It would be much more reasonable to devote funds to increasing the activities of the present Geological Survey by at least a hundred times, in the firm belief that the investment would be an excellent one.

In sum, therefore, one of the most essential things to be done if China is to take her rightful place in the modern world is to devote at least one half of 1% of the national income to scientific and technological research.

The Necessity for Increasing the Prestige of Chinese Science

One of the greatest essentials in post-war Chinese science is to take some measures for increasing its prestige in the nation. We in England are in this respect fortunately situated, since the Royal Society, the oldest and probably the most famous of all scientific societies in the world, includes in its fellowship nearly all British scientific workers of any considerable achievement, and while conferring upon them a distinction as high as that to be obtained in any other walk of English life, is itself in a position to be consulted if necessary on all important affairs of State in which science plays a part. In my opinion, the prestige of science is not yet high enough in China. A distinguished Chinese engineer remarked to me once that in the United States, technical men had their reward in money, while in the Soviet Union, they had it in prestige, but that in China, there was neither money nor prestige for the technical man. I am aware that there are prizes given by the Ministries of Education and Economic Affairs and that there is a 'People's Livelihood Medal'; but I wonder whether it would not be desirable to institute a new 'order of chivalry', citations to which should be given by the Government itself, say, through the Executive Yuan, to the most outstanding Chinese scientists. Thus, for technologists and engineers, there might be an Order of the Tribute of Yü, for agricultural scientists an Order of Shen Nong, and for scientists in general an Order of the Dream Pool (after the 'Dream Pool Essays' of Shen Kua, probably the greatest scientific book of the Sung Dynasty). Such new orders should be accompanied by considerable publicity and every mark of official approbation for the scientists chosen to receive them. The Chinese Ministry of Information has been rather backward in publicising the work of Chinese scientists, though on occasion it has done so, as in the case of the excellent work at Kuangsi University on natural crop rubbers – this should be remedied in the future and better publicity given by whatever organisation succeeds the Ministry of Information.

These measures should not be confined to pure science alone. It would be quite feasible, and very easy, to institute decorations which could be won by

whole factories (as in the Soviet Union and the United States), and it would be highly desirable to make more use of industrial medals for men of the shop-foreman class on which the running of an efficient industry so greatly depends. Some of the best enterprises I have seen in China, such as the National Epidemic Prevention Bureau's Vaccine Institute in Kunming, obviously have a good esprit de corps and this should be by all means encouraged throughout the industrial world.

Conversely, some more attention might be paid to raising standards generally by setting up registers of men (based no doubt on that begun by the Chinese Medical Association), of qualified engineers and of qualified scientists. Great care should be taken to scrutinise the academic qualifications of those who are appointed to posts such as technical advisory member and so on of the various Ministries.

The Necessity for Finding Political Leaders with an Understanding of the Function and Importance of Science in National Welfare

We come now to the general question of the relations of politics and science in China. If science in China has any shortcomings, it is that it is too readily subject to interference by politicians who, however well-intentioned, have neither knowledge of, nor interest in, science. I wish deeply to express the hope that in the future, as much use as possible will be made of modern-minded men. The ruling group in China today is largely composed, as it has always been, of the scholars, gentry and bankers, whose education is usually based on a fundamentally classical learning. I am not convinced that such men will prove able to direct the industrialisation of China, or even to help anyone else to do so. Their classical education predisposes them to a narrow nationalism. Their representatives among the army generals naturally incline to a mass psychology, which undervalues the use of military mechanisation. They think that perhaps they can use 'western science' as the mythology accompanying a useful set of techniques, without affecting in any way their own way of life or their world-outlook. This is an illusion. Science is bound to transform the Chinese way of life as it is transforming and has already largely transformed the way of life of the West. Indeed, I dislike nothing more than the expression 'western science' sometimes heard, for there is no such thing as Western or Eastern science but only one universal human science, of which the Chinese are the inheritors equally with the West, it being but a historical accident (as I think can be proved) that modern science originated in Western Europe, China herself having previously contributed many fundamental discoveries to world civilisation.

I might mention several psychological reasons for the failure of the scholars, gentry and bankers to appreciate science. Since science has had the effect of greatly raising the standard of life of Western (or modern) countries, the idea arose in China that its main purpose was to contribute to comforts and luxuries, and hence in wartime was a luxury which would have to be done without. To this group of ideas traditional Confucianism contributed, though old-time Confucian austerity was little more than a psychological rationalisation of the poverty of an agricultural pre-industrial civilisation. How shortsighted this was I considered in my mind when I was examining the defences of Hengyang and Kweilin before the Japanese offensive at the end of 1944, and noted that in no case had steel plates been used to strengthen the system of pillboxes and strong points. Yet a steel industry had been built up at great pains and cost in West China. Steel is not a luxury for such purposes as the national defence.

But the psychological failure of many of the officials, gentry and bankers to appreciate science springs from much deeper historical factors. In traditional Chinese economy, the acquisition of wealth was the outcome of high official position in the bureaucracy, and the traditional way of using wealth was to invest it in land or buildings, or to lend it out at interest. The capitalist form of investment in productive industrial enterprises was not practised. This therefore needs all the more encouragement today.

I am not one of those Westerners who pass moral judgements upon the 'corruption' and 'squeeze' so common in Chinese economic life. Westerners who do so are unconsciously affected, in my opinion, by the historical association between capitalism and puritanism in European history. On the contrary, my reading of Chinese history is that this was the way

the system worked through 2000 years of imperial bureaucracy. Since the taxes had to be collected largely in kind, and since the state of communications made it impossible to remit everything to the capital city and later receive sufficient funds to cover local government expenses, the practice necessarily grew up of deducting enough for these purposes before sending the taxes up to the imperial treasury. Hence there developed the custom, universal through all ranks of Chinese society, of everyone sequestrating a certain sum in every financial transaction, and it could only be expected from human nature that everyone should make it as large as was possible without causing unpleasant social consequences. There was really nothing wrong with this system as long as everyone did it and as long as quantitative accounting was unnecessary. But in the modern world, the dollar has to be equated with the therm and the erg. There has to be intercourse with other countries which have fully adopted the quantitative accounting of capitalism or socialism.

Presumably so far as the probity of officials is concerned, there is only one obvious solution. The new system, unlike the old, must pay them in all cases a living wage and then pursue those who still engage in the former practices with all the rigour of the law. This will be a hard transition, but it is absolutely essential for the welfare of China. At any rate, one can see why the old-fashioned minds do not care for science and technology. In designing a radio valve, the electrons cannot be cheated out of their just demands; in constructing roads and bridges, you cannot be content with inferior work, for next summer's rains will find you out. If 10 inches is the minimum safe thickness for the refractory bricks of a steel furnace, it cannot be persuaded to accept 8 – if one tries, it will have its revenge and that quickly. In other words, the world of Nature with which science and industry deal is a world quite different from that world of slow agricultural yields and purely social and personal relations in which Confucianism flourished. It is therefore not surprising that minds of the traditional type should fail to understand the new world.

