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Peaceful Fallout: The Conversion of China's Military–Nuclear Complex to Civilian Use

november 97

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Cover Illustration:
China's nuclear complex

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Peaceful Fallout: The Conversion of China's Military–Nuclear Complex to Civilian Use

by
Yitzhak Shichor

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Zusammenfassung

German Summary

Seit den frühen 90er Jahren ist die Volksrepublik China mehr oder minder freiwillig einer Reihe von internationalen Konventionen zur nuklearen Abrüstung beigetreten. Abgesehen von der Internationalen Atomenergiebehörde, bei der China 1984 Mitglied wurde, trat es dem Nichtverbreitungsvertrag (1991) sowie dessen Erweiterung, dem Trägertechnologiekontroll-Regime (1992) und schließlich dem Vertrag über das umfassende Verbot von Nuklearversuchen (1996) bei. Einer der Gründe für die politische Führung, diese internationalen Verpflichtungen zu akzeptieren, waren die schon seit den frühen 80er Jahren unternommenen Anstrengungen bei der Konversion ihres eigenen nuklear-militärischen Bereiches zu zivilen Zwecken.

Während der gesamten Mao-Ära, von den frühen 50er Jahren bis Ende 1970, wurde der kerntechnische Bereich in China auf- und ausgebaut, hauptsächlich für militärische Zwecke. Dabei verzehrte er eine beträchtliche Menge an zivilen Ressourcen einschließlich finanzieller Mittel, Arbeitskräfte und Ausrüstung. Die friedliche Nutzung von Atomenergie spielte jedoch nur eine untergeordnete Rolle. Bis zum Ende der Mao-Ära hatte der zivile Anteil am Output des nuklear-militärischen Komplex, der aus Angst vor Angriffen über weit entfernte und unzugängliche Teile des Landes verstreut war, nicht mehr als 5% erreicht. Während beträchtliche Erfolge in der Entwicklung und dem Bau von Kernwaffen und Kernwaffenträgersystemen erzielt wurden, begann man, Elemente der Kernwaffentechnik (wie die Herstellung von gering angereichertem Uran und die Entwicklung eines Reaktors für Atom-U-Boote) auch zur Stromerzeugung zu nutzen.

Trotz anhaltender Ängste vor einer äußeren Bedrohung, auch nach Maos Tod 1976, mußte in China aufgrund der Priorität, die im Land dem wirtschaftlichen Wachstum und der Modernisierung eingeräumt wurde u.a. die Konversion der zu wenig genutzten militärisch industriellen und technischen Kapazitäten zu zivilen Zwecken vorangetrieben werden. Der Nuklearsektor wurde hiervon nicht ausgeschlossen. Wenn man jedoch die Konversion des chinesischen militärisch-nuklearen Komplexes mit der anderer Rüstungsunternehmen vergleicht, erkennt man, daß dieser Prozeß um ein vielfaches langsamer verläuft. Dies ist auf seine besonderen Charakteristika zurückzuführen. Der Nuklearsektor ist ein besonders isoliertes und hochempfindliches System mit nur geringer Erfahrung im Bereich der zivilen Produktion und keinerlei Bewußtsein von Marktmechanismen. Er wurde ohne Berücksichtigung der Kosten, unter absoluter Geheimhaltung und strengsten Sicherheitsvorkehrungen und unter Verwendung hochspezialisierter und gefährlicher Technologien entwickelt. Aufgrund der Isolation war der Sektor allerdings nicht so fortgeschritten, wie von der Regierung später behauptet wurde. All diese Faktoren behinderten eine reibungslose Durchführung der Konversion zu zivilen Zwecken.

Nach und nach begann der chinesische militärisch-nukleare Bereich auch mit der Produktion ziviler Güter und der Nutzung seiner Technologien für zivile Zwecke. Um diese Produkte sowohl im Inland als auch im Ausland zu vermarkten, wurden neue Holdinggesellschaften gegründet. Bis Mitte der 90er Jahre erreichte der Anteil der zivilen Produktion von über 300 Konversionsprojekten im chinesischen nuklear-militärischen Komplex nach offiziellen Angaben 80% der gesamten Produktion. Gleichzeitig wurde die Produktion von hochangereichertem Waffen-Uran und -Plutonium drastisch reduziert oder sogar gestoppt. Chinas wichtigstes Entwicklungszentrum für Kernwaffen in Qinghai wurde außer betrieb genommen und den zuständigen zivilen Behörden übergeben.

Das wichtigste Ergebnis bei der Konversion nuklearer Kapazitäten ist jedoch der Bau und das Betreiben von Atomkraftwerken, die hauptsächlich im Süden, Osten und Nordosten Chinas anzutreffen sind - Gegenden, in denen die industrielle Produktion gelegentlich aufgrund von Energieknappheit durch Stromausfälle unterbrochen wird. Zusätzlich zu den in großem Maßstab angelegten Kernkraftwerken werden kleinere Kernenergieprojekte, wie Kernfusions- Kernspaltungs-, schnelle Neutronen- und gasgekühlte Reaktoren entwikkelt. Obwohl ein Teil der zivilen Technologie und Ausrüstung importiert wurde, stammt viel aus chinesischer Produktion und wird sogar in andere Länder, wie z. B. Pakistan, Iran, Algerien und Syrien, exportiert.

Die Konversion des militärisch-nuklearen Bereiches in China zu ziviler Nutzung scheint keineswegs unumkehrbar zu sein und sie bedeutet auch keine Zurückstufung der militärischen-nuklearen Programme. Beijing führt weiterhin Nuklearwaffentests zur Entwicklung neuer Kernwaffen und Kernwaffenträgersystemen durch und läßt verlauten, daß der Besitz solcher Waffen immer noch notwendig sei, um sowohl die Sicherheit des Landes als auch seine Souveränität zu gewährleisten.

Summary

Since the early 1990s, the People's Republic of China has become committed, willingly or otherwise, to a number of international conventions aimed at nuclear disarmament. In addition to the International Atomic Energy Agency, which China joined in 1984, these include the Non-Proliferation Treaty (1991) and its extension, the Missile Technology Control Regime (1992) and finally, the Comprehensive Test Ban Treaty (1996). One of the reasons why Beijing accepted these international commitments was that since the early 1980s it had already taken steps towards the conversion of its own nuclear military complex to civilian use.

Throughout the Mao era, from the early 1950s to the late 1970s, China's nuclear complex was launched, built and expanded primarily for military ends while absorbing considerable civilian resources including funds, manpower and equipment. Though on the agenda, the peaceful use of atomic energy was marginal and by the end of this period the civilian output of China's military–nuclear complex, deliberately spread over remote and inaccessible inland locations for fear of external aggression, had reached no more than 5 percent. Still, while achieving remarkable results in the development and testing of nuclear weapons and delivery systems, Beijing had begun to consider using its nuclear military technology (e.g. the production of low-enriched uranium and the development of a nuclear submarine reactor) for generating electricity.

Although external threat perception was still high following Mao's death in late 1976, the priority accorded to economic growth and modernization called, among other things, for the conversion of China's underutilized military industrial and technological capacity, nuclear included, to civilian use. Yet, compared to other defense–industrial enterprises, the conversion of China's military–nuclear complex has been considerably slower due to its unique characteristics: a particularly segregated and highly sensitive system with marginal experience in civilian production and no awareness of market mechanisms, having been developed with little regard to cost, in total secrecy and under tight security using very specialized and dangerous technologies which, because of its isolation, had not been as advanced as Beijing later claimed. All these factors have defied easy conversion to civilian use.

Gradually, however, China's military–nuclear complex began producing civilian goods and using its technologies for civilian purposes. To market both, at home and abroad, new trading and industrial corporations have been created. By the mid-1990s, the share of civilian production output value by over 300 conversion projects undertaken by China's military–nuclear complex had reportedly reached 80 percent of total output value. At the same time, the production of highly enriched weapon-grade uranium and plutonium had been drastically reduced or even stopped altogether, and China's main nuclear weapon development center in Qinghai had been permanently decommissioned and handed over to civilian authorities.

Yet, the most important achievement of China's nuclear conversion is the construction and operation of nuclear power plants, primarily in the south, east and northeast where serious electricity shortages occasionally disrupt industrial production. In addition to these large-scale nuclear power plants, smaller nuclear energy projects such as fusion-fission, fast neutron, and gas-cooled reactors are being developed. While part of the civilian technology and equipment has been imported, part is not only of Chinese origin but has also been exported to other countries, such as Pakistan, Iran, Algeria and Syria.

However, the conversion of China's military–nuclear complex to civilian use is not by any means irreversible, nor does it imply a downgrading of military–nuclear programs. As a matter of fact, while nuclear conversion was going on, Beijing continued to undertake nuclear weapons tests, to develop new kinds of nuclear weapons and delivery systems, and to claim that the possession of such weapons was still essential to safeguard not only its security but also its sovereignty.

Preface

One of the ironies of the post-Cold War era is that, while China is being increasingly considered a ‘threat,’ not only in regional terms but also in global ones, much of its defense system has allegedly been converted to civilian use. Launched in the late 1970s, this policy had been primarily motivated by domestic, mostly economic but also social, considerations, as well as by the changing international situation which has led to a reduced threat perception within China. While covering cuts (in the 1980s) and a moderate real increase (in the 1990s) of military appropriations, a demobilization of over one million troops (or one quarter), a regular economic employment of part of the armed forces, and the transfer of military facilities and services to civilian use, most of Beijing’s defense conversion policy has obviously centered on its military–industrial complex.

The enormous problems which had affected this complex under China’s socialist command economy even more than other state-owned enterprises have become more acute during the post-Mao transition to market economy. These problems include a huge production overcapacity and overemployment; outdated technology, equipment and management methods; isolation, departmentalization and insensitivity to the market; and economically irrational geographical distribution. Nonetheless, shortly after its defense–industrial conversion had been launched, Beijing began to claim incredible success. By the mid-1990s civilian production had reportedly accounted for about 80 percent of China’s total defense–industrial output, covering over 15,000 products. Ostensibly outstanding compared not only to the conversion agonies and failures of most if not all other countries, but also to the reform agonies and failures of China’s own state-owned industrial sector, China’s comprehensive defense conversion deserves a careful study.

The current study deals with the conversion of China’s military–nuclear complex which, though providing an extreme example of the problems mentioned above, has allegedly managed to undergo successful conversion. Following the introduction which suggests some links between the domestic and international incentives for China’s military–nuclear conversion, the paper is divided into two main parts. Underlining the predominance of military considerations in China’s nuclear policy under Mao, the first part provides the dimensions of China’s military–nuclear infrastructure, organization, and development, achieved with Soviet support and then independently. It also traces the origins of the post-Mao conversion. This conversion is the subject of the second part which deals with the origins and organizational adaptation to civilian nuclear production and its achievements, emphasizing its principal accomplishment—nuclear power stations. A third part then shows that, extensive as it may be, China’s nuclear conversion has only marginally affected its military–nuclear potential.

Research and writing of this study, in itself part of a larger project on China’s military-to-civilian conversion, have been done with the support and encouragement of several organizations and people. I am grateful to the Rockefeller Foundation’s Bellagio Study and Conference Center which offered me residence fellowship (May–June 1996); to the Deutscher Akademischer Austauschdienst (DAAD, the German Academic Exchange Service) for providing me with a grant to spend two months at the Bonn International Center for Conversion (BICC, June–August 1996); to Dr. Herbert Wulf, BICC Director, for inviting me, and to the BICC staff and especially to Dr. Jörn Brömmelhörster who patiently and consistently assisted not only with the logistics but also with his knowledge of conversion in general, and Chinese conversion in particular. The final revisions of this paper were done while I was a visiting fellow at the Sejong Institute, Korea, in April–June 1997.

I would also like to thank the library staff of the Hebrew University’s Harry S. Truman Research Institute for the Advancement of Peace, and especially Mr Riccardo Schwed, curator of the East Asia collection; to the American Cultural Center in Jerusalem which for a few years willingly and generously provided me with essential sources on China; to the Frieberg Fund and the Hebrew University’s Faculty of Humanity Research Fund for their financial support. Many out-of-print Chinese books were retrieved with the help of the Israeli Embassy staff in Beijing, and especially through the efforts of Ms Huang Ling of the Chinese Academy of Social Sciences. The University of Hong Kong’s Universities Service Centre proved to be a goldmine of books and articles, and I am grateful to Mr Ka Po Ng for his relentless assistance. Mr Zhang Hongbo, Ms Wen Zhang, Mr Huang Qinghong of the Hebrew University, and Professor Ling Jie, who was a visiting fellow at the Truman Institute, made valuable contributions to this study by summarizing many Chinese sources.

Introduction

On 24 September 1996, China's Vice-Premier and Foreign Minister Qian Qichen became one of the first international leaders to sign the Comprehensive [Nuclear] Test Ban Treaty (CTBT). This act concluded months, if not years, of speculation as to China's nuclear disarmament intentions and pre-conditions for joining the CTBT. Beijing's *explicit* preconditions included a firm international commitment to total nuclear disarmament; the adoption of a 'no first use' policy, which China had proclaimed as early as October 1964, by all nuclear powers; better inspection of nuclear sites to avoid deception; and an insistence that the treaty would allow so-called "peaceful nuclear explosions" which could be used not only for pure theoretical scientific research but also for applied research and a variety of practical civilian purposes such as predicting earth tremors, dumping garbage, mining and, last but not least, the ultimate destruction of nuclear weapons.[1]

Implicitly, Beijing has been concerned that, unlike the more advanced nations, which would still be able to simulate nuclear explosions under laboratory conditions even after signing the CTBT, China's lower science and technology standards would lead to nuclear stagnation and, therefore, to backwardness. To overcome Beijing's concerns and 'lubricate' its sliding towards the CTBT, Washington by late May 1996 had reportedly decided to implement an earlier agreement and help China in building what was to become the world's largest laboratory for the controlled use of nuclear fusion and in conducting research into the peaceful use of nuclear energy.[2] It was perhaps this agreement between the Texas Thermonuclear Fusion Research Center and the Chinese Academy of Sciences which finally paved the way for China's acceptance of the CTBT. Indeed, in early June 1996, Beijing dropped all its former preconditions and objections to the CTBT, still announcing its intention, and right, to conduct one last nuclear test before September. As it turned out, this test—China's 45th—was conducted on 29 July, shortly before the CTBT discussions were to be resumed in Geneva. Within hours, the Chinese Government issued an official statement pledging an immediate moratorium on nuclear tests.[3] Less than two months later Beijing signed the treaty.

This was another step in China's slow and apparently painful march towards downgrading its military–nuclear posture. Except for their 1964 unilateral commitment not to be the first to use nuclear weapons, the Chinese for a long time declined to join any international nuclear convention which had been negotiated and signed without their participation. One of the late-comers, China in January 1984 became the 113th state to be admitted to the International Atomic Energy Agency (IAEA). Yet it was only in the early 1990s that Beijing has practically been forced, and tempted, by the United States and Western countries to abide by international arms control agreements which included the Non-Proliferation Treaty (NPT, in December 1991) and its extension, and the Missile Technology Control Regime (MTCR, in February 1992). While China's endorsement of these agreements has been rather vague and its implementation of their clauses somewhat controversial,[4] there is no doubt that as the twenty-first century approaches China's international military–nuclear options have become greatly limited.

Yet, the fact that most of these limits have been exogenously imposed on China does not necessarily imply that they do not conform to its revised foreign, and domestic, policies. On the contrary they do, which is probably why Beijing finally agreed to accept these limits in the first place. To be sure, long before they were 'manipulated' into joining these arms control agreements, the Chinese had already taken voluntary measures and made preparations in this direction by gradually converting part of their military–nuclear complex to civilian use. By the mid-1990s, after China had signed the CTBT (and the other above-mentioned conventions), both processes converged reaching their climax and interdependence.

