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Civil and Defence Science and Technology: China 2025

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The rise of China is an accomplished fact. Many analysts are today trying to describe the various aspects of that rise. Military power is probably the foremost of the aspects that we in India will like to define. This article attempts to put together the facts behind what China is trying to build indigenously and through reverse engineering. The overarching facts of China's military rise are unabashedly described by the Chinese themselves. By 2030, they expect that they will be at the same level of GDP as the United States. The Chinese foresee a decline in the currency of nuclear weapons thereby improving the importance of their huge conventional forces that separate them from the rest of the world. How will they arm this conventional force? The Chinese are even keener than the Indians that they should arm their armed forces without outside dependence. An attempt is made here to describe how successful they can be.

Technology Forecasting

The methodology for technology forecasting has many theories. All of them require a current database to work upon. The US Navy uses a certain methodology, which includes the following four steps:[1]

- Look at emerging new capabilities;
- Assess current industry trends and extrapolate growth;

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- Look at technical standards and emerging obsolescence; and
- Prediction on intentions, trends and wild cards.

By and large, it is this methodology that has been followed in this article.

China, like India, had its frontiers of technology solely in the defence area up to 1989, after which the civilian technology sector, driven by the computer and telecom industries, surged past the defence sector. The Chinese technology sector hierarchy was also modified to incorporate this change. However, even after the restructuring, there still exists a strong civilian technology sector and an equally separate defence sector.

Current Restructured Hierarchy

The hierarchy that prevailed up to the late 1980s was recognised as not delivering advanced science. Whether the present set-up does so will be assessed later in the article. The composition of the present hierarchy (Fig. 1) is as follows:[2]

The Ministry of Science and Technology (MoST)

The ministry, staffed by about 230 employees, has three main functions:

- Formulating strategy and policy for Science and Technology (S&T);
- Administering technology development zones; and
- Managing and publishing S&T information.

The method of auditing the functions of the S&T world is interesting and lies outside the ministry, under the National Centre for Science and Technology Evaluation (NCSTE). The NCSTE has audited 1,000 S&T projects, including the 863 programme. Some of the key S&T programmes run directly by MoST are:[3]

- Key Technologies R&D Programme: It allocates 17 per cent of its funds to agriculture, 40 per cent to high technology and the rest to social development.
- National Hi-Tech R&D Programme (863 Programme): It is a massively funded programme, covering 5,200 projects in 230 subjects, including biotechnology, information technology (IT), energy, materials, telecommunication, marine technology, space and laser programmes. In the future, many of the bigger inputs to defence R&D will come from this programme.

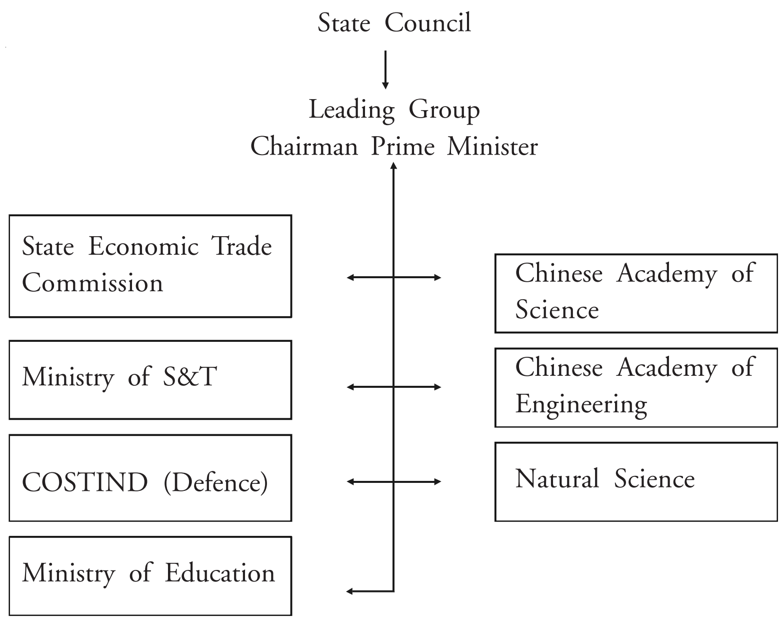

Fig. 1. Overall hierarchy of Chinese civilian S&T (Source: Cao, S., University of Oregon, 2002 as quoted in US Embassy, Beijing's Special Report, Summer 2002).