Moreover, from the standpoint of the man of wealth, who in any society is primarily interested in acquiring more, science is only one of the ways in which profits may be increased and often not the easiest way. Under capitalism, the intensive advertising of an inferior product may be much cheaper than any scientific improvement of its quality, while under contemporary Chinese society, investment in land or the setting up of new banks (very prominent in some Chinese cities during the war) may be easier ways of making money than truly productive industrial enterprises. The government, therefore, should have a programme for the fostering of science and the industrialisation of the country based on a broad recognition of the human needs of the people and the safety of the nation, and it should be prepared to exert some pressure on the wealth-owning groups to induce them to participate in the programme.

This is not the place for an analysis of the causes for the terrible decay of heavy industry in Free China during the later stages of the war (even if I were capable of making it) – doubtless, it was due to the monetary inflation and could not have been avoided. But there can be no doubt that it was very bad for the morale of the Chinese technologists who had given all possible skill and hard work towards building up industry in the western provinces, only to see it wither in the bud to 30% of its production capacity or less. What is much more worrying is the fear that the recovery of all industry throughout China will be delayed or indefinitely postponed unless modern-minded, industrially minded, men are placed in control. And moreover, unless this is done, the large industrial accessions which the circumstances of the ending of the war have mercifully brought intact into Chinese hands will not be properly exploited.

The exact economic structure which China ought to aim at is of course a very great problem which is rather outside the scope of this report. I often question, however, whether it is necessary for China to retrace all the steps in the weary road of the development of capitalism in Western Europe. The proposals of Sun Chung-Shan that heavy industry, mining, power production and all communications should be owned and operated by the State, while light industry should be left for individual enterprise, seem to be an excellent compromise. Under the new Labour Government in England, we are coming to a somewhat similar compromise ourselves.

If China is suffering, as I suggest, from a traditionalistic psychology on the part of many

politicians and officials who do not appreciate or understand the sciences and industry, this is not a phenomenon peculiar to China. Even in Western Europe and in England, we also have long suffered from a ruling class trained wholly in classical learning and out of touch with the changes which science was bringing to the people's livelihood. The problem is no doubt graver in China, since capitalism is a much more recent growth, and the former system of bureaucratic feudalism so old and deep-rooted.

During the war, I have noticed a number of instances which indicated a failure of the government to appreciate the needs of technology. There were many things which could probably not have been avoided. Thus, the planning for the production of motor fuel substitutes, involving the operation of a number of low temperature coal and lignite carbonisation plants, was as a whole excellent, and if we had not one single high temperature carbonisation plant in the country, this was doubtless due to a loss of the equipment at Hanoi and Rangoon successively. Yet the case of the Academia Sinica's small hard-glass plant was one which showed lack of appreciation of the needs of science and technology even engaged purely on war work. This plant was the only one in China which could make Pyrex and Jena glass, a substance absolutely essential in chemical analysis; from Shanghai, it was evacuated to Kunming and then after being bombed, to the country near Anning. But it still worked. It did not close down until forced to do so for financial reasons in the winter of 1943–1944. Yet this was a key industry, very small, but essential for the functioning of the sciences both pure and applied.

I cannot feel that there are, in the most important ministries concerned with Science and Technology, enough technically trained men; or else, for some reason, they have much less influence than their bureaucratic colleagues. For example, the Lunghai Railway locomotive repair shops at Baochi have done a wonderful job in keeping the railway running during 5 years of isolation; fighting the water which eats away the staybolts, the sulphur-containing coal which eats away the fire-boxes, and the vegetable oil which deposits large lumps of carbon in the cylinders. They have been lacking in all normal supplies. For making their Babbitt metal, they have been forced to buy old kettles from the town and melt them down in order to obtain the necessary tin. But how is it that this can happen in China, one of the greatest tin-producing countries in the world? I have seen thousands of ingots in Yunnan and Kuangsi, only one of which would have sufficed for the needs of the repair shops in Shensi. Yet in spite of repeated applications to the Ministry, no tin was ever forthcoming.

A comment which is made by every technical expert who visits China is that all Chinese organisations are overstaffed with bureaucratic personnel, unskilled labourers, business staff and the like. River steamers carry crews much larger than necessary. Universities and hospitals are burdened with needless officials. Thus, the National Central Medical School in Chêngtu has 300 employees, but only 80 of these are scientific and technical (30 professors and 50 assistants of excellent quality); the balance is made up by secretarial staff. Thus in the attached Hospital, the Cashier has 4 assistants, the Treasurer 5 and the Secretary 6. This may be a method of disguised unemployment benefit for refugees and others. Or it may be considered a relic of the family system. While it will doubtless disappear as the processes of industrialisation and opening up of new natural resources go on, it imposes at present a severe strain on scientific institutions which need every dollar for equipment and apparatus. Measures ought to be taken to shield scientific and technical organisations from this burden.

Numerous are the ways in which a backward-looking and timid political mentality injures the growth of science in China. In the first place, there is the question of mass education and mass enthusiasm. Party politicians seem unduly nervous of mass education, yet I remember an old and eminent American engineer, who had had close personal experience of the Russian Revolution, telling me that one of the outstanding features of the Soviet industrialisation process had been the enthusiasm of the mass of the people for it. Of anything similar he saw now little trace in China. The mass education movement indeed gives the impression of a force which has burnt itself out. In my travels, having occasion sometimes to stay a few nights in some small town, I have examined the Popular Education Hall in some old temple, with racks for newspapers, but no newspapers on them, a

library but no books in it and so on. It does not seem that the Ministry of Education's wartime adult education programme has been very successful either. Young teachers have not been able to inspire old farmers, and funds have been lacking. I suggest, therefore, that mass education in science and technology, with a view to interesting the people in the industrialisation programme, should receive much more government attention than hitherto, and that any political hesitations should be overruled.

Within the universities also, there are undesirable political interferences with science. The government should take a lenient view of the case if the social opinions of some good scientists should be found to be unorthodox. This is our practice in England, and I think China can much less well afford to throw away a good scientist than England can. Dismissal of scientific professors for causes nothing to do with science is a suicidal policy for any government which wishes to encourage science in China.[3] The same applies, of course, to students. Indeed, it must be said that there is a direct connection between science and democratic freedom of thought. This is seen throughout the history of science and nowhere better than throughout the course of the Second World War. The Nazis and Fascists started the war with a much more highly developed application of science to warfare than the Democracies; they had perfected the use of tanks and bombers, and had introduced such devices as the magnetic mine. But the more the war went on, the more they were overhauled and finally passed by the scientists of the Democracies. It was not the Axis powers which developed radiolocation (radar), penicillin, shaped plastic explosives, the Norden bombsight, the Leigh light, the Bailey bridge, the proximity fuse, but the use of magnesium in airplane alloys, and finally, crowning instance, the intra-atomic energy bomb. It has, in fact, recently been revealed in the testimony before the Senate Committee (United States) on Science Legislation, that the Germans abandoned all basic scientific research between 1940 and 1942 because they thought they were winning easily without it. From this terrible mistake, they never recovered, in spite of considerable developments in submarine technology and in the indecisive field of rocket weapons. The Chinese government will be well-advised to prepare henceforward for a considerable measure of freedom of thought in the Chinese universities, for only in such an atmosphere can science and technology flourish. Minor causes of damage to science from political quarters may be seen in the 'capture' of certain specific scientific posts by specific political groups. A man may thereupon be introduced to such a post, not because his scientific training qualifies him for it but because that particular group had been responsible for financing his study abroad. Or for reasons which are quite non-scientific, a new institute may be created, though the funds available are quite insufficient either for staffing or equipping it. This leads to the vice of 'sign-boardism'; gates with important-looking inscriptions on them and very little within; institutes existing mainly on paper.