Quite a number of studies have dealt with the *international* aspects of China's nuclear arms control and disarmament policy.[5] Almost none has exclusively dealt with less known *domestic* aspects of China's nuclear disarmament, not merely as an economic necessity but also as an essential component of its nuclear arms control policy. By ignoring this link we miss one of the crucial explanations for Beijing's ultimate agreement to sign the CTBT and join other relevant agreements. "Nuclear disarmament requires, among other things, detailed planning for the economic conversion of nuclear weapons production facilities to purely civilian uses."[6] In this respect, and despite their advertised reluctance to participate in these conventions, the Chinese may have been better prepared than others. Their nuclear conversion policy implying, among other things, an essential reduction of nuclear weapons and weapon-grade fissile material production, had not only expedited and legitimized China's participation in various international nuclear disarmament conventions but, moreover, practically compelled it to do so. Or, to put it differently, according first priority to economic development and modernization, Beijing would have found it difficult, if not impossible, to proceed with simultaneous military and civilian nuclear programs without joining these conventions.

This study proposes to provide the link between the international and the domestic aspects of China's disarmament policy. The first part provides an overview of China's (overwhelmingly military) nuclear establishment, infrastructure and programs to the end of the 1970s, underscoring those elements which had provided the basis for China's later civilian nuclear program. The second and principal part concentrates on China's nuclear conversion, its motivations, policy-making and implementation. Finally, the third part explores some implications of China's conversion policies on its nuclear military power and programs.

China's Nuclear Complex under Mao: Military Predominance

China's leadership, and Mao Zedong himself, had undoubtedly been aware of the peaceful uses of nuclear energy and technology as early as the 1950s and had, as a matter of fact, taken initial research and development (R&D) steps in this direction. Yet, civilian considerations have always been subordinate to Beijing's military considerations, especially since the late 1950s, as its threat perceptions increased and relations with Washington as well as with Moscow deteriorated. Consequently, the scarce economic resources were allocated to building and expanding a predominantly military–nuclear complex whose civilian output had reportedly reached no more than 5 percent by the late 1970s, at the end of the Mao era. Thus, while its huge military–nuclear human, material and scientific infrastructure had an enormous conversion potential, China had very limited experience in the civilian use of nuclear energy and technology.[7]

Reliance on the Soviet Union

China's military–nuclear complex is the youngest among its defense–industrial enterprises.[8] Although some publications and rudimentary facilities related to theoretical nuclear physics had existed in half-a-dozen research and academic institutes before the foundation of the People's Republic of China (PRC), no significant applied research had been done due to the almost total lack of personnel and equipment. This situation began to improve as of April 1950, when the newly established Chinese Academy of Sciences organized the Research Institute of Modern Physics (RIMP, later renamed Institute of Atomic Energy) and started enlisting Chinese scientists at home and abroad. Those who returned to China brought with them personal connections, books, equipment and materials which provided the foundations for contemporary China's nuclear research, soon to acquire military implications.[9]

Indeed, as early as May 1952, Premier Zhou Enlai reportedly chaired a meeting of the party's Central Military Commission (CMC) with the participation of prominent People's Liberation Army (PLA) figures including Zhu De, Peng Dehuai, Nie Rongzhen and Su Yu, which discussed national defense construction within the First Five-Year Plan (1953–1957). For the first time, the issue of developing non-conventional weapons came up, scientists were requested to forward their comments, and preparations were made for further development. In February 1953 Qian Sanqiang, one of China's foremost nuclear physicists and RIMP Director, led for the first time a 26-member scientific delegation to the Soviet Union which discussed nuclear issues and visited nuclear facilities. Following this visit, Qian prepared a proposal for the state on the development of nuclear energy. On the basis of his proposal, in the autumn of 1954, just before the beginning of the Sino-Soviet governmental talks, Peng Dehuai and Li Fuchun proposed building a nuclear reactor and a cyclotron with the assistance of the Soviet Union. In line with this proposal, the Ministry of Geology established the Second Office of Reconnaissance Survey Commission in December whose responsibility was to prepare for uranium exploration after specimens of uranium ore had been investigated and analyzed throughout 1954.

Shortly afterwards, on 14 January 1955, Zhou Enlai held another meeting to learn more about nuclear reactors and weapons and the necessary conditions for the development of Chinese nuclear science and technology.[10] By that time, some tests and theoretical research had already been begun by leading scientists (such as Qian Xuesen and others) and the exploration of uranium ore was about to start. Also, progress had been made in the development of nuclear detectors, nuclear electronic instruments and other equipment; the extraction, analysis, purification, and measurement of uranium; and the research and preparation of heavy water and high purity graphite.

The next day, 15 January, Mao Zedong presided over an enlarged and crucial Chinese Communist Party (CCP) Central Secretariat meeting, attended by China's supreme leaders (Liu Shaoqi, Zhu De, Chen Yun, Peng Zhen, Peng Dehuai, Deng Xiaoping, Li Fuchun, and Bo Yibo), which discussed the issue of nuclear energy. After hearing reports about China's uranium deposits and basic atomic technology, the meeting passed a historic resolution, kept secret for many years, to develop atomic energy and atomic bombs.[11] Mao reportedly urged all concerned to work hard and get the work done "with or without Soviet aid".

Still, cooperation and negotiations with Moscow on nuclear assistance started immediately afterwards. Indeed, on 17 January, Moscow announced that it would provide China (and some East European countries) with aid to promote research on the *peaceful use* of atomic energy. Three days later, on 20 January, a first Sino-Soviet agreement was signed for the joint prospecting of uranium ores. Uranium Ore Prospecting Teams were now organized by the Third Bureau of the Ministry of Geology's Third Office, established in April 1955. On 27 April, a formal agreement on Soviet assistance to China in tests and research in nuclear physics and using nuclear energy *for peaceful purposes* was signed between the two governments.[12] Moscow agreed to design and deliver to China from 1955 to 1956 an experimental atomic reactor and accelerators of elementary particles; to provide China, free-of-charge, with scientific and technical documentation related to them, as well as with fissile and other materials; and to assist China in assembling them and putting them into action.

To take responsibility for the development of nuclear energy, the CCP in July 1955 formed a 'group' led by Chen Yun, Nie Rongzhen, and Bo Yibo, while the PRC State Council's Third Office, also led by Bo Yibo, assumed responsibility for overall planning and management of China's evolving nuclear technology and nuclear industry. Its civilian use was still high on China's agenda. In his "Report on the Question of Intellectuals" on 14 January 1956, Zhou Enlai pointed out that "the peak of new developments in science and technology is the utilization of atomic energy. Atomic energy," he added, "provides mankind with an incomparably powerful new power source, and it opens up broad prospects for all scientific disciplines."[13]

Consequently, in March 1956 China joined Moscow and ten other socialist countries in the inauguration of the Joint Atomic and Nuclear Research Institute in Dubna, near Moscow. As a founder, the PRC had to contribute 20 percent of the Institute's construction and maintenance expenses, but could use its huge advanced and sophisticated facilities, though *for peaceful (or civilian) purposes only*.[14] While allegedly, or even genuinely, interested in the civilian application of nuclear energy,[15] by that time China's commitment to develop nuclear weapons was spelled out clearly—though not emphasized—in a report delivered by Peng Dehuai in March 1956 at an enlarged CMC meeting. A month later, in his report "On Ten Major Relationships" Mao unequivocally reiterated that China "[would] not only have more aircraft and large guns, but also atomic bombs."[16]

On 17 August 1956, Moscow agreed to help China in building its nuclear industries and research facilities. This agreement, as well as the previous two which covered Soviet support in uranium exploration and nuclear science and technology research, triggered the launching of China's nuclear programs. By September 1956, when the CCP was holding its 8th Congress, nearly forty atomic energy research centers had already been founded all over China.[17] Reorganization was called for. Since the early 1950s, the First Ministry of Machine Building (MMB) had been responsible for civilian production and the Second MMB for all conventional military production. In November 1956, however, China's National People's Congress (NPC) decided to create a Third MMB to take exclusive charge of China's nuclear industry which, though usually referred to by the Chinese as "military" in essence, has always been civilian as well. (In February 1958, when the First and the Second MMBs merged, the Third MMB was renamed the Second MMB to remain unchanged until the early 1980s.)

Further steps were taken in 1957. In September, a high-level Chinese delegation visited Moscow. Following the visit, on October 15, the two governments signed an 'Agreement on Producing New Weapons and Military Technical Equipment and Building Comprehensive Nuclear Industry in China.' This is the most important nuclear arms agreement ever signed between the two countries. It covered the supply not only of experts, technologies and materials but, furthermore, of an 'educational' model of an atomic bomb which the Soviets had allegedly agreed to offer Beijing. Shortly afterwards, however, in early 1958, Moscow secretly decided to back off.[18]

Unaware of this decision, China's Third MMB set up the Ninth Bureau in January 1958 to organize and supervise nuclear arms research and development.[19] The responsibility for receiving and digesting the drawings, information, and the model atomic bomb to be provided by Moscow was assigned to the Nuclear Weapons Research Institute which was set up in Beijing in July. In August, to practically implement the previous agreements, Moscow and Beijing signed another one specifying in more detail the scales, schedules and the supply of materials and equipment for each project.[20]

Some were related to civilian nuclear programs which were still being promoted. In August 1958 a national meeting concerning the peaceful use of nuclear energy discussed the popularization and application of isotopes and, in September, a Isotope Application Committee was established under the Chinese Academy of Science (CAS). This was undoubtedly determined by the fact that, on 27 August, China's first experimental heavy-water slightly-enriched (2.5 percent) uranium nuclear research reactor (with 7,000–10,000 kilowatt capacity, increased between 1979 and 1980 to 15,000), together with a 2.4 million electron-volts cyclotron, were put into operation in China's newly-built 'nuclear village' in Tuoli, Fangshan County, Beijing Municipality. Assembled since May 1956 with Soviet support, according to the April 1955 agreement, this reactor had managed to produce 33 isotopes by the beginning of October 1958, within a little over one month.[21]

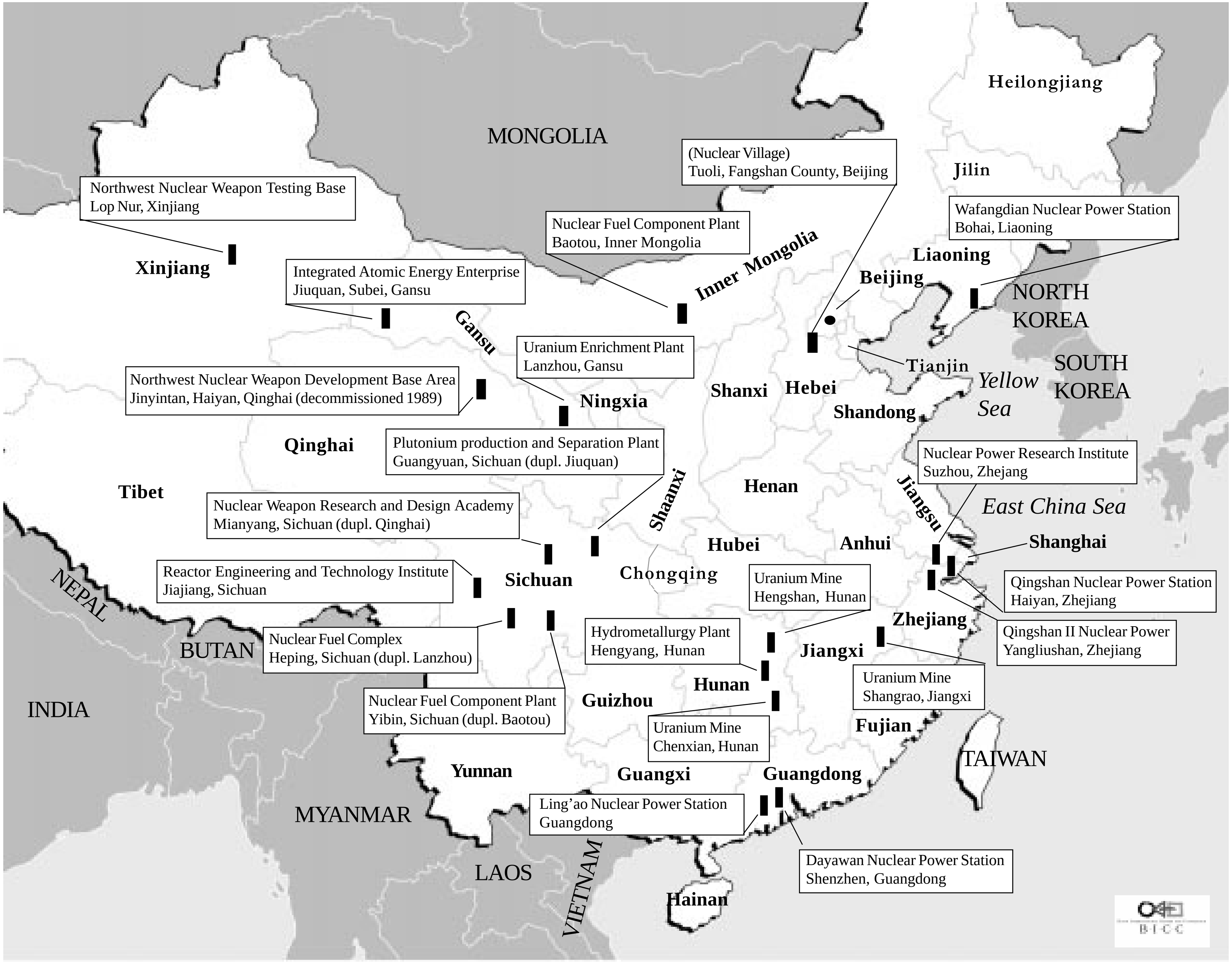
China's only known nuclear installation in 1958 (although small-size experimental nuclear reactors may have already existed in Wuhan, Shaanxi, and Jilin), it had been originally planned to serve civilian industrial and agricultural purposes and produce electricity: allegedly, Moscow had refused to provide China with nuclear arms production technology.[22] Yet by that time the Institute of Atomic Energy (formerly the RIMP, jointly controlled by the Second MMB and the Chinese Academy of Sciences), had already imported Soviet equipment for the gas diffusion laboratory for uranium isotope separation (later to be used in producing enriched uranium for military purposes, though the Institute concentrated largely on basic research and peaceful applications of atomic energy). All aspects of China's nuclear weapon (and missile) program had been supervised since October 1958 by the newly established Commission of Science and Technology for National Defense (COSTND), headed by Nie Rongzhen.

Planning for China's nuclear production infrastructure began in early 1958. On 31 May, CCP General Secretary Deng Xiaoping approved site selection programs for China's first eight nuclear projects: five plants (the Hengyang Hydrometallurgy Plant, Hunan; the Baotou Nuclear Fuel Element Plant, Inner Mongolia; the Lanzhou Uranium Enrichment Plant, Gansu; the Jiuquan Integrated Atomic Energy Enterprise, near Subei, Gansu; and the Northwest Nuclear Weapon Development Base Area, Jinyintan, Haiyan County, Qinghai), and three uranium mines (Chenxian and Hengshan Dapu, both in Hunan, and Shangrao in Jiangxi). The area northwest of Lop Nur in Xinjiang was approved by the CMC in March 1959 as the test base (see map 1).

By that time Sino-Soviet relations had already deteriorated and, on 20 June 1959, Moscow informed Beijing that it would "temporarily" suspend its commitment to supply an atomic bomb teaching model together with information and drawings, while it was holding negotiations with Washington over a treaty for the partial ban of nuclear weapon tests. This was the earliest indication of the withdrawal of all Soviet aid and experts from China, which was to take place a year later. The Chinese regarded the suspension as a Soviet excuse to back off from the 1957 military–nuclear assistance agreement and thereby prevent, or at least delay, Chinese efforts to develop their own nuclear weapons. Consequently in July 1959, the CCP decided to give up Soviet assistance (which was about to stop anyway), start again from the very beginning, and develop an atomic bomb in eight years.[23] According to this decision, in spring 1960 scores of scientists, mobilized all over the country for the Nuclear Weapon Research Institute of the Second MMB, intensified theoretical explorations on atomic bombs. As priority had been given to the development of the most advanced military technology, arrangements had been made since late 1959 and early 1960 to concentrate human, material, and financial resources on missiles and nuclear weapons projects.