- 'Torch' Programme: It has funded 2,742 projects, of which IT had the largest share. 'Torch' is mainly concerned with establishing hi-tech industrial zones and marketing hi-tech products.
- The 973 Programme: It is mainly in the area of life sciences, mathematics, energy and environment.

S&T Statistics

China spends 1.5 per cent of its GDP or roughly US$ 16 billion on research as compared to 0.8 per cent by India, 2.51 per cent by the United States (US) and 2.9 per cent by Japan. With this expenditure, China is ranked 8th in the world in terms of number of scientific papers published; ahead of Russia and India, which publish roughly half the number of papers that China does.

Chinese Academy of Sciences

Like the US National Academy of Science and the UK's Royal Academy, the Chinese Academy of Sciences (CAS) elects its 650 academicians fairly and democratically.

However, four CAS members were sacked between 2000 and 2003 for what is widely believed to be protests against party interference in science. Unlike the Western institutions, CAS directly runs about 100 research institutes and even encourages them to start industrial enterprises. The organisational structure of CAS is shown in Fig. 2.[4]

In 2000, enrolment in CAS schools stood at 7,500 masters and 6,200 PhD students. The CAS funds the 'Hundred Talents' programme to attract non-resident technical Chinese, mostly in the US. The programme grants up to 2 million RMB per candidate in assembling a research team and up to 100,000 RMB for the purchase of a house. Statistics show that the number of returning scientists in 2000 was 194 men and 9 women, up from 17 and 9, respectively, in 1995. The CAS sends about 420 students abroad every year, of which 400 return. These innovations are totally different from the Indian scene where talented individuals are unlikely to get independent funding outside the control of existing institutions.

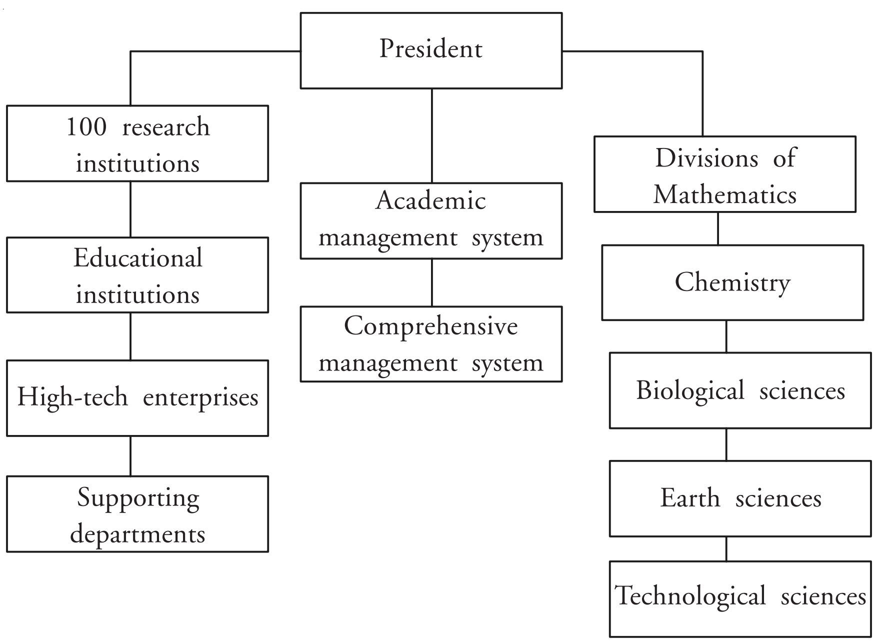

Fig. 2. Organisation tree of CAS (Source: CAS Annual Report 2001).

Chinese Academy of Engineering

The Chinese Academy of Engineering (CAE) has no institutions under it but provides guidance to the engineering community, something like the VDE and VDI of Germany do. The CAE has seven divisions – mechanical and vehicle engineering; IT and electronics engineering; chemical, metallurgical and materials engineering; energy, mining, and civil engineering; hydraulic engineering and architecture; agriculture, light engineering and environment; and medicine and health. All engineering research is done in the universities, particularly in Tsinghua University (the MIT of China). CAE members are elected in manner similar to the CAS.

National Science Foundation of China

Modelled after the National Science Foundation of the US, the National Science Foundation of China (NSFC) has the major task of funding research. Its 1,240 employees scrutinise 24,000 proposals every year of which about 16 per cent are accepted for award of grants amounting to 2.554 million RMB, each award being about 172,000 RMB (about Rs. 1.1 million).