One of the most extraordinary bureaucratic capers which I have come across is the practice, which I understand is fairly widespread in the smaller organisations, of packing up the entire equipment of a laboratory into crates when a change of directors is taking place so that the incoming official will not be able, without great difficulty, to take note of any losses, breakages or deviations from the inventory. Such a procedure, with its consequent interruption of scientific work, would be unthinkable in any modern country.

Finally, I might refer to the intrusion of misplaced national feeling into sciences such as pharmacology. The facts are that modern medicine is a system based on modern science, and that the traditional Chinese medicine (like all traditional empirical arts) is very inferior to it, and very unreliable. Nevertheless, there are undoubtedly some valuable things in traditional Chinese medicine which have not yet received scientific explanations. Probably 1 in 20 of the drugs in the Pên Tsao have true pharmacological activity, and 1 in 40 ought to have a place in the world pharmacopoeia. But a misguided nationalism seen in some Chinese officials desires us to believe that the traditional system is overall better than modern medicine

3. There have even been cases in China (and one quite recently near Chungking) where high-ranking scholars have been arrested and held incommunicado for long periods by the police on quite inadequate grounds; doubtless without the knowledge or approval of the highest organs of government. Such 'disappearing professors' produce the most lamentable impression abroad. One must remember that policemen are proverbially stupid, and the less they have to justify their actions to the public in open courts of law, the more stupid in carrying out their instructions they are likely to be.

and employs scientists to prove that the traditional drugs are efficacious. If they do not, so much the worse for them.

It must also be said that a contemptuous attitude towards science is found in the army as well as among politicians. I have no difficulty in finding instances. The Kweichow Science Institute at Kweiyang was wrecked not by the Japanese but by the quartering of Chinese troops in it. The Shensi Provincial Industrial Chemical Laboratory was forced to vacate its well-planned and equipped building to accommodate American troops and interpreters, but when they recently left, Chinese troops took it over, although the war had ended, and all protestations through the Provincial Government and its Bureau of Reconstruction were of no avail. Similarly, also in Sian, the First Branch of the Army Medical College was forced to accept buildings of an extremely poor and mean description, and there in the small room serving as a Physics Laboratory, I saw how the professor had to have a hand-turned dynamo supplying current, while the bacteriologists were unable to use their centrifuge and incubator, although every petty merchant's store and teashop in the city had electric light. This is not the way to make China a great nation.

From this criticism of a military attitude often seen, I exempt the Chinese Air Force. I have been deeply impressed by the Experiment Station of their Research Bureau at Chêngtu. I consider that it did magnificent work throughout the war.

There is a further consideration of great importance on the borderline of political life and science. Many of the most important benefits which applied science can confer on the Chinese people can only come as the result of a strong and sustained government policy operated over a considerable period of time. I have in mind the whole soil conservation programme, for instance, to which so much has been contributed by Dr W.C. Lowdermilk; the staunching of that continual drain of China's soils down the great rivers which gives its name to the Yellow Sea. Great works of afforestation, such as have been conducted by others in Manchuria[2] and Korea, and great works of water-catchment and irrigation, such as could be made at the foot of the Nan Shan, require for success a political stability, one of the contributory causes of which would be a true appreciation of the worth of these works themselves. There are many other such plans on foot. There is the question of strengthening the dairy husbandry of China. Nutritionists are agreed as to the value of the addition of milk and milk products to the Chinese diet, and agriculturists know how vast the areas are in Kansu, Chinghai Sikang and Kweichow which would be suitable for this kind of farming – but everything depends on stable conditions in which planned development may proceed. So also with the great possibilities of S. Shansi and S. Kansu as fruit growing and canning areas.

A Special Ministry for Science and Technology

What has just been said about the necessity of political stability for planned development leads to the question of whether there could not be a special Ministry set up to take care of all governmentally organised research.

What I have in mind is the following. In the United Kingdom, the principal research organisations of the government are independent of their corresponding ministries. Thus, the Medical Research Council is not a part of the Ministry of Health; the Agricultural Research Council is not a part of the Ministry of Agriculture and Fisheries; and the Department of Scientific and Industrial Research has nothing to do with any Ministry. They all have the status of sub-committees of the Privy Council, a body with a long history which was originally the meeting of the King's counsellors, and they are responsible to Parliament not through any ordinary cabinet minister but through the Lord President of the Council. This system has the very great advantage that long-term research projects are not subject to political interference which might result from short-term political changes. While in the United States, the government research organisations have to a large extent been safeguarded from the 'spoils system', the British plan renders their continuity more effectual still.

One wonders whether the planning of science in China could derive any help from this. Suppose that a special ministry or commission for scientific and technological development were to be set up. Under

it would come the National Agricultural Research Bureau and all provincial agricultural research activities, the National Bureau of Industrial Research and all similar work, the National Geological Survey, the National Institute of Medical Research, the National Institute of Compilation and Translation, and so on. It would have to work in very close connection with the universities through the Ministry of Education, and with the two National Academies. In order to ensure its isolation from ever-changing politics, it might conceivably stem, not like all other ministries and commissions from the Executive Yuan, but from one of the other four Yuan. I hesitate very much to make any concrete suggestion here, but the Examination Yuan must have had historically a close connection with learning and scholarship, so that the requisite conditions might be forthcoming from an association with that. This suggestion may, of course, be impracticable.

In any case, the main point is that some machinery might well be considered which would amount to a 'Ministry of Scientific and Technological Development', so arranged as to be independent of all fundamentally executive departments, and therefore able to carry out long-term research without danger of political interruptions.

The Ministry of Education and the Overseas Study Programme

The next subject on which I wish to touch is the Ministry of Education. Such an organisation may be a necessity in China, but I think the feeling on the part of most of the British scholars who have visited China in recent years has been one of thankfulness that no such organisation is necessary in England. Even without in any way wishing to do so, such an organisation can hardly but exert a blighting influence on the variety and freedom of thought in the universities. However, the only specific criticism which I have of the Ministry is that it does not seem to have a sufficient staff of first-rate scientists who understand the needs of science in the universities. I would recommend that some attention should be given to this point as part of the general programme for the furtherance of science in China during the reconstruction periods. For example, those who are not themselves scientists cannot appreciate the needs of university laboratories for equipment. Even in the best universities such as the National Southwest Associated University, this has been in recent years very poor, and in the more remote ones, such as the National Northwest University or the National Kweichow University, almost non-existent.