These and other nuclear projects suffered twice in the late 1950s and early 1960s. The first reason was that the Great Leap Forward's emphasis on quick results and quantity output undermined the quality and safety norms essential for the construction of China's nuclear industry. For example, the roof of the main shop building of the Lanzhou Uranium Enrichment Plant (also known as the Lanzhou Gaseous Diffusion Plant), construction of which had started in 1958,[24] had to be torn down and rebuilt.

Map 1: China's nuclear complex



Despite the negative effects of the Great Leap Forward, the overall construction of China's eight principal nuclear industry projects mentioned above had made good progress (too late, however, to be used for China's first atomic bomb).

Still, the Great Leap Forward made some positive contributions to China's nuclear development. The first 150 tons of uranium concentrates, used for China's first atomic bomb, were allegedly processed *manually* by thousands of peasants before the construction of the mines could be completed.[25] Yet from July to August 1960, when these projects were nearly completed, China's nuclear establishment was seriously shattered a second time when Moscow backed off from its commitment to supply the teaching model of an atomic bomb together with relevant information and drawings; unilaterally tore up all agreements and contracts it had signed with China; abruptly stopped the supply of equipment and materials; and recalled 233 experts who were helping China in the build-up of its nuclear industry. They departed taking with them drawings, blueprints and information, causing heavy losses and many problems.

This could not have come at a worse time since in the early 1960s, following the collapse of the disastrous Great Leap Forward, Beijing had to cope with the gravest economic, social, and political crisis since the establishment of the PRC in 1949. The crisis also seriously disrupted the construction of the Northwest Nuclear Weapon Developing Base in Qinghai. Still, more determined than ever to proceed with nuclear development independently and resolutely, Beijing despite the difficulties had to find the necessary resources. This determination was reflected in the 'Decisions on Strengthening the Construction of the Atomic Energy Industry,' approved by the CCP on 16 July 1961. Based on thorough investigations held throughout the year, China's civilian leaders (Mao, Zhou and Deng) in November firmly adopted the military leaders' view that, since the construction of nuclear industry and the development of the atomic bomb (as well as research on a thermo-nuclear bomb and a nuclear submarine powerplant) had made great progress, China's first atomic bomb could be tested within three years, just in time for the PRC's fifteenth anniversary in October 1964.[26]

Self-reliance

To meet this crucial deadline, a major mobilization and concentration of resources were called for. Two new organizations were set up to oversee this effort. In late November 1961 the CCP approved the establishment of a National Defense Industry Office (NDIO) under the State Council, while exactly a year later, in November 1962, the CCP approved the establishment of a Special Commission of the CCP Central Committee (CSC) "to strengthen the leadership of production and construction of the atomic energy industry and research, and testing of nuclear weapons."[27] In a virtual process of "civilian-to-military conversion," over the next few years much effort and organizational measures were taken to ensure the supply of all the people, materials, and equipment needed by the nuclear industry. Many new materials which had been imported in the past, were now produced in China and, to be sure, contributed not only to the breakthrough in missile and nuclear weapons development but also to the development of civilian science and other basic industries.[28]

In the spring of 1963, 126 scientists and technicians of the Nuclear Weapon Research Institute in charge of design, experiment and production, had been transferred to the Northwest Nuclear Weapon Developing Base in Qinghai, even before it was entirely completed. In addition to the three uranium mines and five nuclear energy plants put into production or trial-production under the Second MMB by the end of 1963, over 400 factories, institutes, colleges and universities all over China contributed to the effort.[29] As China's military–nuclear program was gathering momentum, threat perception increased, leading the CSC to propose, on 31 January 1964, that to improve national defense and uphold the principle of "leaning on the mountains, decentralization, and concealment" (*kaoshan, fensan, yinbi*), the strategic deployment of the nuclear industry should be readjusted as quickly as possible to build rear-line base areas.[30] These became known as the 'Third Line' or 'Third Front' (*sanxian*).

Two weeks earlier, on 14 January 1964, the Lanzhou Plant managed to obtain for the first time the highly enriched uranium needed for an atomic bomb. Preparation for the test began and in April, following a huge mobilization of manpower and resources, the main projects of the Northwest Nuclear Weapon Developing Base were completed. On 1 May, the first set of usable enriched uranium-235 fuel component was produced by the Nuclear Component Production Plant of the Jiuquan Atomic Energy Complex. On the afternoon of October 16, a little over four years since independent development had begun, China's first tower-mounted atomic bomb with a yield of 22,000 tons of TNT (or 22 kilotons) was successfully detonated at the Nuclear Test Base northwest of Lop Nur, in Xinjiang.

Now, for the first time, the Chinese government declared that China would never be the first to use nuclear weapons at any time or under any circumstances. Beijing also began to explore the possibility of convening a conference of the world's heads of state to discuss the complete prohibition and total elimination of nuclear weapons. Yet a few weeks later, in early December, the second MMB proposed accelerating the construction of a plutonium production line and the development of nuclear weapons. In fact, by that time, the research and design of a nuclear aerial bomb and a nuclear warhead for missile delivery had already begun. These projects were given a boost following China's second and third nuclear tests (on 14 May 1965 and on 9 May 1966), both with an airdropped bomb, the latter including thermo-nuclear materials. Only then, after much preparation and many precautions, a DF-2 (*Dongfeng*, or East Wind, known in the West as CSS-1) medium-range ballistic missile (MRBM) was launched from the Shuangchengzi base in the Gobi Desert northeast of Jiuquan (Gansu Province) on 27 October 1966, successfully delivering a 12 kiloton atomic bomb which was detonated in the air above Lop Nur in Xinjiang, 800km to the west. A similar test of detonating a missile-delivered nuclear bomb has never been attempted.[31] The next stage was to make fast progress in hydrogen bomb (H-bomb) technology.

Explorations and research on the H-bomb began in December 1960. Following the success of China's first nuclear test, decisions were made in early 1965 to accelerate the development of the H-bomb. While China's military–nuclear establishment was being engaged in this project, many civilian plants were mobilized to provide the necessary materials and equipment. More data and experience were provided following 9 May 1966, when the detonation of China's third atomic bomb was successfully accomplished. It contained some thermo-nuclear material (lithium 6) allegedly resulting in a yield of 200–300 kilotons (or 2–3 megatons, over ten times as powerful as the previous experiments). Another test, this time with a reduced-size H-bomb (or an H-bomb principle test) which yielded 122 kilotons, was carried out on 28 December 1966.[32]

Less than six months later, on 17 June 1967, China's first full size H-bomb with a yield of 3.3 million tons of TNT (or 3.3 megatons) was airdropped from a retrofitted H-6A bomber and successfully detonated. Two years later, on 23 September 1969, China carried out its first underground (tunnel-mode) nuclear test in Nanshan (the southern mountains, in the Kuruktag ridge, northwest of Lop Nur). Except for the 17 October 1976 test, all later tunnel-mode underground nuclear tests were carried out in Beishan (or the northern mountains). China's first shaft-mode underground nuclear test (which usually produce higher yields than tunnel-mode tests) was carried out in the Xingeer (or Qinggir) region, also northwest of Lop Nur, on 14 October 1978. (For a complete list of China's nuclear tests, see Table 4, page 32 below.)[33]

Throughout these years work on China's nuclear bombs continued in the Northwest Nuclear Weapon Developing Base which, since 1969, was responsible only for production. The non-production aspects were separated and carried out by the Ninth Bureau, renamed the Research and Design Academy of Nuclear Weapons, which gradually moved to a new base, completed in 1969, in Mianyang (Sichuan Province) according to the 'Third Line' (or *sanxian*) policy.[34] Governed by Beijing's anxieties about the exposure of China's defense–industrial complex in general, and nuclear complex in particular, to external—primarily Soviet—aggression, this policy had been launched in the spring of 1965, following the establishment of a special Nuclear Industry Third Line Construction Headquarters. "Several tens of thousands of people" were transferred to remote Third Line areas, less accessible but more defendable. In a retrospective view, the Chinese still think that the decision was correct. Yet, "the main problems in Third Line construction were the influences of 'left' ideology and restricted levels of knowledge, excessive emphasis on locating the plant sites near mountains and the need for decentralized deployments, and low standards for construction of living facilities, all of which created certain forms of irrationality in production deployments and inconveniences in work and life."[35]

According to this policy, which later complicated and slowed down China's nuclear conversion efforts, new facilities had been built in the inland provinces expanding and duplicating China's main nuclear centers, most of them in Sichuan Province (see map in Figure 1): the Mianyang facility duplicated the Haiyan (Qinghai) Northwest Nuclear Weapons Research and Design Academy; the Yibin Nuclear Fuel Component Plant, used for producing and processing weapon-grade plutonium, duplicated the Baotou Nuclear Fuel Component Plant (in Inner Mongolia); the Heping Nuclear Fuel Complex duplicated the Lanzhou Nuclear Fuel Complex (Gansu Province), used for gaseous diffusion uranium enrichment; and the Guangyuan plutonium production reactor and plutonium separation plant, the largest in China, duplicated the Jiuquan Atomic Energy Complex (Gansu).[36] One of their main tasks had been to weaponize and then serial-produce H-bombs, which were then deployed from the early 1970s to the mid-1980s. This process along with many other nuclear weapon achievements were especially remarkable since they coincided with, and suffered from, the upheavals of the Cultural Revolution.

It has been usually assumed that, unlike conventional weapon development which was more seriously affected by the Cultural Revolution, the predominant non-conventional weapon development was shielded and therefore only marginally harmed. Indeed, Mao himself pointed out clearly that plants, mines, and research institutes under the Second MMB "were important top secret units bearing important significance to defense construction and enhancement of preparation for combat. Absolute safety [had to] be provided to these plants and stable production of these factories [had to] be safeguarded." Radical revolutionary Red Guard activities were strictly forbidden. Nonetheless, the research and development of nuclear projects, particularly the H-bomb, were disrupted by the turmoil to such a degree that R&D personnel had to be moved to safer sites in order to continue their work. Later, compensations were paid and apologies rendered to many nuclear scientists and experts who had to endure persecution and humiliation. Zhou Enlai reportedly managed to frustrate a decision made by Lin Biao to move (rather than duplicate) the nuclear fuel plants from Jiuquan (in Gansu) and Baotou (in Inner Mongolia) further inland. A serious loss of nuclear fuel production was thereby prevented. To avoid further paralysis and ensure continued R&D, military control was enforced over all defense industry ministries, including the Second MMB, until the early 1970s.[37]

The military origins of nuclear power

While most of China's nuclear military projects had been practically irrelevant to civilian needs, one can be singled out: the R&D of nuclear power plants for submarines. Basically, the return of these pressurized-water reactors is similar to that of a land-based pressurized-water nuclear reactor power station, though the former provides power to turn the propellers while the latter generates electricity.[38] The development of a submarine nuclear power plant was began as early as 1958 by the Reactor Research Office of the CAS Institute of Atomic Energy.[39] Having progressed slowly due to technical and bureaucratic disagreements, and given a lower priority in view of scarce resources which were allocated primarily to the development of nuclear weapons and missiles, the nuclear submarine project was suspended in late 1961 by the CSC. Nevertheless, two swimming-pool type experimental reactors were successfully built by the Institute of Atomic Energy and Tsinghua (Qinghua) University and research on low-enriched nuclear fuel and materials which were needed for the pressurized-water reactor began.

In August 1963 the CSC approved the merging of existing organizations into the Institute of Submarine Atomic Energy Power Engineering (better known as the Institute of Nuclear Power, or INP), later to become associated with the Second MMB. Based on the recently adopted Third Line policy, in January 1964 the Second MMB decided to establish the Reactor Engineering and Technology Institute (Institute 194) in Jiajiang, Sichuan Province (north Leshan and Emeishan). Yet, work on the preliminary design of the nuclear power plant, which had been resumed in early 1965 and approved by the CSC in July, was seriously disrupted by the Cultural Revolution. 'Emergency Measures' undertaken from March (when a 'nuclear submarine power reactor project headquarters' was established) to November 1967, including telegrams by China's top leaders, a "Special Official Letter" issued by the CSC in August, and the personal intervention of Mao Zedong on 18 July 1968 finally led to the expediting the project. Following hard work involving more than 800 INP scientists and technicians transferred from Beijing to the nuclear reactor research and design base in the difficult terrain and climate of Jiajiang, Sichuan, and 8,000 soldiers and civilians who worked on the construction site, civil engineering and installation of the land-based prototype reactor were completed on 28 April 1970. All that was needed now to test the prototype was fuel.

Work on researching fuel elements for a submarine nuclear power plant began in 1958. In the early 1960s research was carried out in the CAS Shenyang Metals Research Institute and in March 1963, the Second MMB established a nuclear fuel research office in the Baotou Nuclear Fuel Element Plant (known as Plant 202, in Inner Mongolia). In August 1967 it began to build a production workshop for nuclear submarine power reactor fuel and in April 1970, precisely when the prototype reactor was completed, the first batch of nuclear reactor fuel was successfully produced. The fuel used for China's submarine nuclear power reactors, as well as for its nuclear power station reactors is low-enriched uranium-235 (with content of less than 5, usually 3 percent) compared to high-enriched or weapon-grade uranium-235 (with content of 90 percent or more).

The trial-run of the land-based prototype began on 1 May 1970, and it reached full power on July 30. By December 1979, when the reactor was shut down, over 530 items had been tested. An identical submarine nuclear power plant was built simultaneously and installed into a submarine on 26 December 1970. Sea trials began on 23 August 1971, after dock trials had been completed. By 1974, when China's first nuclear submarine was commissioned, a couple of steam generator failures had been repaired and China's submarine nuclear power plant proved successful, though long distance and deep water trials were still to come.[40]

The successful completion and trial operation of these pressurized-water reactors, both on land and at sea, as well as the fuel reprocessing experience, not only made a considerable contribution to China's military strength "but also trained personnel and accumulated experience for the development of the nuclear power industry in China."[41] Unfortunately, this statement by no means implied any significant headway in China's nuclear power development. Originally, the reactor built in Beijing with Soviet support from 1957 to 1958 was supposed to serve civilian purposes and produce electric power (see above). This was however never accomplished due to the Sino-Soviet conflict, to the priority given to military needs, and to bureaucratic haggling.

Claiming a leading role in nuclear power, the Ministry of Electric Power (set up in 1955 and combined in 1958 with the Ministry of Water Resources) began to design and research pressurized-water reactors as early as 1959 yet, since all relevant information had been classified as military thus becoming practically inaccessible, progress was slow. In the 1960s the study of nuclear power was undertaken by a division within the Electric Research Institute, later to be transformed into an independent Nuclear Power Research Institute in Suzhou.[42] In this military–civilian competition, which was to be settled in the early 1980s, the Ministry of Electric Power and Water Resources had always been at a disadvantage compared to the Second MMB.

It was on 11 September 1966, that a joint report submitted by the Second MMB and Shanghai Municipality to Premier Zhou Enlai proposed, for the first time, to build a nuclear 10,000 kilowatt pressurized-water power reactor in eastern China.[43] Nothing much was done about this due to the Cultural Revolution, though research continued at the Institute of Nuclear Energy Technology, Tsinghua University, and at the Shanghai Nuclear Research Institute. Once the Cultural Revolution had subsided, the issue of nuclear power stations resurfaced and Zhou Enlai stated in November 1970 that the Second MMB was not only a "ministry of explosions" (*bu guang shi baozhabu*) but that it should also be involved in nuclear power. As CSC chairman, he listened to reports on the construction of nuclear power stations on December 15.[44]

These reports culminated in a proposal by the Shanghai Municipality Nuclear Power Station Engineering Leadership Group to build a 300,000 kilowatt (or 300 megawatt) pressurized-water nuclear power plant. First initiated by Zhou Enlai on 8 February 1970 (hence its code-name "Project 728"), it was submitted on October 25, adopted by the State Council in August 1973, and formally approved by the CSC headed by Zhou Enlai on 31 March 1974. On 13 April the State Planning Commission issued its "Notice Concerning the Inclusion of the Shanghai Nuclear Power Plant in Plans" so that the Second MMB and Shanghai Municipality incorporated "Project 728" into their capital construction plans for 1974. Earlier, "to adapt to the need for nuclear power in developing the national economy, development of fuel elements for nuclear reactor power stations got underway in 1973 and construction of a production line for this type of element began in 1975 [in Yibin, southern Sichuan]."[45] Progress, however, was very slow and China's first large-scale civilian nuclear program was disrupted and aborted mainly for political reasons and bureaucratic–technical debates. At the same time, China's military–nuclear programs had made considerable headway.