Education

China produces about 25,000 masters graduates every year, increasing at the rate of 10 per cent every year. Many universities give subsidies from profitable enterprises spun-off from the universities. Average tuition costs are 10,000 RMB (about Rs. 70,000) per year. Supporting the universities are about 17,000 vocational schools. Private educational institutions are beginning to open up and admit students who cannot get into government institutions. At present, the strength of this set-up appears to be the vocational schools, which may explain China's huge manufacturing base.

Beijing University

It is the nation's largest university and has a faculty and staff of 17,000 members and 21,402 students. It offers 85 undergraduate majors, 146 masters and 97 doctoral programmes. Considered to be the top ranking science university in China, it has 12 of China's key national laboratories, including one world leader in rare earths material research. It has one national defence laboratory, six education laboratories, seven public health laboratories, and two national centres of engineering research. The most popular subjects for research are IT, bio-medical engineering, nano sciences and nano-technology. The staff, whose salaries are low, supplement their income by tuitions and consulting, often by as much as 200 per cent. About 60 per cent of the Bachelor's classes go abroad, mostly to the US, of whom allegedly 50 per cent return (doubtful).

Tsinghua University

This university has a research grant of 700 million RMB and has launched its own micro-satellite. It also runs a 10 MWe high temperature gas cooled nuclear reactor and has 15 key laboratories. Also, 24 CAS academicians and 24 members of the CAE are from Tsinghua. It is the leading publisher of scientific papers in China and it received 60 per cent of the total funding sanctioned for modernisation of universities in 2000. Tsinghua researchers applied for 441 patents in 2001 of which 77 per cent were inventions. Tsinghua has spun-off 60 enterprises, which earned US$ 1.3 billion in gross revenue in 2001.

From the year 2000, around two to four universities are moving into new buildings and premises every year and as a result, by 2015, China will have totally new university complexes. This author visited the Fudan University in mid-2009 and saw infrastructure that compares with the best Western universities.

Brain Drain

China has had a tradition of its best going abroad to study since 1911. Most of the students going abroad from China are government sponsored. Many private students also go but no records are available for them and it is suspected that many are illegal. Since 1978, when the Chinese reforms started, most of the students going abroad are not returning. However, the government continues to sponsor foreign study. Table 1 illustrates the growth in number of students.

Table 1. Chinese students abroad (Source: China's Statistics Yearbook 2001, National Bureau of Status by China)

Year	Total enrolled	No. abroad	No. abroad as % of total
1980	21,604	2,124	9.8
1985	8,731	4,888	5.6
1990	93,018	2,950	3.2
1995	145,443	20,381	14.0
2000	301,239	38,989	12.9

The number of Chinese students who did not return home is difficult to estimate. One estimate put the number at roughly 200,000 in 1998. The US Embassy in Beijing estimates that 80 per cent of Chinese students in the US become American citizens. During the period that Chinese student numbers went up from 5,000 to 35,000 that of Indian students increased from 10,000 to 24,000. It is estimated that in 2005, more Indian students went to the US than from any other nation. Today, Indian students outnumber the Chinese students. But China has almost 60,000 students studying in Japan.

So far, China has not been successful in combating the brain drain despite the 'Hundred Talents' programme. There is also a Young Scientists programme that funds only scientists below the age of 45 years. But most analysts feel that when per capita income in China rises to US$ 4500, expected after 2020, more Chinese students might be tempted to come home. They admit that differences are narrowing but the turning point is still some way off.

Success of Civilian S&T

The CAS and MoST have encouraged research institutes and universities to establish industrial enterprises. Some of these enterprises have been so successful financially that their profits have gone back to strengthen both the university and the institutes. CAS, as mentioned earlier, has spun off about 100 enterprises, most of them in the fields of IT, new materials, electro-mechanical integrating and most surprisingly bio-medicine. Between 1975 and 2000, the earnings of CAS enterprises increased from US$ 49.5 to 296 million. Some specific success stories of CAS are:

- San Huan Corporation: In 1995, the San Huan Institute was given a 3.5 million RMB loan to market goods with permanent magnetic materials like mobile phones, audio speakers and magnetic resonance imaging (MRI) equipment. The company is now listed on the stock exchange.
- Shanghai Genius Advanced Materials Company: It manufactures advanced plastics and has supplied to Haier, Volkswagen and Mitsubishi. The gross income of this company has grown to US$ 500 million annually.
- Sinosoft Group: This company, spun-off from a research institute, has a registered capital of US$ 600 million and makes multimedia, surveillance and security equipment, and is into museum management, document scanning, highway

systems and postal systems software. In what completes the circle, the profits of this company may be used to invest in a specialised software university.