I understand that the Ministry also exercises a censorship function on scholarly works produced by university professors. During the war, this may have been desirable as a safeguard against the publication of second-class work, but I consider that it is much to be deprecated in normal times. It is, in my opinion, much better to let university professors publish quite freely. Afterwards, through the medium of the book-reviews in the scholarly and scientific journals, justice is done upon scholars by their peers, and every work, whether good or bad, finds its own level. Government censorship, even in the interests of learning, is open to grave abuses and should be discontinued.

The question of the relations between the Ministry, the National Universities and the Private ('Christian' or 'missionary') Universities hardly comes into the field of this Report. If I were to say anything on this subject, it would be that while I have no particular interest in the specifically religious side of these private foundations, I must state that some of them, particularly Yenching University, Fukien United University and formerly Lingnan University, were (and doubtless again will be) of a distinctly high level scientifically and that West China Union University has done a great deal for medical science in West China. From the scientific point of view, therefore, they should not be neglected or ignored by the government. On the general principle of state versus private universities, I am of opinion that it is very desirable to have a certain number of private universities, just as is the case in the United States, where California has both the State University of Berkeley and the Private University of Stanford. This acts as a safeguard against undue political interference which might occasionally occur and tends towards greater variety and freedom of thinking. Fortunately, in England, our universities (anciently religious foundations) are neither 'private' nor 'state'. While the Government exercises no

day-to-day control over their activities, such as a Ministry of Education would, it furnishes them with large funds annually, administered through a special Government Grant Committee. The real control occurs only every 20 years or so, when a Royal Commission on University Education is formed, and proceeds to visit each university in turn, taking evidence on all relevant subjects. Finally, it promulgates its findings, and its decisions subsequently have to be adhered to. It would be a matter for thought whether in China also some such system of more remote control might not be advantageously substituted for day-to-day control, since it permits of longer periods in which the running of this or that piece of machinery or policy can be studied.

It may be said that in England, we do have a Board of Education and that its name has recently been changed to Ministry. This is true, but one must remember that the main function of the British Education Board is that of supervising and inspecting schools, not universities; lower education, not higher. It preserves standards by approving textbooks and teachers. But it does not even have the right of election and dismissal; this is held by the decentralised Education Committees of every town and county, and they may emphasise any political complexion so long as the academic standing of the teachers is up to the Board's requirement. Still less does the Board (and therefore the government) have any voice in the appointment of university professors; this is accomplished by Boards of Electors set up by the University in question and constituted largely of the leading scholars of the subject in question, many of whom may be professors of the same subject in other universities. In general, a university is self-governed by a Senate elected from among the whole teaching faculty, and this in effect appoints a President. The Board of Education is not concerned.

I think it would be very worthwhile for a small group of Chinese educationalists to go to England specifically to study our democratic university system, the details of which are rather complex, and it would then be well worth considering carefully what steps could be taken in China towards the freeing of the Chinese universities from bureaucratic dead weight. Such a mission would, I am sure, be most warmly welcomed, and I would do my best to give it all the aid in my power.

Before passing on to the question of foreign study for advanced and post-graduate students, I would say a word on the question of the health of boys and girls at school and of students in the universities. This is, of course, only one aspect of the general level of health in the country. According to my experience, it is extremely low. Preventable diseases such as trachoma, scabies, and various affections of the skin and scalp are almost universal. Tuberculosis takes a very heavy toll of university students, while the army is riddled with nutritional oedema and dysentery. Elephantiasis and every kind of parasitic infestation are found. On such a basis, how is it possible to obtain good education and good scholars? In spite of all that the National Health Administration has been able to do through the war years, the fringe of the problem is hardly yet touched. And all this is at a time when even such dreaded diseases as bubonic plague and cerebro-spinal meningitis, to say nothing of septicaemia, cholera and typhoid, have been completely conquered by the sulpha-drugs and the newer antibiotics prepared from moulds, such as penicillin. It should therefore be one of the first concerns of the Chinese Government to set up large-scale factories in the best-industrialised areas for making sulpha-drugs and antibiotics on a scale commensurate with the vast needs of China's great country. These medical aids should then be distributed to the people through an improved network of government health stations, of which there should be at least one in every hsien city. A Ministry of Education may well meditate upon the untold losses of potential talent through disease in childhood and adolescence.

With the policy of the Ministries of Communications and Economic Affairs of sending large numbers of students abroad for periods of study, I am, of course, in the most cordial agreement. The numbers of these should be counted in thousands rather than hundreds, up to the highest limits which the Western countries can be persuaded to take. The outgoing personnel is, of course, and should continue to be, of many kinds, for example, professors revisiting the West for refresher periods of research, young research workers going to complete their research experience and gain the PhD degree, young

technologists going to obtain works practice, and last but not least, the very important group of superior foreman types. This last group deserves particular attention, for China is even more deficient in shop foremen than in trained engineers. Here the language difficulty is acute, for such men can hardly be expected to have had sufficient education in foreign languages. Provision should therefore rather be made for intensive training of such men within China by specially invited foreign technical training experts, who can lecture and demonstrate through the medium of interpreters.

Returning to the higher academic groups, it will, in general, be better to send young scientists to be the pupils of great men individually, rather than to cultivate special sciences in the abstract. The great scientific traditions of the West have generally been handed down personally from one generation to another, and the results have usually been best in my experience, where Chinese scientists have been the inheritors of specific personal traditions such as those of Rutherford in physics, Conrady in optics, Spemann in embryology or Morgan in genetics. From time to time also, some of the most eminent Western scientists should be invited to spend a period of work in China.

I suppose it is understood that after the war, there will be a big drive to improve the foreign language, especially English, teaching in the Chinese schools. I understand that before the war, the standard of this teaching was much higher than it was when I had the opportunity to observe it. It cannot be too much emphasised that the industrialisation and modernisation of China depends upon that manifold intercourse with the rest of the world which only a thorough knowledge of at least one other language besides Chinese can give. The part which the simplified 'Basic English' can play here as an international language is not quite clear, but deserves attention, and I should also like to refer to another, more recently proposed, international language, 'Interglossa', which is composed entirely of Greek and Latin roots (so well and widely known as the basis of all scientific technical terms) and Chinese grammar. In this connection, I consider that an urgent need for the Chinese student is a handy glossary of the most important Greek and Latin roots with their equivalents in Chinese. This would reduce the strain on the memory. One can see from typescripts made by Chinese that they usually have no idea of the origin of technical terms derived from Greek and Latin because they do not know where to insert the hyphen when dividing a word at the end of a line.

I think I need hardly say that the plan, believed to be entertained by some politicians, of despatching to each Western country an official explicitly or implicitly charged with watching over the political ideas of the students sent to that country will not prove acceptable to those Western countries whose assistance is desired. A university dean once said to me 'The Government does not want to train good scientists able to think for themselves, nor even good technologists; it only wants party followers with a technical smattering'. I am sure he was being much too pessimistic. In politics, it is just as it is in theology. I remember years ago arguments in England as to whether theological colleges should be located within the great free-thinking universities or not. The best conclusion was that the man who has carefully considered all the other possible systems of theological or political belief, and still adheres to his own, is the only ultimately reliable supporter of that system. If the great party of Sun Chung-Shan wants keen and faithful supporters, it will not get them by the methods of fear, but only by free enquiry and rational conviction.