By the time of Mao's death in September 1976, China had conducted 18 nuclear tests altogether, including three tower-mounted, two underground, two atmospheric, ten airdropped, and one missile-delivered.

Under Mao, strategic weapon programs, as well as the industrial infrastructure supporting them, were given a solid priority over all other aspects of conventional weapon production.

Twenty years before his death he had said: "If we are not to be bullied in the present-day world, we cannot do without the bomb. Then what is to be done about it? One reliable way is to cut [conventional] military and administrative expenditures down to appropriate proportions."[46] Meeting a Japanese Socialist Party delegation on 21 April 1957, Mao elegantly rejected its suggestion that China, like Japan, should use atomic energy *only* for peaceful non-military purposes. He said: "That is fine. We have no money, or other economic resources. It takes a lot of capital and electricity [to develop the atomic industry], but we have neither of them". He went on to emphasize China's need to have atomic and hydrogen bombs as a defense measure against the United States.[47] Strategic weapon programs had thus become "the keystone of all military industry, whose sophistication and competence (not to mention budgets) outdistanced all other modern economic activities in China."[48] Under different priorities and less threatening circumstances, this accumulated production potential, and claimed sophistication, competence, advanced technology and expertise, could also have been used for non-military purposes. Such circumstances, domestic as well as international, and a new order of priorities, emerged after the death of Mao in September 1976 and the overthrow of the radical Gang-of-Four leadership a month later.

China's Nuclear Complex after Mao: Military–Civilian Combination

Unlike the Maoist leadership whose principal preoccupation especially from the late 1950s to the late 1970s had been China's socio-political transformation and revolutionary change based on self-reliance, its successors, led by Deng Xiaoping, have underscored economic growth and modernization at home, and stability and openness abroad. Following these guidelines, adopted by the crucial Third Plenum of the Eleventh CCP Central Committee in December 1978, China's defense industries were urged to start experimenting with civilian production and to engage in foreign trade, technical exchange, and international cooperation with other countries.

It is important to note that the principal incentives for China's military-to-civilian conversion in general, and nuclear conversion in particular, have been endogenous rather than exogenous.

When the initial (experimental) policy was put forward, China's threat perception was still high and Moscow was still regarded as the main and most immediate danger to Chinese security. Nonetheless, it was social and primarily economic considerations which had motivated the rather vague idea, put forward in the late 1970s, that much of the nuclear (and conventional) defense industry potential, used in the past almost exclusively for military production, had an underutilized human and material surplus capacity which now could and, indeed, should be converted for civilian purposes.[49]

Origins and organization

Foreshadowing the forthcoming policy transformation, some defense industries tentatively, boldly and almost voluntarily began to convert part of their surplus military potential to civilian use as early as 1977, immediately after Mao's death. Shielded and cultivated from above, the nuclear industry—the pearl in the crown—was apparently slow to detect the new drift, until 1981. It was then that Beijing decided to cut down investment in capital construction of the nuclear industry by 30 percent, as well as funds for purchasing nuclear products, and to postpone or to partly postpone eleven large- or medium-scale projects. This policy continued throughout the Sixth Five-Year Plan (1981–1985), forcing the nuclear industry to concentrate its human and material resources on mining, metallurgy, and the production of nuclear fuel and civilian nuclear equipment. Yet, to successfully accomplish conversion, China's nuclear industry had to overcome its unique problems, in addition to those shared by other defense (as well as all state-owned) industries.[50]

To begin with, while all defense industries in China (and elsewhere) had been secluded from the market forces for many years, the nuclear industry was a particularly closed system which, because of its sensitivity, had been developed in total secrecy and under tight security measures. Secondly, geared almost exclusively for military purposes, China's nuclear industry and research complex have been so highly specialized, and dangerous, that "the existing production facilities and equipment could not be directly converted to civilian production." Also, working entirely for the government and absorbing huge, and often wasteful, state financial, human and material resources, "its business philosophy, management system, economic policy, operational methods, and work styles all were incompatible with the requirements of conversion to civilian status."[51]

Thirdly, although some of China's defense industries, especially Third Line enterprises, were scattered all over the country, two thirds of China's nuclear complex were located in deserts and mountainous regions, far away from the main urban commercial and industrial centers. The consequent difficulties in transportation, communication, and information further complicated conversion. Moreover, since the late 1970s, many talented young people have declined to study the nuclear science profession because of the Third Line inhospitable living conditions, thus creating concern about training China's next generations of nuclear scientists and technicians.[52] Finally, whereas other defense industries had earlier managed to gain at least some experience in civilian production which could be useful and helpful for conversion purposes, the nuclear industry had failed to accumulate much significant experience in civilian production (although a small number of civilian reactors and programs existed), and practically none whatsoever in what was to become its principal civilian preoccupation namely, nuclear power plants. In fact, due to its complete isolation from the rest of the world, and the adverse effects of the frequent political turmoil, China's nuclear establishment had not been advanced as far as Beijing later claimed, despite its remarkable military achievements.

Bearing in mind these difficulties and limitations, China's nuclear industry managed—though at a much slower pace compared to other defense industries—to make enormous progress in implementing its policy of "preserving military [needs] while converting to civilian [production]" (*baojun zhuanmin*), first put forward at a Second MMB working conference in April 1979.[53] Now responding to the official line, a joint Second MBB and COSTND conference held on 12–13 February 1981, confirmed the earlier policy that the nuclear industry should give priority to assuring military needs while shifting its focus towards the national economy.

To do this and to overcome the shortcomings, a variety of means and policies were adopted leading to reorganization which reduced centralized state control, and increased flexibility, decentralization, initiative, competition, 'civilianization,' 'openness' and thereby transparency. An outstanding example of this approach is China's military reprocessing plant, construction of which was completed at the Jiuquan Comprehensive Atomic Energy Base in 1970. Since the early 1980s it has operated according to the principle of *baojun zhuanmin*, by assuring military production while at the same time developing civilian goods.[54]

In the gradually evolving decentralized economy, marketing these goods has become indispensable. One of the early organizational measures in this direction, taken by Beijing as early as 1980, was to allow each of the defense industries to establish its own trading corporations. Accordingly, the Second MMB set up the China Nuclear Energy Industry Corporation (CNEIC), also known as China National Nuclear Corporation (CNNC).[55] This was the beginning of a gradual process of changing the names, and nature, of the defense-industrial ministries themselves. As a symbolic step, the Second MBB, associated for so long with defense production, became the Ministry of Nuclear Industry on 4 May 1982, a name intended to give it a more respectable and civilian look though it still remained under firm military control through the Commission of Science, Technology and Industry for National Defense (COSTIND), established at the same time. Shortly afterwards additional corporations were established to deal with specific civilian aspects of China's nuclear industry, such as the China Isotope Company (December 1982), China Nuclear Instruments and Equipment Corporation (March 1983), China Zhongyuan Foreign Engineering Company (April 1983), and the Nuclear Industry Development Research Center (October 1983).[56]

A number of work conferences convened in 1984 and 1985 reiterated the long-term policy of transferring nuclear military technologies to civilian uses. By the end of 1984, much progress had already been made.[57] In January 1986 Beijing reconfirmed that the (former military) Ministry of Nuclear Industry would remain in charge of China's nuclear power construction and in July, in a further step towards civilianization, the Ministry (along with the other defense industrial ministries) was placed under the direct administration of the State Council, while COSTIND remained responsible only for their military R&D and production. Finally, in April 1988 the Ministry of Nuclear Industry was replaced by the China Nuclear Industry General Corporation (CNIGC, *Zhongguo Hegongye Zonggongsi*) under a newly created Ministry of Energy Resources, which in turn replaced and combined all the ministries dealing with energy (coal, petroleum, and nuclear).[58]

By the early 1990s the CNIGC had become a nationwide industrial conglomerate employing a total of 200,000 (of whom 78,000 were scientists and engineers) in over 200 enterprises and institutions.[59] Its responsibilities cover uranium geology and exploration, uranium ore mining, nuclear fuel processing, development of nuclear reactors, production of nuclear instruments and equipment, nuclear scientific and technological research, engineering design and construction, foreign economic relations and trade, as well as domestic and overseas engineering contracts, not necessarily or directly related to nuclear technology (for example, undertaking a housing project in Jordan).[60] It has adopted a policy of relying on its claimed superior technological advantages through improvement and modification, and concentrates on nuclear power construction, isotope applications and radiation-technology applications to such an extent that military-to-civilian conversion has been occasionally referred to as the second founding (or second take-off) of China's nuclear industry (see also Annex).

Some conversion achievements

By the mid-1990s, China's nuclear industry had launched over 300 projects for shifting military technology to civilian use, including the production of rare earth, chemical fertilizers, magnesium metal, titanium dioxide, and electrolytic aluminum, thereby also providing employment for people made redundant by the closing of military facilities.[61]

Indeed, while the total nuclear industrial output increased by an annual average of 20 percent during China's Eighth Five-Year Plan (1991–1995), reaching 12 billion renminbi (RMB), the value of civilian goods produced by nuclear industry enterprises increased by an annual average of 38.3 percent during the same period (24.4 percent in the Sixth Five-Year Plan, 1981–1985) reaching nearly 4 billion RMB in 1995 alone.

By that time, the share of civilian products in the total output value of China's nuclear industry had allegedly reached 80.0 percent, up from 5.2 percent in 1979 (4.7–5.0 percent in 1980), when reform began.[62] This should be regarded as an outstanding accomplishment in view of the enormous difficulties

Table 1: Civilian output value of China's defense industries

(Share in their total output value, in percent)

	Nuclear	*Space*	*Aviation*	*Ordnance*	*Electronics*	*Shipbuilding*
1979			16.8	9.0		
1980	4.7	48.2	16.3	21.0	82.1	30.0
1981		35.4	21.9	26.0	89.1	60.5
1982	9.0	47.7	23.9	20.0	88.7	71.4
1983			25.0	20.0		
1984	13.8	53.4	26.2	29.3		
1985	16.3	65.4	40.1	33.4	92.7	77.1
1986	28.0	73.1	60.0	40.0		79.1
1987	33.0	79.1				
1988	33.7	88.2	70.0	48.0	90.0	80.0
1989	40.0		74.0*	60.0		90.0
1990	60.0–70.0		75.0*	67.0		82.0
1992	61.0					
1995	80.0					

Source: Adapted from Paul Humes Folta, *From Swords to Plowshares? Defense Industry Reform in the PRC* (Boulder, Col.: Westview Press, 1992), pp. 222–257.
* Figures extrapolated

mentioned above, and the consequent fact that the growth of China's nuclear industry civilian production has been slow and gradual. In 1985 its output value reached only 16.2 percent of China's total nuclear industry output value, climbing to 40.0 percent by the end of 1989. It was only in 1990 that the output value of China's nuclear industry civilian products exceeded, for the first time, the output value of military production (see Table 1).[63] By the end of 1994, more than 400 civilian projects using nuclear technology had been established with a total governmental investment of over 6 billion RMB (US $705 million). In that year, the value of CNIGC's civilian production reached 3.6 billion RMB (US $423 million, reaching US $481 million in 1995), representing 80.0 percent of its total output value. It is expected to more than double by the year 2000.[64]

'Converted' products include mini-reactors, automatic fire-warning systems, petrochemical valves, nuclear power valves, radiation immune medical packs, nuclear medical diagnostic instruments, nuclear radiation detection instruments, etc. Some of these civilian products (such as automatic fire alarms and fire-fighting equipment) are highly profitable. One direct by-product of the nuclear military industry which has civilian value is tritium, produced since May 1968 as a thermonuclear weapon charge. After 1980 a new production line began to turn out tritium luminescent powder which has been widely used in China's watchmaking industry. Also, tritium lamps have been developed and a sideline helium-3 isotope separation facility was launched, producing He-3 at a 99.39 percent concentration.[65]

By the mid-1990s China had reached the capability of producing and supplying over 800 varieties of isotopes and isotope products, which are widely used in the field of industry, agriculture, medicine and scientific research. The research, development and production of isotopes and other nuclear technologies for civilian application had already begun in the late 1950s (see above), but gathered momentum since the early 1980s (see Table 2) producing outstanding economic benefits. "Investment is small, with rapid returns; there are high profits, and little energy is consumed. Therefore [the production of isotopes and other nuclear technologies] are called the 'light industry of nuclear industry'."[66] By the early 1990s, over 70 civilian production lines had been built.

Table 2: China's isotope production

	1959	*1965*	*1975*	*1980*	*1984*
Isotope products	33	33	359	483	462
Delivered goods	210	6,000	33,000	51,000	132,000
Number of users	15	80	729	1,070	1,500
Sales value (million RMB)	0.09	0.28	1.60	5.20	9.77

Source: *Dangdai Zhongguo de Hegongye* (DZHGY) [China Today: Nuclear Industry], 1987, p. 331.

Nuclear medicine, though practiced in Mao's China, expanded greatly afterwards. By the mid-1990s nuclear diagnosis and treatment of certain diseases had become available in over one thousand hospitals across China, benefiting some 13 million patients every year. In late 1995, a national nuclear medicine laboratory was opened in Wuxi at the Jiangsu Atomic Medicine Institute, dealing with research and development of radioactive drugs and diagnostic methods. A few months later, the Shanghai Kexing Pharmaceutical Company was established. Sponsored by the China Xinxing Corporation (a military organization subordinate to the PLA General Logistics Department) and the Shanghai Nuclear Institute of the Chinese Academy of Sciences, it plans to produce nuclear-based pharmaceuticals and medicaments and early diagnosis equipment.[67]

In addition to converting its own facilities, the CNIGC provided other enterprises with military–nuclear technologies and equipment which could be applied for civilian uses. Thus, the nuclear extraction-separation technology had a revolutionary impact on the pharmaceutics industry allegedly becoming as efficient as the world leaders. Uranium-mining geological units "with not enough work to keep them busy" used their advanced prospecting technologies for locating other ores and rare metals. In less than three years, for example, they delivered more than 50 tons of gold to the state.[68] Their filtering and ventilation technologies have been applied to the tobacco industry. Nuclear detectors and instruments are gradually becoming widely used in the medical field, the petroleum, coal, and chemical industries, metallurgy, papermaking, transportation, geology, environment and public security. Applied to agriculture, nuclear technology has contributed to great progress, breeding nearly 400 of species of new crops (allegedly accounting for one third of the world's total of new crops), increasing yields (allegedly by 5 million tons per year), reducing insect damage, prolonging the storage life of agricultural products through radiation food preservation technology, thereby creating economic benefits estimated at around 3 billion RMB and pushing China "to a leading position in this field."[69]

Finally, one of the most visible manifestations of military-to-civilian conversion is 'base closure.'

> Chinese examples of a complete abandonment of PLA installations are not only rare but almost unknown.

Among them, the best known (and publicized) is the case of what used to be known as Plant 221 in Qinghai. Permanently decommissioned in 1987, it had been officially called the Northwest Nuclear Weapons Research and Design Academy (*Xibei Hewuqi Yanjiu Sheji Yuan*, codenamed the Ninth Academy), the main center for China's military–nuclear development for nearly thirty years, since it was initiated in July 1958.[70] Situated in Haiyan County 3,200m above sea level east of Qinghai Lake (also known as Kokonor) and 103km west of Xinning, Qinghai's capital, the base, with its 1,170sq km of forbidden zone had appeared on ordinary maps as grassland.[71] Handed over in June 1993 to Qinghai's Haibei Tibetan Autonomous Prefecture, it has become its new capital, now called Xihai Town, "attracting some 5,000 new households from other parts of the prefecture in only two years." Xihai Township now consists of 18 industrial sectors and four residential areas.[72] This agricultural and industrial prosperity is officially explained, first, by the "well-developed infrastructure" including cheap electricity, concrete roads, ready-to-use factory buildings, apartment buildings, shopping centers, theaters and cinemas, hospitals, and sports and recreation centers; and second, by the "reliable ecological environment" based on strictly monitored and supervised radiation count which is said to be only 0.1 percent of the national safety standard.[73] This base closure is regarded by Beijing "as the world's first retired research and production base for nuclear weapons," and as "a product of China's shift of its nuclear industry from military to civilian production" which also "embodies the longstanding principle of the Chinese Government to thoroughly prohibit and dismantle all nuclear weapons." Yet, China's most important and prestigious civilian project—and the most important task in the conversion of its military–nuclear industry—is the gradual construction of China's nuclear power stations.