- Legend Group: This is probably the most successful spin-off. Today, it has a share of almost 30 per cent of China's personal computer (PC) market. Its net profits are over US$ 100 million annually.

University Enterprises

Of all the universities, Peking and Tsinghua have spun off the largest number of enterprises. The net profit of all university-run enterprises is estimated at 1 billion RMB. Some other successful examples of enterprises born out of universities are:

- Tsinghua Tongfang Company: The Tsinghua University spun off the Chengzhi company, which in turn spun off the TUEG company that specialises in IT, energy and environment. This company then spun-off Tongfang, which makes chemicals, medicines and automobile parts.
- Founder: A successful spin-off of Peking University, its expertise is in laser imaging and processing for newspaper publishing. It is also into computer hardware, display terminals and laser printers. This company has since established the largest electronic publishing database.
- Zhongguancun Science Park (ZSP): It is China's Silicon Valley and was set up in a corporate effort by CAS, MoST and State Scientific Councils. It is spread over 280 sq. km and has the research laboratories of Microsoft, Nokia, Hewlett Packard and Mitsubishi. ZSP has a gross output of 26 billion RMB and has opened offices in California, Amsterdam and Tokyo. The enterprises in ZSP earned a total of US$ 3 billion in foreign exchange in 2005 and are expected to earn US$ 8 billion in 2010.

Today, all provinces of China have at least one technology park where the laws of privatisation and labour are different from the rest of the country.

Strategic Thrust

Looking at the emphasis on the PhDs in Beijing University and Tsinghua University, the type of enterprises spun off from the CAS institutes and universities, and the emphasis on investment in ZSP, it is clear that the Chinese civilian S&T is concentrating in the following specific areas:

- Nano-technology and nanoscience;
- Bio-medical equipment;
- Biotechnology;
- Laser and optic-mechanics;
- New materials; and
- Hardware for IT and telecom.

Apart from these areas, major research institutions in mining, oil exploration and water management exist outside the ambit of MoST and these are funded by other ministries.

Deductions

As stated earlier, the number of scientific papers published in China today is almost double of what is produced in present day Russia and India. However, many analysts have begun to question as to how the former Soviet Union managed to create many islands of state excellence in an otherwise impoverished society, and leap ahead in medicine, armaments, shipbuilding, aeronautics, satellites, space, nuclear engineering and nuclear physics while China does not seem to be able to do the same, using the same state methodology. This is an interesting but tricky question. This author spent many years in the former Soviet Union and the chief difference between the Soviet Union of the 1950s and 1960s, and China of today is the wide gap between the average Soviet university's high academic standards and the present standards of Chinese universities (which are still 10 years ahead of Indian universities). The huge industrial base of the former Soviet Union was created by more than 20 world class universities, of which standard China has only two today. This is changing, but doubts persist whether allowing universities to hive off successful industrial enterprises will not affect the quality of research in the long run. At present, China has only 11 scientists per 100,000 people compared to 81 for the US and 92 for Japan.

There are two other sectors in which R&D is beginning to boom in China – the local industry R&D and multinational corporation (MNC)-funded R&D centres. Actually, these two sectors should exist solely in the field of applied R&D, an area that has now been 'encroached' upon by CAS institutes and universities. Whether the experiment with spinning off enterprises is successful or not, there is little doubt that as industries in China grow, these two areas of applied R&D will grow in a healthy way, but they will not be at the cutting edge, an area that can only be occupied by basic research.