It is to be hoped that China will not have to bear alone the whole financial burden of the training of the thousands of scientists and technologists which she needs. I am glad that during the past 2 or 3 years, the British Council has invited about five professors and 40 students annually, and that besides these fellowships, there have been others given by the Federation of British Industries and ad hoc bodies such as the group of British pharmaceutical firms which recently gave eight special travelling fellowships. No suspicion of 'educational imperialism' now attaches to such help. If formerly it was thought that Ruritania-trained students would, on returning to China, insist on using only Ruritanian products, the situation now is very different when it is agreed on all hands that China must instal, and be assisted to instal at the earliest possible moment, all the equipment necessary for making the products of modern civilisation herself.

The American State Department and other institutions such as the Rockefeller Foundation are

participating in the training programme on a large scale. Now that the Sino-Soviet Treaty has been approved, it is much to be hoped that many scientists and engineers will be sent, and will be invited, to the Soviet Union, which in the vast extent and grandeur of its industrialisation has much to offer which cannot be obtained from either the United Kingdom or the United States. In view of the long common frontier with the Soviet Union, and the complementary nature of Soviet and Chinese economies, there should be a complete reversal of the suppressive policy towards Russian language teaching which has prevailed in recent years,[4] and a big effort should be made to encourage it. One might also suggest that more use should be made of the Dominions in the British Commonwealth. There are great experiments on drought and forest areas, and in mining, in Canada, while in Australia an exceptionally striking participation of science in all phases of the national life has been necessitated by the special difficulties of agriculture in that country. India also has much help to give to China, and from my personal acquaintance with Indian scientists, I know how willing they will be to give it.

The whole question of sending men abroad to bring back knowledge and experience for the modernisation of China involves consequences almost philosophical which require mention. A rather common conception is that embodied in the following quotation from a speech made by an eminent Chinese politician:

> The civilisations of China and the West are different in their origins and different in their achievements. In no sense is Chinese civilisation generally inferior to that of the West; it merely happens that at the present moment we are deficient in natural science and the making of machinery; that is to say in material culture; it is in this respect alone that others are ahead of us, and consequently it is upon these matters that the emphasis should be laid when determining the object of sending students abroad. We have to repair our own deficiencies by acquiring the strong points of others. As regards spiritual culture, what we possess is already far superior to that of other people, and there can be no question of our going to study theirs, nor must we bring theirs back here and try to apply it in China. In so far as we learn from them on the non-material side, we must confine ourselves to those methods of scientific control which lead to the development and progress of industry, in order to be guided by them ourselves. These are the major premises that we must have in mind.

I find myself in complete disagreement with this conception. It assumes, as I said above, that science can be accepted by China, not as the supreme transformer of man's whole world-outlook, but as the mythology accompanying a useful set of techniques. This idea is untenable. Moreover, modern science cannot be fully understood without understanding the social setting of European civilisation in which it took its rise. It necessitates, therefore, some understanding of Greek philosophy and Roman law. To fail to see this is to make just as big a mistake as the Westerners who firmly believe that China's purely agricultural civilisation was a product of the people rather than the environment, and that the Chinese never made, indeed were incapable of making, any contributions to the history of human discovery and invention. How absurd this is, the facts of the discovery of gunpowder, printing and the compass may show. These three discoveries were most appealed to at the time of the Renaissance in support of the developing idea of Progress, of the view that the Moderns were better than the Ancients. Yet these three discoveries were all Chinese, not European. Conversely, the idea that Confucian social philosophy is a full and sufficient doctrine for China, having little relevance outside her borders, is also an illusion. Confucian social philosophy, introduced to Europe through the Latin translations of the 17th-century Jesuits, deeply affected European social thought, especially by its Pelagian belief in fundamental human goodness and by its Mencian statement of the people's right to rebel against tyrants. Incorporated in the social philosophy of the Encyclopaedist and Enlightenment periods, it paved the way for the French Revolution, and hence became one of the foundation stones of that body of

4. I knew personally of a case in which a young scientist associated with one of the best Chinese universities was imprisoned because he had a Russian dictionary sent to him through the post. Although ultimately released, he did not get his dictionary back, nor could the police be made to apologise.

progressive and democratic social thought which the Axis in our time wished to destroy but could not.

The fact is that despite all narrow nationalisms, mankind forms one family. Euro-American social philosophy (for is there not a direct line of descent from Aristotle to Jefferson and from Anaxagoras to Paine?) can be no monopoly of the Euro-American peoples, and Chinese social philosophy is no preserve of the Chinese. All peoples of the earth have the right to participate in the whole human heritage. Hence, as I think, the Chinese Government would do well to encourage the more socially relevant forms of Sinology in the West, when opportunity arises, in order that knowledge of Chinese achievements in the history of thought may be more widespread. And far from trying to use modern science as a tool without regard for the social setting in which it grew up, the Government should encourage Chinese students to acquaint themselves as fully as they can with the whole history of thought in the West.

Scientific Societies and Other Organisations

I have now spoken both of the great research institutions and of the universities; it remains to say something about other organisations which are quite important for the growth of the sciences and technology in China. I do not feel that the specific Scientific Societies have so far been sufficiently supported and encouraged. Yet in the West, they have been powerful instruments in the development of science. In China, they have already reached high standards and have published journals of high quality, such as the *Chinese Journal of Physiology*, edited by Gen. Robert Lim. During the war, the quality of publications such as *Sinensia* (the *Journal of Zoology* edited by Academia Sinica), *Science Record*, the *Journal of the Chinese Chemical Society* and the *Meteorological Magazine*, has been remarkable having regard to the difficult conditions of their preparation.

These societies urgently need accommodation for central offices, meeting rooms and libraries, such as the British Chemical Society has in London, and a government wishing to encourage science would pay attention to the question of assistance in providing them. Government grants of funds to help them in the reconstruction period would be highly desirable.

It is most important that the regular publications of these societies (as also of the universities) should be sent abroad systematically. In the past, there has been too great a modesty on the part of Chinese scientists in this matter. Even when the journal is published wholly in Chinese, the presence of Chinese students in the West affords plenty of opportunities for having any articles of special importance translated into Western languages. However, it is greatly to be hoped that the practice of publishing a journal entirely in Chinese will cease as soon as possible. A scientific or learned journal ought at the very least to have a translation of its title, and the tabulated list of contents, on the front page. If possible, each contribution should also have a summary in one or other of the Western languages. During the war, the omission of all translations of titles has been excused on the ground that there were not enough printers in Free China who could set alphabetical type – in peacetime there will be no excuse. To publish in a language which the main body of the scientific world cannot understand is a contradiction in terms and the very stultification of nationalism. At the same time, I am in favour of the wider use of Chinese as one of the great world languages, as was done in the versions of the United Nations Charter, and consider that steps should be taken to have Chinese abstracts prepared and published by international scientific organisations and congresses. The statement of this view will suffice to indicate that I see nothing wrong with the Chinese language as a logical instrument for the presentation of scientific statements (always providing that the necessary support is given, as advocated above, to the National Institute for Compilation and Translation).