Generating civilian nuclear power

Whereas China had been faster than some of the most advanced nuclear nations in developing nuclear weapons, and is one of the world's largest uranium producers, it has been lagging behind all of them in terms of building nuclear power plants. In 1990—one decade before the end of the 20th century—China was the only one among the world's five nuclear powers not to have an operative nuclear power plant. In fact, for about a quarter of a century after it had acquired its initial nuclear capabilities (including uranium extraction and enrichment, designing and constructing reactors, and building a variety of nuclear weapons), Beijing failed to develop commercial nuclear power plants.

This failure can be, and often is, attributed to the following reasons: for one, there had been no real need for nuclear power as China had enough oil and enormous coal resources to cope with its rather moderate industrial build-up. For another, Chinese sources occasionally mention political power struggle and radical revolutionary opposition as the main reason for failing to develop nuclear power plants. Others point to institutional contradictions, competition and friction among different bureaucratic authorities.[74] Yet the two principal and intertwined explanations, which become even more meaningful for today's perspective are, on the one hand, the overall priority given in the 1960s and 1970s to military over economic considerations and, on the other hand, the lack of sufficient economic resources, and particularly low uranium enrichment capacity, to simultaneously support a military and a civilian nuclear program.

It has been the reversal of China's order of priorities since the early 1980s putting economic considerations above military ones and creating new economic resources that has finally enabled the Chinese to become engaged in developing nuclear power generating facilities. They were now in a position to employ tens of thousands of under-employed nuclear scientists and technicians; apply their nuclear military experience and technology (primarily the low-enriched uranium nuclear submarine reactor) for civilian purposes; divert at least part of their weapon-grade uranium enrichment production capacity to producing civilian-grade uranium needed for power plants; and, last but not least, import more advanced nuclear power technology, something which had been impossible and inconceivable in the 1960s and 1970s. Once the decisions had been made, the overall 'successful' conversion of China's military–nuclear industry, including the construction of large nuclear power plants, was guaranteed—not only because of the structural reform or its technological 'superiority' but primarily because of the special treatment it still gets from the state, not to mention exceptional funding.[75]

In addition to their symbolic value as a manifestation of progress, nuclear power plants have now become essential to overcome some economic and ecological problems created by China's unprecedentedly accelerated modernization, not only in Chinese terms but in global terms as well.

Both the need for and the location of China's power plants have been determined by a consistent slowdown of oil production and a growing shortage of energy supply, particularly to the fast-growing economies of its southeastern regions. As of 1994, for example, demand for electricity outstripped supply by 20 percent. Using non-nuclear energy sources, such as coal, oil, or hydro-electric potential, would have led to greater expenses, pollution, road and rail congestion—coal shipments already take up about 40 percent of China's railroad capacity—and faster depletion of scarce national resources.[76]

This is why, following Mao's death and the return of Deng Xiaoping 'from the cold,' nuclear power stations became a 'hot topic.' On 11 August 1977, the Second MMB and Hunan Province submitted to the State Council a joint 'Request for Instructions for the Construction of a 125,000 kilowatt Nuclear Power Plant in Hunan' to be completed in 1985. While nothing much has been heard about this request, Li Xiannian approved a 'Report on the Question of Constructing the 728 Nuclear Power Plant' in February 1978 written by the State Planning Commission, State Construction Commission, and State Science Commission. Apparently, disagreements emerged because on 31 January 1979, Gu Mu convened leaders of these organizations, as well as representatives of the First MMB, the Second MMB, and the Ministry of Electric Power and Water Resources for a conference to study issues related to the construction of a 300,000 kilowatt pressurized-water nuclear power plant in Shanghai. The nature of these disagreements can be guessed by reading the concluding lines—and between them: "The conference felt that the main purpose of this project was to gain an understanding of nuclear power plant design and equipment development technologies, not to build several nuclear power plants. The work had already gotten under way so it was not appropriate to take rash actions." [77]

Throughout 1979, the Second MMB continued to claim predominance in the field of nuclear power. On 2 July it submitted a 'Request for Early Approval of the Construction of Two Experimental Nuclear Power Plants' to COSTND and on 21 September it established its 'Nuclear Power Bureau.' It was only on 2 January 1980 that the CCP Central Committee agreed not only that research on nuclear power plants be reinforced but, moreover, that the Second MMB "is the ministry of atomic energy industry" (*shi yuanzineng gongyebu*) and as such should assume unified responsibility regarding the peaceful uses of atomic energy, while organizing cooperation.[78] Consequently, on 27 October 1981, the Second MBB decided to establish the China Qinshan Enterprise Company (*Zhonghua Qinshan Qiye Gongsi*, also known as *Huaqin*).

Shortly afterwards, in November 1981, "Project 728" was finally approved by the State Council and it is in this context that the NPC decided on 4 May 1982, to rename the Second MBB "the Ministry of Nuclear Industry" (*Hegongyebu*). Its 300,000 kilowatt nuclear power plant—China's first—would be built in Qinshan, Haiyan County, Zhejiang Province, based on the decision of the State Economic Commission made on 2 November 1982. Yet, its construction was still delayed by on-going debates about technical and other issues. These included the reactor type (pressurized water, heavy water, or gas-cooled); the strategy (self-reliance or import); the enrichment technology (gas diffusion or gas ultra-centrifugal process), and the role of nuclear heat and R&D for advanced reactors (high-temperature or low-temperature nuclear heating reactors). This debate over China's nuclear energy policy was finally resolved in early 1983 at a joint meeting of the State Science and Technology Commission and the State Planning Commission, attended by over a hundred experts and technocrats. In addition to issues of reprocessing, recycling and safety, the policies adopted included the following:[79]

- The Pressurized Water Reactor should be adopted as the major reactor type for the first generation of Chinese nuclear plants.
- The unit capacity of each commercial power reactor should be in the range of 900 to 1,000 megawatts.
- The domestically designed 300 megawatt prototype Pressurized Water Reactor should also be built in order to gain experience.
- Foreign nuclear plant equipment and technology should be imported to combine with indigenous and coordinated R&D efforts.
- China should become self-reliant in its nuclear fuel supply, and the gas-centrifugal technique should be developed as the mainstream fuel process.
- Nuclear heat-production should be developed and a low-temperature heating prototype reactor should be built to gain experience.
- Research work on advanced reactors such as fast breeder, high-temperature reactors, and fusion reactors should be continued.

It was on the basis of these policies that the building of China's nuclear power stations began. Located in Qinshan (in Hangzhouwan, or Hangzhou Bay, Zhejiang Province, 100km south of Shanghai), and Dayawan (or Daya Bay, near Hong Kong and Shenzhen, China's most prosperous Special Economic Zone, Guangdong Province),[80] the first two power plants have flexibly combined China's own experience and technology with foreign experience and technology. Professor Ouyang Yu of the Chinese Academy of Engineering, chief designer of the Qinshan Nuclear Power Plant, China's first, had successfully designed a nuclear reactor for military use in 1966.

Construction of Qinshan began on 1 June 1983. While the initially planned state investment had been 1.3 billion RMB, China spent a total of 1.776 billion RMB in building the Qinshan Nuclear Power Plant. Using a standard pressurized-water reactor, local technology and equipment, supplemented by knowledge gained from China's nuclear submarine reactor experience, as well as some imported components (worth about US $100 million, or nearly 42 percent of its total cost), this is a relatively small-scale one-generator reactor with an installed capacity of 300 megawatt (300,000 kilowatt). It was completed by the Chinese mainly on their own and went into operation on 15 December 1991, entering the power grid in 1992. Its annual electricity generation increased from 1.7 billion k/h in 1993 to 2.2 billion k/h in 1995, 26.6 percent above the plan, with a high rate of efficiency and safety, and minimal damage to the environment. One reason for these achievements is Qinshan's full nuclear power generator simulator set, completed for the first time in China in November 1995 at a cost of US $5.45 million. It is being used for training operators, verifying procedures, obtaining information, raising performance levels and efficiency and for promptly preventing or handling problems and emergencies.[81]

Daya Bay, China's second nuclear power plant, had been based on a joint venture approved by the Nuclear Power Leadership Group (established by the State Council on September 1983 under Li Peng) on 12 December 1983.[82] Its construction began on 3 October 1986. Using a US $4.2 billion investment, this joint venture—perhaps China's biggest to-date—between Guangdong's Nuclear Power Company (75%) and Hong Kong's China Light and Power Company (25%), with an investment of US $1 billion, was planned to supply 70 percent of its electricity to Hong Kong and 30 percent to Guangdong. Unlike the Qinshan power plant, the Daya Bay power plant relies heavily on foreign technology, imported from France (two 985 megawatt generators) and the United Kingdom (the steam turbines and non-nuclear equipment). Trial power supply to Hong Kong began in August 1992 and the two reactors became operational in February and May 1994 respectively. In 1995 it reportedly provided more than 10 billion k/h of electricity (though with some breaching of safety procedures) and in its first two years of operation it generated a combined output value of over US $700 million.[83]

The next step is the second-phase construction of the Qinshan Nuclear Power Plant (or Qinshan II). Approved in late 1995 following a State Council decision made in early 1986 with a total investment reaching 14.2 billion RMB, it was launched on 2 June 1996, after years of preparation. Located in Yangliushan (126km south of Shanghai and 92km north of Hangzhou) and based on two power-generating units of 600,000 kilowatt capacity each, construction of the project is planned to take six years with the first power-generating unit going into operation in June 2002. When entirely completed in June 2003, the plant would provide 7 billion k/h of electricity for east China to help overcome its serious energy shortage.[84]

According to the policies adopted in 1983 and 1984 which insisted that fuel for China's nuclear power plants would come from Chinese sources, nuclear fuel for the Qinshan and Daya Bay as well as other nuclear power plants is to be provided by the converted Yibin Nuclear Fuel Component Plant on the southern border of the Chengdu Basin in Sichuan (formerly known as Plant 812). Now a subsidiary of the (nuclear industry's) Jianzhong Chemical Industry Corporation, it officially went into production in April 1994, nearly twenty years after its construction had begun in 1975, in cooperation with France's Framatome Nuclear Power Group, on whose technical assistance it has relied since the early 1990s.[85]

Qinshan's second-phase is the first of four new nuclear power plants with eight generating units, to be built during China's Ninth Five-Year Plan (1996–2000). When completed, they would add 6.6 million kilowatts thus raising China's total installed nuclear capacity to 9 million kilowatts. The second project, the construction of which began in July 1996, is Guangdong's Ling'ao Nuclear Power Plant, just one kilometer east of the Daya Bay Nuclear Power Plant and 60km away from Hong Kong. By the year 2000, this will become China's second largest energy enterprise next to the Three Gorges Project. Investment in its two 985,000 kilowatt generating units will reach US $4.5 billion to be covered by US $400 million of capital stock, US $2.3 billion of—mainly British and French—export credits, and US $1.8 billion of foreign commercial loans, to be raised by China's Industrial and Commercial Bank, an agent of the State Development Bank. As a replica of the Daya Bay plant, all the generating equipment needed will be imported, probably from France. Ling'ao's two reactors are due to be commissioned in 2002 and 2003, the same as Qinshan II. The third project is Qinshan third-phase or Qinshan III: two 700,000 kilowatt CANDU (Canadian deuterium-uranium reactor) generating units heavy water reactor, to be built with Canadian financial and technical assistance according to an agreement of cooperation on the peaceful use of nuclear energy signed in November 1994, and a memorandum of understanding signed in October 1995. And the fourth project is Wafangdian nuclear power plant (on the coast of Bohai Bay, Liaoning Province), using two VVER 1,000 megawatt Russian reactors to be designed by the Atomenergoproyeky Institute in St. Petersburg.[86]

Four additional power plants, to be built in the provinces of Jiangsu, Shandong, Fujian and Jiangxi, have passed pre-feasibility studies but are still waiting for governmental approval. Long-term plans have been made to build additional nuclear power plants at Yanjiang (226km west of Hong Kong), in Guangdong and in a number of other provinces and cities including Hunan, Hainan, Heilongjiang, Jilin, Nanjing and Chongqing. Zhao Renkai, vice chairman of the China National Nuclear Corporation said that China's installed nuclear capacity will reach 15,000–17,000 megawatts by 2010, 30,000–40,000 megawatt by 2020, and 150,000 megawatts of operating capacity by 2050.[87] These predictions are very optimistic.

It is too early to judge the long-term economic contribution of China's nuclear power plants which is still extremely marginal in domestic terms.

Of China's total electric energy supply, around 81 percent is still produced by coal and oil, and around 18 percent by hydroelectric power. The share of nuclear energy in China's total electricity output was 0.3 percent in 1993 and 1.0 percent in 1994, or 0.1 percent of the total world nuclear energy production. This is far below the 17 percent share of nuclear power generation in the total world electric energy production (to reach 24 percent by 2001) or other countries' achievements (such as 80 percent of France's total generated power, or 22.7 percent of Japan's). China's two operational nuclear power stations (0.5 percent of the 430 all over the world) have a combined installed capacity of 2.4 million kilowatts (less than 0.7 percent of the total international capacity of approximately 345 million kilowatts). By 2001 China will have six operational nuclear power stations (slightly over 1 percent of a total of 558 predicted for the world as a whole with a combined installed expected capacity of 9 million kilowatts, 3.75 times its current capacity, still less than 2 percent of the total international capacity of 460 million kilowatts.

According to official Chinese sources, the installed capacity of nuclear power plants by the year 2020 is expected to account for more than 6 percent of China's total electricity generating capacity.[88] In fact, while China's nuclear electricity generation is being *expanded* at a great cost, its share in the national electricity generation will gradually *decrease* because more conventional power stations are being built, and much faster. Yet, since China is a big country, the contribution of nuclear-generated electricity should be examined on a regional rather than a national basis. Indeed, while some regions will have no nuclear power stations well into the twenty-first century (the north, northwest, southwest and, until 2010, also the northeast and the center), and while the share of nuclear electricity in the east will remain rather small, the share of China's nuclear electricity in the south had already become meaningful by 1995—over 9 percent of its installed capacity and nearly 12 percent of its electricity generation—and would become even more significant by 2010 (14 percent of installed capacity and over 17 percent of electricity generation, see Table 3).

Table 3: China's nuclear electricity capacity and generation

(In gigawatt and trillion watt/hour)

	Installed capacity						*Electricity generation*					
	1995		*2000*		*2010*		*1995*		*2000*		*2010*	
Region	Gw	%	Gw	%	Gw	%	Twh	%	Twh	%	Twh	%
North	-	-	-	-	-	-	-	-	-	-	-	-
Northeast	-	-	-	-	5.0	5.70	-	-	-	-	27.5	6.20
East	0.3	0.56	0.9	1.03	5.1	2.83	1.6	0.58	5.0	1.17	28.0	3.17
Central	-	-	-	-	2.4	2.78	-	-	-	-	13.2	3.25
South	1.8	9.21	1.8	5.34	9.8	14.00	9.9	11.78	9.9	6.84	53.9	17.08
Southwest	-	-	-	-	-	-	-	-	-	-	-	-
Northwest	-	-	-	-	-	-	-	-	-	-	-	-
China (total)	2.1	1.06	2.7	0.9	22.3	3.55	11.5	1.20	14.9	1.02	12.6	0.42

Source: Adapted from James P. Dorian, *Energy in China, Foreign Investment Opportunities, Trends and Legislation* (London: Financial Times Energy Publishing, Pearson Professional Ltd., 1995), pp. 107–109.