When looking at China's civil S&T, the question is whether the rise of China will be supported by Chinese R&D and, if so, from which sector of R&D will the big push come from. The answer is that any competition between China and India in the economic sphere will be decided by the levels of applied R&D by Chinese industry and MNC research. But the competition between China and the US will be decided solely by the strength of China's pure research, which is only done by the CAS and Chinese universities, especially as the US begins to start placing its critical R&D list on the Export Control List. Some details of advances in civil S&T are listed below:

- Human embryonic stem cell research: A great possibility is seen in harnessing biotechnology into cell research. It is likely that rapid advances will be made as the Chinese have a large number of human embryos to test. The Sun Yat Sen University has been in the forefront of publishing the most doubtful claims so far. But, in the forefront of regulated research is the Shanghai Huide IVF China, run by a returning Chinese US citizen, and Beijing Medical University.
- China, with its limited agricultural acreage, is not convinced about any biosafety claims. The head of agricultural research in Beijing University has suggested that the US-European Union (EU) dispute be used to further the market for Chinese genetically modified (GM) seeds, which are now freely available to Chinese farmers.
- Legal support for R&D exists in a number of ways in China as in India and include priority in public sector undertaking (PSU) procurement for domestic suppliers, a tax deduction for R&D expenses, tax rebate for technology import, a value added tax (VAT) rebate for software and complete deductibility of payroll expenses for software development.

The Critical Technologies List

Before analysing China's defence science, it will be useful to look at what the US feels constitutes critical technology. The US feels that its primacy cannot be maintained and superior US technology cannot be supplied to competitors, unless such competitors are well below what is seen as the 'sufficiency' levels of each technology. The sufficiency level is the level at which its owner country can become a potential threat to the US. In the weapons of mass destruction (WMD) area, these sufficiency levels are described only in a broad and generalised way, because the effect of even a relatively crude WMD device is 'adequate' as an offensive weapon (Table 2). It will be seen that although the take-off weight to payload ratio of the most advanced Chinese intercontinental ballistic missile (ICBM) is far inferior to the US' MX or the Russian TOPOL missiles, the Chinese have been placed at the same level as the US, because the DF31 missile, although inferior, is considered adequate to threaten the US.

The data given in Table 2 is from 2001. As discussed earlier, many Chinese capabilities in defence areas like missile delivery technology, cruise missiles and, most surprisingly, combat aircraft have already been put on par with the US. This judgment of the US Department of Defence is obviously flawed, but a detailed explanation exists in various amplification tables provided later in the study. The only technology allegedly not available with China as of 2001 as compared to the US, with regard to ICBMs and theatre missiles is the ability to marry the global positioning system (GPS) and other terminal guidance technology to the warhead.

But it is interesting to look at the cruise missile technologies in which China is considered equal to the US.[5] They are:

- Control surface actuators (airframe)
- High wing loading
- High thrust to weight jet engines
- Small turbine engines
- Advanced high energy fuels
- Digital topographic maps to support GPS
- Dynamic test equipment
- Sprayers in the airstream
- Small nuclear weapons

India, for instance, is considered deficient in all these areas, barring engine technology and advanced fuels, where it is considered seriously deficient. Considering that China has no long-range successful land attack cruise missile today (2009), this evaluation of the US is extremely doubtful. It is, however, true that a Chinese long range cruise

Table 2. Technology assessment level in critical technology list of the US: WMD comparable achievements of US/China/India (WMD only) (Source: The Military Critical Technologies List (MCTL), WMD, 1998, Office of the Under Secretary of Defence for Acquisition and Technology, Washington, D.C.)[6]

	US	China	India
Means of delivery technology	ND	ND	Low in all categories
Missiles (theatre)	ND	ND	Low in PBVs, TEL guidance and control
Missiles (ICBM)	ND	Low in GPS and terminal guidance	Low in airframe, low in propulsion, very low in guidance and control
Cruise missiles	ND	ND	Low in airframe, quite low in engines, very low in guidance and control
Combat aircraft	ND	ND	Low in weapons integration, very low in radar signature, very low in high power engines
Artillery	ND	ND	Low in high energy change
Military IT	High	ND	India in security, equal in info-exchange
Biological warfare	High	One step lower in all areas – technologies detection, delivery	Low in detection, low in research
	High		Low in discrimination, detection and defence
Chemical weapon	High	Low in detection and defence	Poor in fusing component manufacture, primitive weapons
Nuclear weapon	High	Unequal to US in fusing and firing, in creating fissile material China and India are roughly at same level except in HEMP, SREMP and pulsed power where China is superior	

ND: No difference

missile is just around the corner. Similarly, since China has no completely indigenously built modern jet fighter, it is doubtful whether the US and China are on par in this area (Table 3). The same doubts extend to smart weapons, stealth and bomb/dynamics.

Table 3. Combat aircraft technology comparison (Source: Department of Defence MTCL Part II, Washington, D.C.)