Besides the societies so far mentioned, there are some, such as the Science Society of China and the Chinese Natural Science Society, which have interested themselves in spreading the knowledge of science along broader popular lines, and these should be very greatly encouraged, by substantial government grants or otherwise. Like the famous British Association for the Advancement of Science, they have played, and should increasingly play, a most important part in the development of science.

Here we have touched on scientific and technical popular education, as I did further back in connection with the mass movement for industrialisation. I have been very pleased with the general idea behind the several Provincial Science Institutes. These institutes forward popular education by wall newspapers and by the preparation of museums and exhibitions, and they embody workshops where scientific apparatus is made for schools and colleges. The Kansu one at Lanchow seemed to hold the greatest potentialities, the Kuangsi one at Kweilin made the best apparatus and the Kweichow one at Kweiyang had (until its destruction by quartering of Chinese troops at the end of 1944) the best and most instructive exhibitions. Unfortunately, I failed to see the Fukien one at Shahsien. I recommend that every effort should be made to assure the expanded functioning of these institutes, of which there should be at least one in every province.

This brings up the question of provincial activities in science generally. I was deeply impressed by the progress made in Fukien province, where, under the earlier guidance of Gov. Chen Yi, a special Provincial Academy of Sciences had been set up. Although at the time of my visit it had been starved of funds, and was only just managing to get along, the idea was quite sound, and this was apparently the only province which had made such an initiative. Naturally, what I said above concerning the enhanced support which Academia Sinica and the Peiping Academy ought to receive, is also applicable to this and to any other Provincial Academies which may be founded. I was also impressed in Fukien by the excellence of the Provincial Meteorological Service (the best I have seen in China), the Provincial Geological and Soils Survey, and the Provincial Pinewood Root Oil Motor Fuel Cracking Factories (a most outstanding achievement of wartime improvisation).

Other provincial activities which especially impressed me were the Bureau of Reconstruction of Kansu province; the Bureau of Education of Szechuan province, with its excellent scientific apparatus factory at Supochiao near Chêngtu; and the provincial Agricultural Experiment Station of Kuangsi at Shatang near Liuchow.

Lastly, I wish to say a few words about a matter which could naturally not have a high priority during the long years of war, but to which serious attention should now be given. I refer to the preservation of ancient monuments. No country in the world has a more magnificent inheritance of evidences of antiquity than China, yet little or no interest is taken in them. When I visited Tunhuang's famous painted cave-temples at Chienfotung in 1943, I found that nothing was being done to preserve them; Tang tiles were scattered everywhere and used for improper purposes, the painted plaster was falling down in large pieces and not being collected in the museum, and anyone who came was allowed to roam at will while the policemen made a meagre living by taking rubbings of inscribed stones for sale. I reported to Minister Chen Li-Fu accordingly, but the last news I had was that even the temple which his Ministry maintained there as a 'research institute' had been closed. Other famous sites such as Yunkang are believed to be no better off.

But it is not only famous sites about which I feel concerned. Every hsien city of this great country has a Confucian temple which enshrines the greatest of Chinese intellectual traditions. I remember particularly the beauty of those at Chienkang in Yunnan and Yungchang in Kansu. But everywhere, they are decaying and mouldering. At Sian itself, the Tang capital of Changan, the Confucian temple has been wrecked by the quartering of soldiers, and the terraces of the central shrine of the sage itself, with all its beautiful carving, are today polluted with ordure. This is a disgrace to the nation.

The remedy is not difficult. Let a National Commission for the Preservation of Ancient Monuments be established as soon as possible, in close connection with Academia Sinica. Let it be staffed with archaeologists and scholars, not politicians, and provided with both adequate funds and publicity. Within a few years, excellent results will accrue. One should not forget that under quiet conditions, China could work up an important tourist traffic. Why should travellers visit the pyramids or temples of Egypt when they could visit the Nestorian Stone at Sian or the carved Buddhas of Yunkang?

Similarly, liberal financial support should be given to the National Museum, now still languishing in its evacuation retreat at Lichuang. No one would dispute the justice of the view that the Tunhuang

manuscripts, bought by Sir Aurel Stein long ago when the Hanlin Academy was dead and Academia Sinica not yet born, should ultimately be returned from the British Museum to Chinese keeping. But Western scholars will be more ready to agree to such a transfer when the Chinese Government shows by its actions a genuine and sincere regard for the welfare of its own great monuments of antiquity.

Moreover, if the as yet undiscovered antiquities of China are not to remain for ever hidden, if Chinese archaeologists are to take the place they deserve among the archaeologists of the world, Academia Sinica must as soon as possible be furnished with sufficient funds and facilities to undertake again extensive excavations. The Anyang investigations deeply affected our knowledge of world history. But why has no systematic investigation of the prehistoric sites in Kansu been made, or of the Han city of Changan, or of the Chou tombs near Hsienyang and the Sui tombs near Wugung? The importance of Chinese archaeology for world history is so great that the Chinese archaeologists ought to receive the fullest support of their government. Moreover, all those who have served as Chinese Ambassadors in Western countries will bear me out regarding the prestige which China gains from her art and archaeology.

Industrial Organisations and Industrial Welfare

In the industrial field, my experience of the factories under the National Resources Commission and the arsenals under the Army Ordnance Administration has been uniformly excellent. Often have I been amazed at the continued effort which has been devoted to constructing and operating a highly complicated plant in some remote part of the country, a task frequently rendered more difficult than ever by the necessity of conducting so much of the work in underground air-raid protection tunnels. I found that one could always depend upon finding good organisation in such factories and arsenals, and as high a level of technique as the situation permitted. The fine work of the Kansu Petroleum Administration also deserves a special mention.

I was deeply gratified to find that in your book *China's Destiny*, you expressed yourself as determined to put into practice as soon as possible the bold plans of Sun Chung-Shan for the improvement of communications, especially railways. It may be a commonplace observation, but I have been deeply impressed by the difference which even one railway makes to the atmosphere of an entire province – one may compare Hunan and Kuangsi, for instance, with Szechuan and Kweichow. It is obviously imperative that all the Western provinces be linked up in the general railway system at the earliest possible moment. This means completing the Kunming-Kweiyang-Chungking-Chêngtu line and constructing a line from Chêngtu by Kuangyuen to Lanchow, linking with the Lunghai Railway at Tienshui just as the former line will link with the Chienkuei Railway at Kweiyang. I am looking forward very much to returning to China 20 years from now and travelling all over west China by rail. If the Lashio-Yunnanyi-Kunming railway is completed, as I trust it will be, it will be possible to travel from India or at least from Burma to Peiping by rail. No doubt the through-passenger function of these railways will, in the coming days of air travel, be restricted enough, but the important point is that until rail communications cover west China, the operation of the factories and the exploitation of the economic minerals in these provinces cannot be profitably carried on.