Notes:

Gw – gigawatt
Twh – trillion watt/hour

In addition to these large-scale nuclear power plants, the nuclear complex has also worked out a long-term plan for the development of smaller-scale nuclear energy sources, and accelerated the R&D on fast neutron breeder reactors, high temperature gas cooled reactors, and fusion-fission reactors. In 1981 research began on nuclear-generated thermal energy and a number of nuclear heating experimental reactors have been tested.[89] China's first 5 megawatt thermal low-temperature district heating reactors went critical and delivered heat to a local grid in November 1989. It is part of a larger project of building safe urban heating reactors to satisfy a tremendous potential market demand for nuclear heating reactors, especially north of the Yellow River.[90]

An experimental fast neutron reactor, to be owned by the Chinese Academy of Nuclear Energy, is expected to be completed by the year 2000. Compared with neutron reactors in ordinary nuclear power plants, fast neutron reactors are capable of raising the utility efficiency of uranium resources sixty- or seventy-fold. Development of fast neutron reactors is essential for meeting China's growing energy needs in the next century. For the same purpose, researchers, mainly from Qinghua University's Nuclear Energy Technology Design Research Institute, have been engaged in the construction of a 10 megawatt high-temperature gas-cooled experimental reactor, to be completed before the year 2000. Capable of providing high-temperature heat effect, "this type of reactor has great potential for application in China's long-range energy system, because it not only generates electricity efficiently, but can also be used in the supply of thermo-electricity, heat extraction from thick oil, and coal gasification and liquefaction."[91]

To overcome its energy shortage China also started controlled nuclear fusion research in the 1950s. Its HL-1 (*Huanliu*, or circulation) Tokamak device was completed in 1984 and was approved after thorough examinations in November 1985, making much progress in nuclear fusion research.[92] It is on this basis that Germany decided to donate an ASDEX unit, an advanced controlled nuclear fusion experimental device. After renovation, it will be used by the Southwest Physics Research Institute (in Leshan, Sichuan) to experiment with electricity generation.[93] Negotiations have also been held between the University of Texas Thermonuclear Fusion Research Center and Hefei's Institute of Plasma Physics of the Chinese Academy of Sciences to jointly upgrade its HT-7U Superconductive Tokamak Control Thermonuclear Fusion Device. Put into operation in December 1994 in Hefei, Anhui Province, this experimental facility is China's largest international research cooperation project ever carried out with other countries.[94]

These international exchanges and the involvement of foreign governments in China's civilian applications of nuclear energy in general, and particularly in nuclear power plants programs (in terms of providing technology, equipment, expertise and capital) highlight additional dimensions of China's nuclear conversion policies.

Some international aspects of conversion

It should have been expected that because of its traditional secrecy and isolation, China's nuclear complex would remain shielded from external probes and interaction. In fact, it has become more exposed and transparent than other defense industries, for a number of reasons.

Endogenously, Beijing's 'Open Door' policy, and its fundamental assumption that it could by no means modernize without external support, have been particularly applicable to the nuclear industry precisely because it had been self-reliant and cut off from the international community for so long so that it could not share the enormous progress made in the field of the peaceful uses of nuclear energy. Exogenously, it is precisely because of the sensitivity associated with nuclear industry, unlike that of other defense industries, that foreign governments, corporations and international organizations have all along insisted on 'unpacking' China's encapsulated nuclear establishment to facilitate monitoring, inspection, and security safeguards—as a precondition for cooperation.

This is why, as early as 1980, China began to sign bilateral cooperation agreements for the peaceful use of nuclear energy with more than ten countries (including Yugoslavia, Italy, Romania, France, the United States, Germany and Brazil, as well as Japan and Australia); to regularly participate in international activities related to this issue; and to establish trade and other relations with some

100 firms all over the world. As mentioned above, following long negotiations, the PRC in January 1984 became the 113th state to formally join the International Atomic Energy Agency (IAEA) which has now been allowed to supervise all Chinese exports of nuclear technology. Moreover, since the early 1990s China has been party to the NPT, MTCR, and CTBT. All these developments have increased the transparency of China's nuclear enterprises and forced them to 'open wider' in order to increase their international cooperation, as well as competition.

Indeed, based on its accumulated experience, and while still *importing* nuclear power plant technology and equipment from Russia and the West, China began *exporting* nuclear power generation technology and equipment. In early 1992, for example, China began building a 310 megawatt nuclear power station in Chasma, 260km southwest of Islamabad in Pakistan, which is expected to become operational in 1998 (its construction was completed in late 1995). Based on the Qinshan model, the 205 tons 310 megawatt turbogenerator with inner water-cooled stator and rotor, as well as pressure heaters, condensers, water tanks and other non-nuclear devices, were built in Shanghai and shipped to Pakistan under IAEA supervision, inspection, and approval.[95]

Algeria provides another example. In 1986, the construction of a two-phase Chinese-designed research reactor was launched in Ayn Oussera, 260km south of Algiers. In April 1991— following reports by the media that the reactor could produce weapon-grade uranium or plutonium—Algeria formally acknowledged its existence for the first time, claiming however that it was a small 15 megawatt research reactor, fueled by slightly enriched uranium unsuitable for nuclear weapons. This was confirmed not only by the Chinese but, moreover, by an IAEA inspection in early 1992. Also, in November 1991 China agreed to sell Syria a 30 megawatt swimming-pool type research reactor. Approved by the IAEA, this small neutron reactor can analyze neutron activity and produce isotopes but can hardly produce weapon-grade plutonium.

Yet, the prospects of using civilian research or power nuclear reactors for military purposes has raised Western, and especially American, concern primarily in the context of Sino-Iranian nuclear relations (see below). Iran's nuclear power program had originated in the late 1960s when the Shah announced a plan to build a chain of 23 reactors. Following extensive negotiations with American, European, and other suppliers in the 1970s, this plan, which had already been in its initial implementation stages at the time of his downfall in 1979, was considerably slowed down afterwards when US–Iran relations deteriorated. Iran's nuclear power infrastructure was further hit in the 1980s during the war with Iraq, and again in the early 1990s when Germany, France and Argentina decided to suspend their nuclear cooperation programs with Iran and to impose more rigid restrictions on the supply of nuclear technology and equipment.

It is against this background that Iran turned to China. In 1987 China began to assist Iran in establishing a 20 megawatt capacity nuclear research reactor northwest of Isfahan. Under US pressure, this deal has reportedly been suspended.[96] In 1991 the Chinese stated that their nuclear relations with Iran (and other countries) were based on three preconditions, namely peaceful applications only, IAEA approvals and inspection, and the customer's commitment not to transfer any nuclear technology or know-how to a third party without Chinese permission. Following an understanding reached in September 1992, China signed an agreement in February 1993 to provide Iran, an NPT signatory, with two 300 megawatt nuclear power plants and to assist Iran in mineral surveying and production of fuel rods needed for this reactor, in addition to the supply of nuclear technology for medical, scientific, research, and training purposes.[97] This agreement was later suspended and postponed, officially due to 'technical' and 'financial' problems, but unofficially due to US pressure.

Other potential Middle Eastern customers for China's nuclear technology include Egypt—which has negotiated with China the acquisition of a 300 megawatt power reactor, to be built near Alexandria[98]—Saudi Arabia, Bangladesh and Iraq. A Saudi diplomat who had defected to the United States in May 1994 claimed that as early as January 1989 China had been ready to sell the Saudis a small nuclear research reactor.[99] Unconfirmed reports claim that earlier, between 1984 and 1986, Beijing had helped Baghdad to conduct a feasibility study with regard to the construction of a nuclear power plant with Chinese assistance. If indeed such cooperation had existed, it has been suspended following the embargo imposed on Iraq in retaliation for its invasion of Kuwait.[100]

To sum up the civilian dimensions of post-Mao China's nuclear system: until the mid-1990s most of China's nuclear complex conversion effort had been directed towards the production of *nuclear*-derived civilian goods, equipment and technology. In the coming Ninth Five-Year Plan (1996–2000), however, China plans to establish a new pattern of civilian production and management which would combine nuclear and *non-nuclear* aspects; technology, industry and trade; as well as combining old bases in the western regions with new bases along the coast. The China National Nuclear Corporation would be gradually reorganized into a mixed-type shareholding corporation solely funded by the state. By the year 2000 the nuclear industry civilian output, maintaining an annual growth rate of 20 percent, would have doubled compared to 1995.[101]

This is one of the most important explanations for China's successful nuclear conversion.

While somewhat released from the state's embrace, China's nuclear complex not only enjoys its considerable material and financial incentives but also exploits its ability to mobilize whatever resources are needed once a decision is made.

As it has managed to overcome exceptional difficulties and drawbacks, the slow and gradual process of nuclear conversion only underlines this ability and determination. At the same time, the increased use of nuclear energy, technology, manpower, and facilities for civilian purposes by no means implies that China has given up, or plans to scale down, its nuclear military arsenal.

China's Nuclear Conversion: Military Implications

To be sure, some of China's military leaders must have become somewhat concerned about the negative implications of conversion policy on arms production in general, and nuclear weapons production in particular. Apparently, these concerns are well-founded and reflect the growing indications that China is no longer producing fissile material for nuclear weapons and, moreover, has no intention of resuming production in the future. Most of China's nuclear weapons factories have reportedly closed down or stopped operating. It appears that, in 1989, China's uranium enrichment facilities had begun a process of conversion from military to civilian production, to provide low-enriched nuclear fuel both for its own nuclear power stations and for export. These two needs possibly absorb China's entire low-enriched uranium production capacity, leaving no capacity for producing weapon-grade high-enriched uranium. Consequently, in 1991, China allegedly also decided to stop producing weapon-grade plutonium in its Jiuquan, Baotou and Yibin facilities.[102]

Yet, from the very beginning of its conversion policy Beijing has consistently reiterated that civilian production would be undertaken only after satisfying military needs so that defense production would not be affected. Accordingly, the termination of fissile material production should not be regarded as an irreversible process. At the same time it should be regarded as an indication that China had already produced a significant stockpile of weapon-grade highly enriched uranium (perhaps three tons, or even more) and separated plutonium (perhaps one ton), which is enough to add roughly 200 nuclear weapons to its arsenal (estimated at 300) or a potential increase of nearly 70 percent.[103] Put differently, China's main strategic constraint is not a shortage of nuclear weapons but a shortage of adequate delivery and interception systems.

> To be sure, as we have seen, until the early 1990s, and unlike its other defense industries, China's nuclear industry output value was still predominantly military, rather than civilian.

The transfer of surplus nuclear resources and technology to civilian use, the greater decentralization of the civilian elements of China's nuclear establishment, and its increased exposure to the outside world, may have only marginally affected China's nuclear military programs or its capabilities. On the contrary, it is quite possible that profits from the sale of civilian nuclear products, both at home and abroad, have been used to invigorate military–nuclear production, which could have been affected by the relative reduction in defense expenditures. This had been one of the earliest incentives for China's conversion policy. Also, the import of civilian nuclear technology, equipment and instruments, and the greater interaction with the international civilian nuclear scientific as well as commercial community could, and probably would, benefit China's nuclear weapons development as well.

While reluctantly joining the NPT, MTCR and the CTBT which ostensibly limit its nuclear options, Beijing still displays no doubts as to the usefulness of nuclear weapons and the effectiveness of nuclear deterrence. "We cannot simplistically think that the emergence of high-tech weaponry has replaced the position and role of nuclear weaponry, neither can we simplistically think that because of its extremely gigantic destructive power, nuclear weaponry has totally negated its own prospects to be used as a weapon."[104] Even if all the treaties and agreements signed by the United States and Russia (which possess 95 percent of over 20,000 nuclear warheads in the world) were to be completely implemented, China could not ignore the fact that they would still have a combined nuclear arsenal of 7,500 warheads—equivalent to 1,600 million tons of TNT—and 1974 carrier vehicles.

While primarily concerned by the nuclear arsenals of the United States and Russia, the Chinese have been carefully watching other nuclear, or potentially nuclear, threats. A noteworthy example is Japan whose potential nuclear threat is double-edged. On the one hand it not only enjoys US nuclear protection (in a defensive as well as an offensive sense), also providing diversified support and services to US military–nuclear forces in the West Pacific Ocean, now aimed at China above all other targets. On the other hand, especially since the early 1990s, Japan has been blamed for purchasing and accumulating large stockpiles of uranium ores; for already activating a number of uranium enrichment plants; for recovering plutonium through the reprocessing of nuclear waste produced by its own 49 nuclear power reactors and also imported from abroad; for exploring new nuclear fusion methods; and for using high-speed macrocomputers to simulate all nuclear explosion processes in three-dimensional space, thereby sidestepping the need for actual nuclear testing. Already regarded as a 'paranuclear state' by international observers, Japan reportedly has all the key components, including the detonation devices and missile technology, needed to make nuclear weapons, and could become nuclear very quickly, perhaps within a year.[105]

Beijing still insists that a nuclear confrontation is avoidable, yet claims that a "nuclear environment" may emerge in the future battlefield, especially in relation to a deterioration of local wars. "When countries possessing nuclear weapons and high-tech conventional weapons are involved in a war with their conflicts intensified, the possibility of using nuclear weapons cannot be ruled out. Nuclear weaponry, therefore, is still a trump card in the hands of nuclear nations."[106] International agreements notwithstanding, the Chinese believe that the scope of nuclear proliferation has been significantly enlarged in recent years. Making nuclear weapons has become that much easier following the rapid development of science and technology as well as the disintegration of Moscow whose unemployed scientists and technicians have been ready to offer their services for sale abroad and whose supervision on domestic nuclear manpower and hardware has eroded considerably. Under these circumstances, nuclear deterrence remains an important means to be used particularly in high-tech local wars. Beijing's Orwellian conclusion is: "The stronger our national defense muscle and the more sufficient our preparations for the high-tech warfare under the condition of nuclear deterrence, the smaller the possibility of the break out of nuclear wars."[107]

Indeed, from the late 1970s and early 1980s onwards, while the PRC was 'converting' its nuclear military industry to civilian use, great quantitative—and especially qualitative—progress was made in its nuclear weapon program.[108] In that period China conducted 27 of its 45 nuclear tests, starting 1964 (see Table 4),[109] though the growing international protests against nuclear testing, and especially Japan's more recent decision to freeze its grant assistance to China, among other reasons, led Beijing, first, to stop all atmospheric tests (the last had been conducted on 16 October 1980 while China's official announcement giving up nuclear testing in the atmosphere was made in March 1986); then to slow down its nuclear tests (for example, two had been conducted in 1995 and 1996, instead of the three predicted); and finally to join the CTBT. This was undoubtedly a difficult decision since China, one of the five nuclear powers, had not managed to carry out more than 45 tests, a little over 2 percent of the total 2,035 nuclear tests, the same as the United Kingdom. This is why, before joining the CTBT, China wanted to gather as much nuclear data and experience as possible.

In addition to these nuclear tests, nuclear weapon production processes were improved; China's first generation nuclear submarine was completed and tested;[110] and the design and development of all strategic missile warheads was completed. Research and development of a new generation of nuclear weapons began emphasizing miniaturization, maneuverability, penetration, safety, reliability, and accuracy—essential requirements of tactical nuclear weapons. It is only since the early 1980s that Beijing has begun to attach great importance to tactical nuclear weapons. While 'conversion' proceeded, much progress was made in this field and, on 19 December 1984, the Chinese allegedly tested their first neutron bomb. "Over the next years, they achieved success in testing these and other low-yield weapons."[111]

The 'conversion' of the military–nuclear industry to civilian use notwithstanding, there is no indication that the PRC is going to give up development of nuclear weapons. In fact, development may well be accelerated.