Technology	US	China	India
Stealth	High	High	Moderate
Propulsion	High	High	Moderate
High energy fuels	High	High	Poor
Digitally drivers actuators	High	High	High
Military grade GPS	High	High	Moderate
Bomb sights	High	High	Moderate
Smart bombs	High	High	Moderate
Bomb flight mechanics	High	High	Moderate

Apart from the WMD list of critical technologies, there is the conventional technological list, referred to as the MCTL Part I, which consists of:

- Aeronautics
- Armament and energetic materials
- Biological systems
- Chemical systems
- Directed and kinetic energy systems
- Electronics
- Grounded systems
- Information systems and warfare
- Marine systems
- Materials
- Navigation
- Power systems
- Sensors and lasers
- Signature control
- Weapon effects and counter-resources

- Nuclear system
- Classified US document in the full version[7]

Amplification of MCTL Part 1

Information Security[8]

This subject is divided into cryptology, digital steganography, identity management and network firewall technology. The sub-division under these four subjects are:

Cryptography	Steganography	Secure identity	Firewalls
Symmetric cryptography		Bar codes	Packet filtering application
Asymmetric		Magnetic stripes	Packet inspection
	Smart cards	Priority cards	

Space Systems

This category has been sub-divided into the following capabilities:

Integration

Examples include anti-radiation hardness, fault tolerance, autonomous operation via artificial intelligence, launch vehicle processing, electromagnetic compatibility (EMC), systems engineering processes and integrated weapons management. In these areas, the Chinese are estimated to be 10 to 15 years behind the US.

Launch Vehicles

At present, a satellite launch in the US costs US$ 90 to 100 million. Russia charges US$ 20 to 50 million. China and India charge less. The largest portion of these costs are on infrastructure and personnel. In these areas, US competitiveness will only decline and China will catch up quite easily.

Structures

New materials, which are lighter, re-usable up to 100 launches and adaptive, are likely to be invented. There is no known Chinese capability in these areas so far.

Propulsion

In the present field of propulsion, the US has no advantages over China. New propulsion technologies include hybrids (chemical, liquid, solid) electric and nuclear thermal. However, the Chinese have no known capabilities in new areas.

Power

Today's acceptable limits are 3-5 W/kg. By 2005/2010, expected increases will be 8-10 W/kg. The US leads in photovoltaic cells, the Russians in nuclear systems and the Japanese in battery powered systems. The Chinese are working on battery systems too, but will remain far behind in deep space exploration.

Communication

The US has no advantage over 34 other countries.

Electronics and Computers

The three parameters considered are radiation hardening, survivability and reliability. In these areas, the US is about 10 years ahead of China as of today.

Guidance and Navigation

The systems used here are so widely of dual use nature that no country has a monopoly in the area. However, the Chinese are about 5-10 years behind the US in being able to integrate GPS into ICBM warheads with high accuracy.

Sensors and Surveillance

Considered the crown jewel of the US space programme, China is about 10 years behind of the US in digital real-time data collection, infrared surveillance and in providing a military integrated architecture. In the last area, the Chinese may even be 15 years behind.

Optics

Information is a bit vague in this area, but it appears that India may be ahead of China in this area. The US is ahead, but not unduly so.

Vulnerability Signalling

Military space systems must be hard to find, to hit and to kill. The defence of satellites is already an active subject in the US and is being managed as follows:[9]

Hard to find	Reduced signatures
	Deception
	Reconstruction
Hard to hit	Autonomous movement
	Manoeuverability
	Attack warning
Hard to kill	Resistant to lasers and kinetic weapons

There is no known research in China in these areas, although they are known to be working actively on anti-satellite (ASAT) weapons, while the US is far ahead in satellite defences.

Aircraft Control

There is no critical technology identified, the denial of which will stop China from reaching the same level of combat aircraft manufacture as that exists in the US. The present gap between Chinese third generation and the US fifth generation is obviously attributable to purely human deficiencies.

Marine Systems

Only a few such systems are considered critical and they include:

- Manufacture and repair of specially designed propellers;
- Water screw propellers with power > 7.5 MW;
- Pump jet propulsion of power > 2.5 kW;
- Variable pressure tunnels for measuring cavitation and accurate fields;
- Passive mounts for vibration in 10-100 Hz;
- Active noise reduction measures for noise reduction > 6 db;
- Acoustic signature coatings;
- Infrared (IR) signature 0.7-20 μm; reduction techniques;
- Radio-frequency signature reduction 1 MHz to 1,000 GHz > 15 db;

- Unmanned untethered submersible vehicles;
- Underwater data transmission and vision systems of > 150,000 pixels and low-light level television (LLTV) cameras; and
- Argon lights usable to 1,000 m.