It ought to be possible to utilise the water-power of the western rivers, such as the Mekong and the Salween, and it would be desirable to erect beside the power stations plants of considerable size for atmospheric nitrogen fixation, so that fertiliser would be available for the fields of the Szechuan basin and further north from a source much nearer than the coast. I think all opinions agree as to the necessity of abundant fertilisers for Chinese agriculture, which, by raising the productivity per man power, will release a portion of the population for industry, and hence for payment for imports.

The savage scheme for the damming of the Yangtze in the gorges has fired the imagination of the technical world, and it is greatly to be hoped that means may be found for financing this enterprise which would give China the largest electric power plant yet built, provided that other more evenly spread items of industrialisation were not starved of capital thereby.

It is a great question how far Chinese industrialisation need follow the characteristic Western patterns based primarily on the iron and steel industries. Historically, English stocks of coal and iron were very large relative to the size of our island and its population, and later the stocks of coal, iron and oil available in the United States were found to be enormous. But though China has iron and coal of inferior quality scattered in relatively small amounts in every province, her only really large coal deposits are the as yet unworked ones in Shansi. Nearly four-fifths of China's potential coal resources are in Shansi adjacent to parts of Honan and Shensi. The Shansi coal field is one of the greatest in the world and contains both anthracite and bituminous coal of good quality. The Manchurian supplies (principally round Fushun) are much more developed, owing to historical circumstances, but are relatively small. The iron ore of Manchuria, on the other hand, is abundant, though not of very good quality and the adjacent part of Inner Mongolia (Chahan) has also extensive supplies. Nevertheless, in relation to the total area and population of the sub-continent, the supplies are probably less than those of Europe and the New World.

This position, however, is not nearly so serious today as it might have been 50 years ago. At the present time, aluminium and magnesium have become almost as important as iron and steel, owing to the rising dominance of air transport, and for a great variety of uses, plastics (some of which have tensile strength equivalent to that of steel) may advantageously be substituted for the ferrous metals. Recent researches show that China has large reserves of aluminium (bauxite) in Yunnan and Kweichow, and Manchuria has been the world's third greatest magnesium producer. Plastics, again, may be manufactured from all kinds of agricultural products and even waste, and are therefore particularly suitable for potentially vast Chinese industries.

In this connection, great care should be taken to utilise to the full the natural products of the country, and here mention may be made of the work done during the war by the Chinese Air Force Research Bureau Experiment Station, which, making use of the extraordinarily high tensile strength of bamboo, has built powered airplanes of bamboo to 80% by weight and gliders to 95% by weight. While methods of this kind would probably not suffice to produce large freight transport or passenger planes, they might well produce large numbers of small passenger planes or seaplanes suitable for short flights linking up the country in a network of airlines. In the same category comes the soya bean as a raw material for the plastics industry.

A special word 'chemurgy', has been invented for chemical industries dependent on the growing of special crops. The most outstanding example of this is the production of rubber from crop plants and not from the rubber tree, which has been very successful in the Soviet Union and the United States, and has been pioneered in India and China. But there are many others. China's predominantly agricultural background should strongly favour a transition to industrialism along these entirely new lines.

Some processes, of course, which were prominent features of Euro-American industrialisation, must also form part of that in China. Such, for instance, is the coal tar industry, the high temperature distillation of coal or lignite, without which there can be no benzene, and hence no basis for a great organic chemical industry.

Advantage will naturally be taken of the high position occupied by China in the production of certain minerals (highest world producer for tungsten and antimony, second highest for talc, and fourth highest for brine products and tin). There are, moreover, many promising resources hardly as yet at all exploited with modern techniques, such as Sikang gold and mica, Yunnan copper and lignite, Kweichow mercury, Chinghai borax, and Kansu and Szechuan oil.

While in general I adhere to the usual concepts of planned centralised industrial development, I think also that there should be for a long time to come some scope for the activities of the Chinese Industrial Cooperatives, an organisation which does not seem to have had all the support it might have had during the past few years. The remoter areas can thus be supplied with consumers' goods in such a manner as to utilise all available local talent and in conformity with the family system. In border areas, too, where the Chinese agricultural meets the nomadic pastoral economy, cooperatives would be

particularly helpful. The Baillie Schools (technical schools) of the C.I.C.[3] have impressed me as among the best examples of technical education which I have seen in China, ranking equally with the Agricultural Vocational (Extension Teachers') Training School at Shatang near Liuchow and deserve strong support coupled with freedom to experiment along their own lines.

It should be put on record that in most cases, the welfare of the workers (so far as my wartime experience goes) has been comparatively well looked after in the government factories and arsenals. In certain places, such as the Tzuchung Power Alcohol Factory near Neichiang, Szechuan, this compares favourably (having regard to the generally prevailing lower standard of life) with advanced workers' welfare in Europe. There have been some cases, however, for example, in low temperature coal carbonisation plants not owned and operated by the government, in which I considered that industrial diseases, such as lung affections due to gases and vapours, or cancer due to unrestricted contact of the skin with tars and oils, were not being properly guarded against. Moreover, the reliance on child, or at least adolescent, labour in the Shensi cotton mills and the Yunnan tin mines (to take only two obvious examples) is unsatisfactory and not in the best interests of the nation. I understand (though I personally was not in China before the war) that the conditions of the workers in the industrial regions of Shanghai were notoriously bad. This is something against which the Chinese government must in the future be on its guard. The industrialisation of China will be watched very closely by the working masses of Britain, now ruling in its first powerful Labour government; by the working people of the Soviet Union, whose standard of life has been so much raised in recent years; and by those of the United States, whose labour unions are not without power. In order to retain world sympathy and support, the Chinese government must see to it that industrialisation does not proceed in an unregulated way injurious to the mass of the working people and must show that the low standard of life at which the Chinese people are bound to have to live for some time to come does not necessarily involve the additional evils of preventable disease and improper working conditions.

Wartime Science of China and Britain in Retrospect

Looking back at the part played by scientists during the past Second World War, I consider that they have deserved very well of their country. Leaving their comparatively well-equipped laboratories (some of which were destroyed before their eyes) in the eastern provinces, they journeyed to the western part of the country, and maintained the life of research and technological production under extraordinary difficulties. Long endurance of such difficulties deserves some reward.

Discussing the situation many times both with government officials and with academic scientists, I found that the latter generally strongly emphasised the importance of pure science, even under conditions when the monthly funds available for even an important research institute of Academia Sinica amounted to no more than they would purchase sufficient fuel for the month. They knew that applied science could never flourish without pure science, and they were right. No one can ever say what vast consequences may flow from experiments that seem completely academic. Government officials emphasising, also rightly, the importance of technical training for students, sometimes spoke of a reluctance on the part of scientists to enter government service and take up war work. This can only have been very partially true. The Physics Institute of the Peiping Academy did a most remarkable job of manufacturing microscopes and providing quartz crystals for radio sets; the Chinghua University General Physiology Research Institute tackled many problems of agricultural importance; and many laboratories did what they could towards isolating the active principles of some of the traditionally used drugs, such as the anti-malarials. In so far as it was true, it can certainly not have been due to the old distinction between degrading manual work on the one hand and the clean work of the scholar on the other. I have been very pleased to meet young university graduates working as foremen in mines such as the Tienfu Coal Mines in arsenal foundries, in the Central Machine Works and the like. While there may be some lingering effects, seen even in engineering colleges, of this old reluctance to combine manual and

mental work in the same person, there can be no doubt that the isolation of the scholar is breaking down. I think that the main reason why some scientists held back from taking up war jobs was because they feared that they might never be able to return to the life of pure science, so desperate is the need of the country for applied science. If this is correct, it only shows again the necessity for strong government support for pure science. And it must be admitted that I know of a few cases where after a scientist had taken up special war work, his time was almost completely wasted.