Table 4: China's nuclear weapons tests, 1964–1996

No.	Date	Yield	Type	No.	Date	Yield (KT)	Type
1	16 Oct 1964	22 KT	Tower blast	24	14 Oct 1978	~ 20 KT	Underground
2	14 May 1965	30 KT	Air dropped	25	14 Dec 1978	~ 20 KT	Atmospheric
3	9 May 1966	200-300 KT	Air dropped	26	13 Sep 1979	?	?
4	27 Oct 1966	12 KT	Missile	27	16 Oct 1980	0.2-1 MT	Atmospheric
5	28 Dec 1966	122 KT	Tower blast	28	5 Oct 1982	?	Underground
6	17 Jun 1967	3.3 MT	Air dropped	29	4 May 1983	?	Underground
7	24 Dec 1967	15-25 KT	Air dropped	30	6 Oct 1983	>20 KT	Underground
8	27 Dec 1968	3 MT	Air dropped	31	3 Oct 1984	4-8 KT	Underground
9	22 Sep 1969	20-25 KT	Underground	32	19 Dec 1984	Neutron?	Underground
10	29 Sep 1969	3 MT	Air dropped	33	5 Jun 1987	?	Underground
11	14 Oct 1970	3 MT	Air dropped	34	29 Sep 1988	1-2 MT*	Underground
12	18 Nov 1971	~ 20 KT	Atmospheric	35	26 May 1990	40 KT	Underground
13	7 Jan 1972	~ 20 KT	Atmospheric	36	16 Aug 1990	50-200 KT	Underground
14	18 Mar 1972	100-200 KT	Atmospheric	37	21 May 1992	1 MT	Underground
15	27 Jun 1973	2-3 MT	Atmospheric	38	25 Sep 1992	50-300 KT	Underground
16	17 Jun 1974	0.2-1 MT	Atmospheric	39	5 Oct 1993	80-90 KT**	Underground
17	26 Oct 1975	10-20 KT	Underground	40	10 Jun 1994	10-40 KT	Underground
18	23 Jan 1976	20 KT	Atmospheric	41	7 Oct 1994	40-150 KT	Underground
19	26 Sep 1976	20-200 KT	Atmospheric	42	15 May 1995	40-150 KT	Underground
20	17 Oct 1976	10-20 KT	Underground	43	17 Aug 1995	20-80 KT	Underground
21	17 Nov 1976	4 MT	Atmospheric	44	8 Jun 1996	20-80 KT	Underground
22	17 Sep 1977	~ 20 KT	Atmospheric	45	29 Jul 1996		Underground
23	15 Mar 1978	6-20 KT	Atmospheric				

Sources: Yen Chun, "Unmasking the Secrets of Communist China's 'Nuclear Counterattack' Force," *Kuang Chiao Ching* (Hong Kong), No. 282, 16 March 1996, pp. 32-37, in: *FBIS-CHI*, 10 April 1996, pp. 64-65; John Wilson Lewis and Xue Litai, *China Builds the Bomb* (Stanford: Stanford University Press, 1988), pp. 244-245.

Notes:
KT – kilotons
MT – megatons

* Neutron bomb.
** According to other sources: 20-40 KT

One indication is the growing Western, primarily American, criticism of Beijing's alleged contribution to the proliferation of nuclear weapons. Such criticism had hardly emerged in Mao's time, when China's nuclear program was predominantly *military* and hidden from international inspection; in 1970, for example, China reportedly turned down Qadhafi's request to supply Libya with an atomic bomb. Criticism has, however, emerged in the post-Mao period, when China's nuclear program is supposed to be increasingly and predominantly *civilian* and is moreover exposed to international inspection. Although Beijing, which signed the NPT in 1992, consistently denies that it has provided any nuclear weapons or nuclear military technology and equipment to any country, circumstantial evidence indicates a growing interaction with a number of countries in the gray and fuzzy borderline between military and civilian nuclear applications. There are a number of examples.[112]

Algeria's China-built nuclear research facility, discussed above, has been suspected of serving military purposes. London's *Sunday Times* alleged that, by the size of its cooling chimneys, this must have been a much bigger 40-megawatt nuclear reactor, potentially capable of producing up to 8kg of military quality plutonium a year. Reiterating that the reactor was being used for civilian and peaceful research only, Algeria firmly refuted these allegations and, though it had not yet signed the NPT, offered to submit the Chinese-made reactor to regular IAEA supervision. Since an inspection agreement was signed in January 1992, little has been said or heard about it.

Similarly, although Syria's Chinese-made research reactor is very small and the deal had been concluded indirectly through the IAEA, it still caused concern in Israel as well as in the United States. Rejected initially, the deal was approved in March 1992 only after Syria, an NPT signatory since 1969, had signed a formal safeguard agreement with IAEA. Nothing much has been heard about this reactor which could not have given Syria more than a rudimentary nuclear capability.

Also, by the late 1980s, there had been reports on China's nuclear assistance to Iraq, another NPT signatory, especially the supply of magnet rings and other components for high-speed centrifuges capable of producing highly enriched weapon-grade uranium. Whatever the reliability of these reports, China's military relations with Iraq were suspended following the Gulf War.

China has also been accused of supplying nuclear weapon and uranium-enrichment know-how, technologies and equipment to Iran. In 1992, Washington thwarted an attempt by Iran to acquire two small 20-megawatt research reactors from China and later almost forced Beijing to suspend its agreement to supply two nuclear power stations to Iran. This US (and consequently Israeli) concern about China's alleged involvement in Iran's nuclear military program often reflects political considerations rather than hard facts. For example, the Chinese cyclotron sold to Iran in the early 1990s turned out to be a desk-top research model. It is inconceivable that China has any interest in Iran—or, for that matter, any other countries, including North Korea—becoming nuclear.[113] While its nuclear relations with Iran have primarily been motivated by economic considerations, they have also been determined by political ones. In reflexive terms, Iran is Beijing's proxy as much as Taiwan is Washington's: both are pawns in a strategic game indirectly used to mutually irritate the adversary, deter its unacceptable actions and retaliate against them once taken.

Apparently, China is indeed careful not to engage in any nuclear transfer of military value. Yet unconfirmed reports suggest that such a transfer could take place without the knowledge—let alone the approval—of the central leadership.

While explorations with Iraq had been cut short by the early 1990s, Iran is still a potential client, not to mention Pakistan.[114] Over the years Beijing has been accused many times of providing Pakistan with nuclear equipment, know-how and even a 'blueprint' for a bomb or a warhead to be adapted to Pakistan's Haft-1 short-range missile. In late 1995, for example, the ostensibly *civilian* state-owned China Nuclear Fuel Corporation reportedly delivered 5,000 ring magnets (worth no more than US $ 70,000) allegedly for Pakistan's uranium enrichment plant at Kahuta which is off-limits for IAEA inspection. China may have also helped Pakistan in its plutonium-extraction facilities. Both activities and technologies are clearly linked to a nuclear weapon program.[115]

Occasionally, China has been blamed for exporting sensitive nuclear materials and for transferring dual-purpose technologies and equipment imported from Japan, Germany and other European countries, to other destinations. Needless to say, Beijing has always categorically denied such practices, underscoring the Chinese government's strict control and supervision with regard to end-users and end use. "No Chinese company has ever violated its commitment."[116]

Conclusion

Over the last forty years, China's nuclear complex has undergone two processes. The first, from the mid-1950s to the late 1970s, involved large-scale civilian-to-military conversion. Hundreds of factories and production lines; tens of thousands of workers, scientists, technicians and engineers; huge amounts of funds, materials, equipment, energy resources, transportation facilities, and land were indeed converted from civilian use to military use in order to promote China's nuclear weapon program which was accorded the highest priority. This enormous complex which, furthermore, was extensively duplicated in the 1960s and 1970s, created a vast surplus of skilled manpower, R&D, and production capacities which could not be fully utilized for military purposes.

This process began to be reversed in the late 1970s, involving a gradual—though equally large-scale—conversion, this time from military to civilian. This reverse drive had been motivated by intertwined domestic and international considerations. On the one hand, the overall priority given to economic growth and development called for reactivating and greatly expanding the underutilized human and material capacity of China's nuclear complex. On the other hand, this process of diverting military resources for civilian use was made possible by the double assumption that China's military–nuclear program could be kept alive, and even modernized, if it were smaller, and, secondly, that the perceived threat had declined considerably by the 1980s, and even more so by the early 1990s, following the disintegration of the Soviet Union.

The gradual and rather slow process of China's nuclear conversion reflects not only a conceptual adaptation to the changing international situation but, moreover, the unique characteristics of China's military–nuclear complex.

While sharing the same disadvantages as other state-owned defense enterprises (inefficiency, lack of competition, waste of resources, over-employment, unfamiliarity with the market, absolute dependence on state capital, etc.), China's military–nuclear complex also suffers from excessive secrecy, compartmentalization, sensitivity, isolation and limited experience in civilian applications of military technologies.

Recently, for example, the former Third Line Mianyang nuclear facility in Sichuan, which had once been praised as a model of converting military enterprises to civilian production, was reportedly declared bankrupt. Thousands of its workers demonstrated in protest against the local government. Over 100 were injured and 80 arrested.[117] However, with a fresh start and based on its prestige and allegedly higher technological standards, some of these disadvantages have been transformed into advantages, leading the nuclear industry to impressive achievements in military-to-civilian conversion.

Due to the lack of precise, reliable and consistent data, it is difficult to estimate the value of China's nuclear conversion in quantitative-economic terms. Yet its quality is easier to assess, especially in the fields of agriculture, medicine, and nuclear power. Using its military–nuclear technology and expertise, China has launched a long-term program of nuclear power station construction which would ultimately improve energy supply with less ecological damage and in a cost-effective way, primarily in the south and southeast. It is these civilian achievements which had provided important incentives and paved the ground for Beijing's agreement to join various nuclear international conventions culminating in the CTBT. This, however, does not imply any Chinese awareness of its weakness or any plan to give up, or reduce, its nuclear military system. Dialectically, the fact that China has been willing to join these international agreements and its military-to-civilian conversion policies in general reflect China's growing sense of self-confidence and awareness of its strength.

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[22] Goncharenko, p. 33.

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[24] At the expense of a newly built aircraft factory. *DZHGY*, p. 168.

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[29] *CTDST*, pp. 62, 182-186.

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[38] *DZHGY*, p. 301. There are nevertheless enormous differences. A submarine reactor should be smaller, lighter, more flexible, more tolerant to shock and vibration and especially safer and more reliable.

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[79] The drafting group was headed by Yingzhong Lu himself. See Lu, *Fueling One Billion*, pp. 58-59.

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[81] Zhao Xiyuan, "Qinshan Nuclear Power Station - The Start of China's Peaceful Use of Atomic Energy," *Renmin Ribao Overseas Edition*, 25 December 1995, p. 3 in: *FBIS-CHI*, 22 February 1996, pp. 18-21; Xinhua, 16 January 1996, in: *FBIS-CHI*, 25 January 1996, pp. 19-20 and Xinhua, 18 January 1996, in: *FBIS-CHI*, 23 January 1996, pp. 23-24.

[82] For background and the negotiations process, see: Dori Jones, "South China Project: China's First Nuclear Plant," *The China Business Review*, No. 1 (January-February 1981), pp. 37-40.

[83] Xinhua, 19 January 1996, in: *FBIS-CHI*, 25 January 1996, pp. 17-18; *CTDST*, 163-164; Lin, 11-13. On safety problems see, for example: *Hongkong Standard*, 20 January 1996, p. 1; *South China Morning Post*, 23 January 1996, p. 3, and *Eastern Express* (Hong Kong), 20 March 1996, p. 4..

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[86] *Ching Chi Tao Pao* (Hong Kong), 22 January 1996, p. 17, in: *FBIS-CHI*, 2 February 1996, p. 19; Xinhua, 6 May 1996, in: *FBIS-CHI*, 8 May 1996, pp. 21-22; Xinhua, 11, 17 June 1996, in: *FBIS-CHI*, 19 June 1996, pp. 29, 75; *South China Morning Post*, 7 July 1996, p. 3; Xinhua, 14 July 1996, in: *FBIS-CHI*, 15 July 1996, p. 8.

[87] Quoted in Suttmeier and Evans, p. 17.

[88] Xinhua, 3 April 1996, in: *FBIS-CHI*, 3 April 1996, p. 7.

[89] *DZHGY*, pp. 214-215.

[90] Lu, *Fueling One Billion*, pp. 59-60.

[91] Xinhua, 8 April 1996, in: *FBIS-CHI*, 19 April 1996, pp. 31-32; Xinhua, 1 July 1996, in: *FBIS-CHI*, 1 July 1996, pp. 32-33.

[92] *DZHGY*, pp. 458-459. Tokamak is a device for producing power through controlled thermonuclear fusion.

[93] Xinhua, 12 June 1996, in: *FBIS-CHI*, 13 June 1996, p. 19.

[94] Xinhua, 10 April 1996, in: *FBIS-CHI*, 24 April 1996, p. 35; Xinhua, 22 May 1996, in: *FBIS-CHI*, 22 May 1996, p. 3, and Xinhua, 23 May 1996, in: *FBIS-CHI*, 28 May 1996, pp. 18-19.

[95] Xinhua, 7 February 1996, in: *FBIS-CHI*, 9 February 1996, p. 8; Xinhua, 5 June 1996, in: *FBIS-CHI*, 11 June 1996, p. 39.

[96] *Washington Post*, 17 November 1992.

[97] Jonathan Reynhold, "China's Cautious New Pragmatism in the Middle East," *Survival*, Vol. 38, No. 3 (Autumn 1996), pp. 106-109.

[98] Yiftah Shapir, "Proliferation of Nonconventional Weapons in the Middle East," in: Shlomo Gazit and Zeev Eitan (Eds.), *The Middle East Military Balance 1993-1994* (Tel Aviv: the Jaffe Center for Strategic Studies, 1994), pp. 223-224, 235-236.

[99] *New York Times*, 7 August 1994.

[100] R. Bates Gill, *Chinese Arms Transfers: Purposes, Patterns, and Prospects in the New World Order* (Westport: Praeger, 1992), pp. 112-113.

[101] Li Bin, "Civilian Products Account for the Greater Part of Products Turned Out by Nuclear Industry in China," Xinhua, 10 January 1996, in: *FBIS-CHI*, 24 January 1996, p. 24.

[102] For more information and sources, see: Gronlund, Wright and Liu, pp. 150-151; Alastair Iain Johnston, "Prospects for Chinese Nuclear Force Modernization: Limited Deterrence Versus Multilateral Arms Control," *The China Quarterly*, No. 146 (June 1996), p. 562; and David Albright, Frans Berkhout and William Walker, *Plutonium and Highly Enriched Uranium 1997* (SIPRI: Oxford University Press, 1997), pp. 76-78, 126-130, 358-360.

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[106] Wu Jianguo, "The Nuclear Shadow in High-Tech Warfare Cannot Be Ignored."

[107] *Ibid*.

[108] See, for example: Colonel John Caldwell and Alexander T. Lennon, "China's Nuclear Modernization Program," *Strategic Review*, Vol. XXIII, No. 4 (Fall 1995), pp. 27-37.

[109] More details in: Robert S. Norris, "French and Chinese Nuclear Weapon Testing," *Security Dialogue*, Vol. 27, No. 1 (1996), pp. 48-50.

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[111] Xue, 13-14, 25-26.

[112] The following discussion is based on: Yiftah Shapir, "Proliferation of Nonconventional Weapons in the Middle East," pp. 223-236. See also: Gill.

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[115] *Economist*, 18.5.96, pp. 59-60; *International Herald Tribune*, 11, 13, 15 May 1996.

[116] Xinhua, 12 April 1996, in: *FBIS-CHI*, 12 April 1996, p. 1.

[117] Zhongyang Ribao (Central Daily, Taibei), 19 July 1997, p. 7.

List of Selected Acronyms and Abbreviations

ASDEX	Advanced controlled nuclear fusion experimental device
CANDU	Canadian deuterium-uranium reactor
CAS	Chinese Academy of Science
CCP	Chinese Communist Party
CMC	Central Military Commission
CNEIC	China Nuclear Energy Industry Corporation (also called CNNC)
CNIGC	China Nuclear Industry General Corporation
CNNC	China National Nuclear Corporation (also called CNEIC)
COSTIND	Commission of Science, Technology and Industry for National Defense
COSTND	Commission of Science and Technology for National Defense
CSC	Special Commission of the CCP Central Committee
CTBT	Comprehensive [Nuclear] Test Ban Treaty
IAEA	International Atomic Energy Agency
INP	Institute of Nuclear Power
MMB	Ministry of Machine Building
MRBM	Medium-range ballistic missile
MTCR	Missile Technology Control Regime
NDIO	National Defense Industry Office
NPC	National People's Congress
NPT	Non-Proliferation Treaty
PLA	People's Liberation Army
PRC	People's Republic of China
RIMP	Research Institute of Modern Physics
RMB	Renminbi (currency of the People's Republic of China)

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Annex: China's Converted Military–Nuclear Enterprises: Selected List

1. China's Institute for Radiation Protection (CIRP)

- Founded in 1961, CIRP's predecessor—the North China Research Institute for Industrial Hygiene—was created in 1962 through the merging of the Beijing Research Institute for Industrial Hygiene, the Taiyuan North China Nuclear Research Institute, and the Shanxi Radiation Medicine Research Institute.