China is not known to possess any of these technologies, nor does India. However, all these technologies can be acquired in say 10 years and will increase the efficiency of nuclear submarine operations.

Directed and Kinetic Energy Weapons

These refer to the IR and visible regions (0.3-30 μm) and capable of achieving military levels of power. The beam has to acquire the target, point the ray and deposit enough energy. The limits as expected in 2005 are > 20 kW, aim point < 0.25 μrad and spot size < 0.18 m at 250 km. In this area the Chinese are known to have done considerable R&D, which can be used towards an ASAT weapon.[10] The Chinese, it is assumed, are not more than five years behind the US in large lasers.

China's Military Technology: An Overall View

Figure 3 shows Chinese defence industry's current state after the entire reorganisation process is completed.[11] As can be seen, the ministries are in reality super production agencies sitting on top of factory managers and directly controlling aircraft, electronics, machine building and other industrial activity. In many ways, this situation, which is the result of the re-organisation up to 1994-95, is not much different from the incestuous relationship that existed between PSUs and the ministries in India in the 1980s and, in some cases, 1990s too. We now analyse the structure department-wise.

Aviation Industry

Research conducted by China's aviation industry up to the early 1990s only produced the indigenous version of Soviet aircraft like the MiG 17 and MiG 19. Each of these retro-engineered production models took between 19 and 22 years to produce. New research work that begun in the late 1980s resulted in the JH-7 and J-10, both third generation fighters, one generation behind the SU-27 and the SU-30. The JH-7 is an entirely Chinese designed aircraft, but is an ineffective obsolete aircraft for combat in