It is perhaps worthwhile referring to the measures which were taken in England during the Second World War to ensure the maximum utilisation of the scientific talent of the country in the war against Fascism. There was first a block reservation of all scientists above the age of 21 from combatant service. Then a Register of Scientists was set up, jointly under the auspices of the Royal Society and the Ministry of Labour, in order to find for everyone the job he was most fitted to do and to know in a given case of necessity who was the person most fitted to undertake any specific job which might need doing. I think the record of British science during the war has been a vindication of these methods. The reservation of scientists was systematically reviewed, younger ones being directed to useful work if not already doing it, or invited to accompany the armed forces as 'scientific officers' without military rank carrying out 'operational research', that is, research on the potentialities and utilisation of war weapons. Meanwhile, the utmost support was given to all kinds of war research, for example, in the field of chemical defences and, as we have recently been informed, British nuclear physicists were shifted across the Atlantic to cooperate with their American and Canadian colleagues in the two-billion dollar programme of releasing intra-atomic energy. Besides all this, experienced scientists were attached to every Ministry in an advisory capacity, and special committees were set up to coordinate the scientific work of a number of different ministries and other organisations. The Cabinet itself had a Scientific Advisory Committee, and there was a special Scientific Research Advisory Office in the Prime Minister's immediate circle.

How much of all this would be applicable to China during the reconstruction period, I do not feel able to say. But I consider that these questions of the organisation of science for the national welfare are very relevant to Chinese circumstances and deserve the most serious consideration.

International Scientific Relations

A few words must be said about China's participation in international scientific relations. China's delegation at the United Nations San Francisco Conference played an important, even a leading, part in the demand for the establishment of a United Nations Cultural and Scientific Organisation, which should perform the functions of the old League's Institute of International Intellectual Cooperation on a wider scale and should embody an international science cooperation service continuing many of the activities engaged in during the war period by the national science cooperation offices, as well as forming a nucleus for the international scientific unions and congresses. It only remains for China to continue her pressure in this direction, and her age-old and famous respect for scholars enables her particularly readily to push forward this public work in the comity of nations, which incidentally may be a source of much prestige for herself.

One way in which China could contribute along these lines would be by inviting some forthcoming international scientific congress to meet on Chinese soil. As soon as communications improve, for example, it would be an excellent idea to induce the International Geological Congress to meet in China, for geology has long been one of China's strongest sciences. The visiting scientists could be invited to examine the loess country, the Yangtze gorges, the karst pinnacles of Kweilin and so on.

Another matter worth consideration is that of appointing scientific attachés and counsellors in the diplomatic service. This is a problem now much discussed in a number of countries, and developments in the next few years should be carefully watched.

The preparation of this report has been for me a rather exacting and painful task. It has been frank, because when you asked me to speak of the shortcomings and difficulties of Chinese science, I know that you wished me to be frank. But the task has been painful mainly because I should feel, were I myself Chinese, no small sense of exasperation at the amount of good advice which is tendered, often with so little foundation, by so many well-intentioned, or

at any rate opinionated, foreigners. My only excuse is that for 3 years I have lived among Chinese scientists and technologists, have tried to learn something of their problems, and have essayed to bring to them what help was in my power.

I shall conclude with a few words on the activities of the Sino-British Science Cooperation Office, which during the war I had the honour to direct. Originally sent to China on what was primarily a goodwill mission, I speedily realised that a science and technology liaison office, analogous to what had already been set up in Washington and London, was necessary also in Chungking. Ultimately we depended, on the British side, on the British Council (Science Division) for all matters of pure science, and on the Ministry of Production (China Affairs Office) for all matters of applied and war science. On the Chinese side we were associated, following a decision of your own, with the Council for the Promotion of Science in the National Defence. In numbers, the staff of our office comprised, from first to last 17 scientists, of whom 5 were British and 12 Chinese, and besides these we had a clerical staff of 11, all Chinese. In the course of our travels, the British scientists personally visited some 300 Chinese scientific and technical institutions, laboratories, factories, arsenals and so on. We organised, during the period of the blockade, a supply service from India, and thus brought in, by the medium of the R.A.F.,[4] scientific research equipment, instruments, chemicals and so on, for about 250 Chinese institutions to the value of some £60,000 sterling. We also delivered, on a kind of lend-lease system, about 6000 British scientific and technical books to Chinese institutions. In addition to this, we brought in microfilm and actual copies of 200 of the leading British scientific journals, and combined in a joint distribution system with the Cultural Division of the American State Department, and the Ministry of Education. Innumerable exchanges of information and materials (such as seeds, chemical samples, and the like) were carried on, and about 150 original scientific papers by Chinese scholars were transmitted to the West for publication. Reciprocation was also made by some splendid gifts of Chinese books for British libraries by the Ministry of Education. It is my hope that in the history of Chinese scientific life, our efforts will be worth at any rate a small footnote. They have certainly been inspired, on the part of all of us, by a disinterested affection for your great country, and we have been profoundly rewarded by the many friendships which we have made in the course of our work.

I have the honour to be,
In deep truth and respect,
Your obedient humble servant,

Fellow of the Royal Society

Editor's notes

1. This secret report was written by Dr. Joseph Needham in 1945 to Chiang Kai-shek, the then national leader of the Republic of China. With the permission of the Needham Research Institute, for the first time, we now publish this report to commemorate the 25th anniversary of Needham's passing. Minor edits are made to make the report more appropriate for publication.
2. Historical region of north-eastern China.
3. Chinese Industrial Cooperatives.
4. Royal Air Force.

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Cultures of Science is a peer-reviewed international Open Access journal. The journal aims at building a community of scholars who are expecting to carry out international, inter-disciplinary and cross-cultural communication. The topics include: cultural studies, science communication, the history and philosophy of science and all intersections between culture and science. The journal values the diversity of cultures and welcomes manuscripts from around the world and especially those involving interdisciplinary topics.

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Cultures of Science is an international journal that provides a platform for interdisciplinary research on all aspects of the intersections between culture and science. It is published under the auspices of the China Association for Science and Technology.

It welcomes research articles, commentaries or essays, and book reviews with innovative ideas and shedding a fresh light on significant issues. Research articles report cutting-edge research developments and innovative ideas in related fields; commentaries provide scientific perspectives on emerging topics or social issues; book reviews evaluate and analyze the contexts, styles and merits of published works related to cultures of science.

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