- CIRP has eleven research offices (labor hygiene and occupational disease; radiation dosemetry; radioactive organisms; measurement methods; electronic technology; radiation medicine; radioactive waste disposal; application of nuclear techniques; protection and nuclear safety; etc.), six administrative and service centers for radiation protection, a computer service and equipment center, a technical safety office, an editorial office of books and information, hospitals, factories, etc.

- Its 1,160 employees include 856 scientists and technicians, 175 senior scientists and technicians, and 267 assistant research fellows.

- Services include providing comprehensive environment evaluation, technologies for harnessing radioactivity and industrial waste, biochemical preparations, bio-engineering and tissue culture techniques, immunodiagnosis medical kits, techniques for radiation sterilization and processing, etc.

- Products include various dosimeters, continuous environment monitors, aerosol sampling machines, rock stratum stress gauges for earthquake and landslide forecasts, radon education meters, nucleon scales, and various medicines and medical kits.

- Location: Taiyuan City, Shanxi Province.

2. China Institute of Atomic Energy (CIAE)

- Founded in 1950 as the Modern Physics Research Institute under the Academy of Sciences, it was renamed Nuclear Energy Research Institute in 1958 after launching a heavy water research reactor and a cyclotron, and renamed yet again the China Institute of Atomic Energy in 1984. It has played a key role in China's military–nuclear program.

- CIAE has eight research institutes, over 50 research offices, five pilot-plants, the 'Beijing Atomic Energy High Technology Development Company', joint ventures including the 'Beijing Shuangyuan Isotope Technology Company' and 'Beijing Keyuan Food Additives Technology Development Company', laboratories, a foreign affairs office, an overseas engineering projects office, and various research and testing centers.

- Its 4,500 employees, of which 67 percent are scientific staff, include over 900 high-level research workers, over 1,000 engineers and nearly 1,000 assistant engineers.

- Services include application of nuclear energy and radiation, development and application of energy-saving products, environmental science and environmental protection, biological engineering, etc.

- Products include high polymer materials, new medicines, food additives, fine chemicals, isotope and related instruments and meters, electronic components and devices, heavy water research reactors, cyclotrons, electronic irradiation accelerators, radioactive solutions, sterile generators, etc.

- Location: China Nuclear Town, Tuoli, southwest Beijing.

3. Air Survey Remote Sensing Center of Nuclear Industry (ASRSC)

- Founded in 1963, it is a multi-purpose organization of production and scientific research for air survey, remote sensing application techniques, computers , mapping and demarcation with radioactive instruments.
- ASRSC has five special departments, China's largest air survey team, remote sensing technology application center, radioactive survey measuring station, and 'special organizations.'
- Its 660 employees include 100 senior engineers and over 300 engineers and technicians of various disciplines.
- Services include prospecting and appraisal of minerals; surveying and appraisal of urban planning, engineering, environmental and disaster geology; mapping and analysis of land utilization; various kinds of satellite remote sensing image processing, and optical, photochemical and computer image processing, etc. Products include various kinds of polyurethane
- Location: Shijiazhuang City, Hebei Province.

4. Eighth Research Institute of Nuclear Industry (ERINT)

- Founded in May 1963, it deals with special materials under the Nuclear Fuels Bureau of CNNC. An integrated complex of scientific research, technology and trade, it is mainly responsible for research of applied techniques and technical development and manufactures new products for civilian use.
- ERINT has an engineering technical center for purification filters and research offices for magnetic materials, powder products, metal dust, electronic pastes, and compound materials.
- Products include magnetic rings, filter equipment and materials, shaft casings, diamond blades and grinding equipment and liquids, and a variety of welding and other pastes.
- Its 528 employees include 207 scientists and technicians of whom 44 are senior engineers.
- Location: Jiading County, Shanghai.

5. Beijing Research Institute of Chemical Engineering and Metallurgy (BRICEM)

- Founded in 1958 as the Beijing Research Institute of Uranium Ore Dressing and Smelting, it provided many technological designs and services for China's uranium processing plants.
- BRICEM has over 1,000 employees including more than 230 senior engineers and more than 300 engineers.
- Its main technologies are ore dressing, hydrometallurgy, fine chemistry, organic material synthesis, analysis and testing, environmental protection and waste disposal, and the extraction and separation of individual rare earth elements, including gold.
- Main products include special ion-exchange resin, ion chromatographs, flocculants, various extractants, industrial acid meters, infrared moisture meters, hondrometers, solid state reference electrodes, pyrogenic decomposed graphite products, and standard solutions.
- Location: Jiukeshu, Tongxian County, Beijing.

6. No. 2 Research and Design Institute of the Nuclear Industry

- Since its establishment in 1958 as the Beijing Nuclear Engineering Research and Design Institute (BINE), it has completed the design of over 500 engineering projects and over 1,260 scientific research projects including China's first batch of nuclear industry factories and bases, and has "played an important role in the successful development of China's atomic bombs, hydrogen bombs and nuclear submarines." Following the withdrawal of the Soviet advisers in 1960, it was assigned by the Second MMB to work on a simplified installation for the production of uranium hexafluoride.
- BINE's activities include nuclear reactor physics, reactor protection, environmental protection, waste disposal, machine-building, automatic control, instruments and meters, computers, geological prospecting, heating and ventilation, power supply, etc.
- Its 2,035 employees include 1,678 engineers and technicians, among them 762 senior engineers.
- Services include the research and design of nuclear power plants, nuclear heat supply, nuclear reactors, radioactive laboratories and irradiation techniques. It has also designed factories, more than 70 breweries, more than 20 small- and medium-size thermal power plants, and over 70 civil engineering projects including hotels, theaters, schools, waste disposal projects, department stores, apartment buildings, hospitals, and office buildings.

- BINE has set up agencies in Shenzhen, Beidaihe, and Hainan, as well as a number of subsidiaries, such as BINE New Technology Development Company, BINE Cleaning Technology Development Company, BINE Water Supply and Sewage Development Company and the BINE Automatic Control Technology Institute.

- Location: Huchengmenwai, Haidian District, Beijing.

7. *Shenzhen Kaili Industrial Development Corporation (SKIDC)*

- Founded in 1990, SKIDC operates directly under the administration of CNNC as its 'window' in Shenzhen. It deals mainly with the development, production and marketing of various high technology projects and products such as computers, machinery and electronics, pharmaceuticals, and fine chemicals—based on "the overall superiority" of China's nuclear industry and promoting the transfer of military–nuclear technologies to civilian use.

- Based in Shenzhen, SKIDC has branch offices and industrial bases in Bao'an County and Daya Bay, Guangdong; agencies in Beijing, Shanghai and Guangzhou, and 27 enterprises.

- In the first three years since its establishment, SKIDC has managed to develop aeroplasma cutting machines, a macro information management card system, and a six-color computer embroidering machine. It has also organized military industrial units in undertaking civil engineering projects and labor services, assisted inland nuclear industry enterprises in adopting new technologies and modern management and marketing civilian products, and developed real estate and industrial parks.

- Location: Shenzhen City, Guangdong Province.

8. *Research Institute of Nuclear Power Operations (RINPO)*

- Founded in April 1982, RINPO operates directly under the administration of CNNC. It is China's only scientific research unit for studies of nuclear power operation techniques, combining military with civilian projects. Its main task include ensuring safe, economic, stable and efficient operations of nuclear power plants, undertaking relevant research and experimentation, providing technical service and support for the building and operation of nuclear power plants, and performing administrative functions for their building and running. RINPO is also responsible for designing, testing and developing steam generators for nuclear power installations.

- RINPO has nine units engaged in technical research and production: Research and Appraisal Center for Nuclear Operations; Research Center for Nuclear Power Emulation Techniques; Nuclear Power In-Service Testing Center; Nuclear Power Training Center; Quality Control and Supervision Center; CNNC Nuclear Accidents Emergency Technical Support Center; Nuclear Power Equipment Research and Design Office; Information Study Reference Room; and Pilot Factory.

- Over 75 percent of its 460 employees are technicians, including 130 high-level technicians.

- Location: East Lake New and High Technology Development Zone, Wuhan City.

9. *Gansu Huayuan Enterprise Corporation (GHEC)*

- Founded in 1958 as the Jiuquan Integrated Atomic Energy Enterprise (for producing and processing plutonium and uranium hexafluoride and the final nuclear weapons assembly), GHEC is one of China's first large-scale integrated nuclear energy complexes under CNNC.

- In addition to its headquarters in Lanzhou it has agencies in Shanghai, Beijing and Shenzhen; the Lanzhou Radiation Technology Development Center; the Shijiazhuang Radiation Technology Development Center; and the Shanhaiguan Industry Company and the Shanhaiguan Multiple-Producing Factory in Qinhuangdao, Hebei Province. By 1993, GHEC had 15 subsidiary plants and companies with a total of 33 production lines, producing 77 products.

- Of its nearly 10,000 employees, 26 percent are technicians of whom 13 percent are high level and 30 percent medium level.

- Its products include intelligent automatic fire alarm systems, tritium products, multi-functional ray absorbers, nuclear lamps, nuclear radiation application and food preservation techniques, nuclear instruments and meters, one-shot injectors, infusers, and insecticides and germicides. It has also been engaged in a number of projects such as a production line for anhydrous cupric sulfate powder, a high grade titanium white plant, and a citric acid project.

- Location: Lanzhou City, Gansu Province.

10. Research Institute of Uranium Mining (RIUM)

- Founded in 1962 as the Hengyang Uranium Mining and Metallurgy Design and Research Academy, its more recent multi-disciplinary concerns focus on developing techniques for the dipping and surfacing of such non-ferrous metals as uranium, gold and copper.

- RIUM has seven research offices: mining, mining geology, ventilation and labor protection, mining electronics and machine-building, electronic instruments and meters, chemical and physio-chemical tests, and scientific and technical information. It also has a plasma-cutter producing factory, a radioactivity measurement station and over 30 laboratories

- It has 533 employees of whom 337 (or 67 percent) are technicians.

- Products include bi-directional stone-cutting machines, micro-electrical carryload scrapers, arc-shaped bulldozers, traveling hoisting machines, radioactivity and radio measuring instruments and meters, hydraulic test instruments, and various testing devices. RIUM also offers air plasma-cutting techniques (for stainless steel, copper, aluminum, cast iron, and carbon steel), solvent method uranium mining technologies, heap leaching technologies for uranium, gold and copper, various transportation technologies, smelting and processing technology and equipment, and ventilation and dust-removing techniques for factories and mines (used, for example, by a number of cigarette factories).

- Location: Hengyang City, Hunan Province.

11. China Zhongyuan Foreign Engineering Corporation (CZEC)

- Founded in the early 1980s, CZEC undertakes engineering contracts in the fields of geology, mining, surveying and designing, construction and installation, complete plants and material supply. It also provides research and consulting services and the dispatching of various kinds of labor force abroad; running joint ventures and foreign-funded enterprises, and handles export and import of various commodities.

- CZEC has branch offices or representative organizations in the United States, Europe, North Africa, the Middle East, Southeast Asia and Hong Kong and Macao.

- Location: Haidian District, Beijing.

12. Jianzhong Chemical Industry Corporation (JCIC)

- Originally founded in 1965, JCIC is an industrial-commercial company dealing with production, scientific research, designing, and domestic and foreign trade.

- Its subsidiaries include the Yibin Nuclear Fuel Component Factory (used for producing and processing plutonium for nuclear weapons and now supplying the Qinshan and Daya Bay nuclear power plants with low-enriched uranium), Haikou Jianzhong Perfurmery Industrial and Commercial Company, Metallurgical and Chemical Branch Factory, Chengdu Jianzhong Lithium Battery Factory, Chengdu Jianzhong Marble Factory, Jianzhong Perfumery, Jianzhong Elevator Works, Jianzhong Xinghua Industry Company, Jianzhong Silk Factory, Jianzhong Liquor Factory, Jianzhong Physio-Chemical Research Institute, and Jianzhong Designing Institute. It has agencies in Beijing, Shanghai, Hainan, Chengdu, and Chongqing and its own means of transportation including railway lines.

- Its nearly 10,000 employees, including more than 2,300 engineers, technicians and other specialists, among them 340 senior engineers.

- JCIC's products include nuclear fuel, high purity non-ferrous metals (such as lithium and calcium alloys, lithium salts, lithium batteries, marble and granite slabs, table tops and arts and crafts, essential oils and perfumes, lifts, medical supplies, regenerated PVC leather, pure silk and silk goods, liquors

- Location: Yibin City, Sichuan Province.

13. Huaguang Industry Corporation (HIC)

- A possible facility for enriching uranium to weapons grade, HIC is now engaged in civilian production and has a number of departments including production and planning, personnel, finance, and marketing. In addition to its Hanzhong headquarters with its own railway and highway lines, it has agencies in Beijing, Shanghai and Xi'an.

- Its 3,030 employees including 400 technicians provide the following services: technical development and transformation of related technologies; the designing, construction and machining for civil engineering projects of average industries; physico-chemical analysis; environmental appraisals; waste disposal and technical training.

- HIC's products include microcomputer ionmeters, homogenizers, high-precision electric compensators, high-grade cosmetics, soaps and detergents, and a variety of drinks, such as fiveleaf tea, tea-bags, and cola.

- Location: Hanzhong City, Shaanxi Province.

14. Wuzhou Industry Corporation (WIC)

- Founded in 1969, WIC is an inter-provincial and multi-industrial enterprise integrating production, management, scientific research, and training personnel.

- It has more than a dozen subsidiaries including an electrolytic aluminum factory, a thermal power plant, a water works, the Hefei Fiber Spinning and Weaving General Plant, an aluminum processing plant, a cement works, a machine-building factory, and a transportation department. The Guangxing Aluminum Company is a joint venture. WIC also has business departments or agencies in Beijing, Shanghai, Hefei and Chengdu.

- WIC's more than 7,800 employees include 275 medium level and 64 senior engineers and technicians.

- Its main products include aluminum ingots, aluminum wire rods and coils, Portman cement, diamond saws, PVC resin doors and windows, industrial gases, and various medicines and medical kits.

- Location: Chengdu City, Sichuan.

15. Nuclear Industry Physiochemical Engineering Research Institute

- A comprehensive applied technology research organization, it was known as of 1961 as the Gaseous Diffusion Laboratory for Uranium Isotope Separation of the Institute of Atomic Energy, and in 1963 became the Tianjin Physics and Chemistry Engineering Academy. In the late 1960s it was engaged by the Second MMB in research on the technologies of gaseous diffusion for weapon-grade enriched uranium. Since the 1980s it has applied its military technology to civilian production.

- An affiliate of the China Nuclear Industrial Corporation, the institute has 11 research offices specializing in basic theories, laser, chemicals, machinery, automation, new materials, physiochemical analysis, and information. It also operates three workshops and the management departments.

- Its 800 researchers and technical personnel undertake appraisals of environmental impact, control of industrial waste, and treatment of radiated matters.

- Main products include super-pure metal filter systems, oil submerged electric pumps, air pressure crushers, automatic watering machines, automatic control systems for flour mills, monosodium fluoride, fluoride electron gas, frequency variable speed governors, colliders, speed reduction machines, revolving jet pumps, and various meters.

- Location: Hedong District, Tianjin

Sources: Jin Zhude (Chief Ed.), *Guide to International Cooperation and Investment with Enterprises of China's Defense Industry*, Vol. I (Beijing: The China Association for Peaceful Use of Military Industrial Technology, 1993), pp. 1-36; John Wilson Lewis and Xue Litai, *China Builds the Bomb* (Stanford: Stanford University Press, 1988).

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