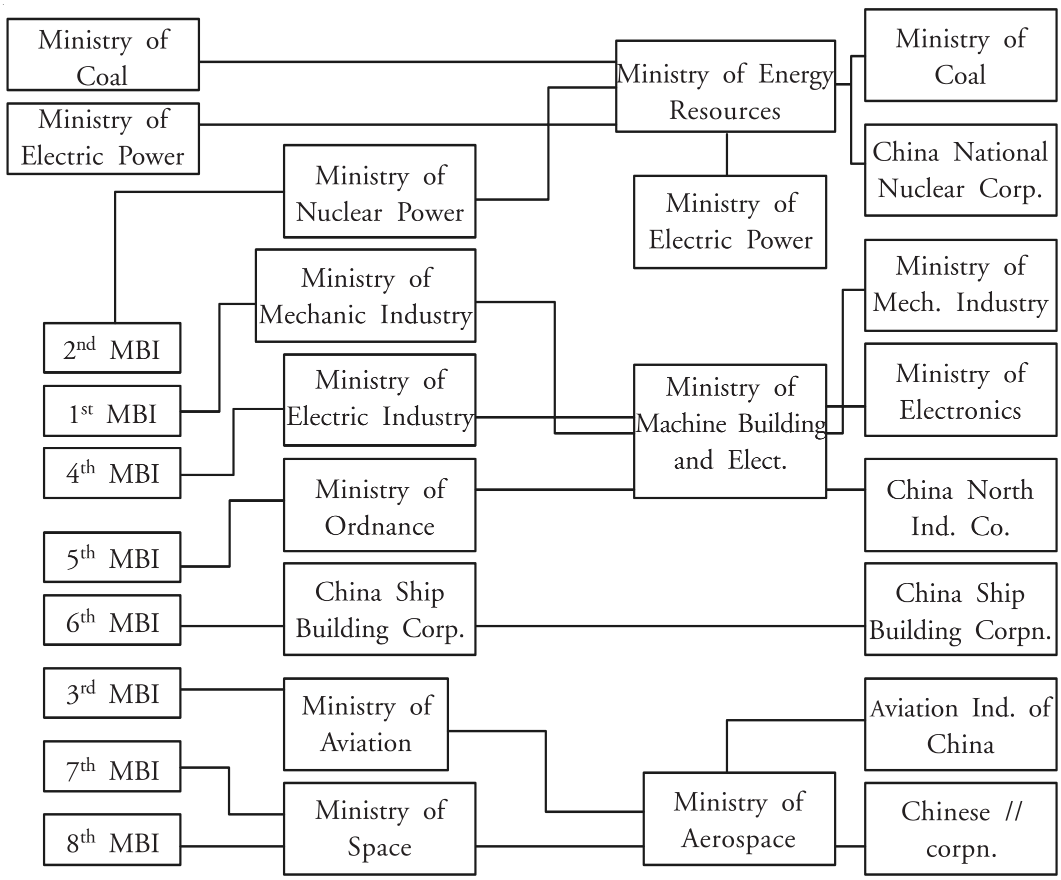

Fig. 3. Present structure of Chinese defence industry. MBI: Machine Building Industry (Source: Modernising China's Military, RAND Corporation, Santa Monica, 2005).

the 21st century. The later version, the J-10 is of Israeli design, taken from the Lavi, but has no matching Chinese engine (1005). In the field of engine manufacture, the Chinese have the Kunlun, but this engine has inadequate power for any serious combat application in the 21st century. Another engine, the WS-10, is under development and may be operationalised in the next five years. In rotary wing aircraft, the Chinese have completely retro-engineered the Dauphin, including all engine components, but is expected to produce a militarily relevant helicopter by 2010, which will be totally indigenous. The helicopter indigenisation programme, if it succeeds, will have taken 25 years. Until the WS-10 engine[12] is produced, China cannot manufacture heavy aircraft like bombers or transporters. This ability will be achieved by 2010-15.

Aviation Industry's Future up to 2020

The days when China's military aviation industry could remain ahead of the civilian technology sector are over. Improvements in China's third generation technology can only come from a heightened level of domestic civilian R&D and, hence, the effort made in this article to establish the status about its civilian technology sector. Some of the most capable people in the aviation research are increasingly opting for private industry. The major factor that drives technological progress in military aviation in the West is competition, a factor lacking in China. The lack of competition goes right down into sub-system manufacturing, components, simulation and design. Unless all these are privatised and access to capital by these industries is not automatic, greater efficiencies will not drive the aviation industry. Although the Soviet aviation industry managed to do without competition, there is no comparison in the resources allocated in China and those made available to Sukhoi and Mikhoyan. Some of the changes that can revolutionise the Chinese military aviation industry include:[13]

- Open bidding for R&D and production contracts;
- Integrate design and production as in Sukhoi or Boeing; and
- Privatise airframe and component manufacture, and make them raise capital in the market.

These reforms will probably take place by 2010-15, in which case, the Chinese aviation industry may be able to stand on its own in some areas. While the gap between China and the US or France will narrow by 2020, the generation of aircraft that China manufactures indigenously will lag behind the West certainly up to 2020-25.

Ship Building Industry

Between 1978, when reforms began, and 2005, the Chinese ship building industry has made truly impressive gains. China is the second largest ship builder in the world and owns 15 per cent of the world merchant ship tonnage. Design bureaus are locked in with shipyards and the combination competes both for domestic and foreign orders. Pre-fabricated and modular construction techniques are prevalent and ships built after 2000 compare with the best in low-cost shipping. The upper end of merchant ship building, like high pressure liquefied natural gas (LNG) tankers are still dominated by the Europeans and Japanese. The same state of affairs prevails with the fishing industry.

The developments in civilian ship building have not benefitted warship and submarine building. Warships before the 052 and 053 series are inferior in design, noise suppression and capability to all classes of Indian warships, even the *Leanders*. The 052 class is a moderate success story, particularly its phased array system, which catapults Chinese warship building two generations ahead. Propulsion and main weapons are still imported and there do not seem to be any weapon systems on the horizon that will change the situation drastically by 2020.

In the case of submarine building, up to 1989, the Chinese were building 1950s vintage Soviet design boats. After the import of the *Kilo* class, the Chinese have received a massive input of design and equipment technology, including quieting anechoic tiles and diesel electric propulsion techniques. China makes no world-class torpedoes, but has retro-engineered the *Exocet* for underwater firing. The prognosis for 2020 is that China will still lag behind the West and in some areas behind India in sensors, weapons and building techniques. The Chinese will be ahead in nuclear reactors, nuclear submarines, underwater ballistic missile technology while in SSNs, the Chinese boat is still expected to be well behind the West.

Force Multiplier Technology: Missiles

The Chinese missile industry is the most successful by far. China's solid fuelled DF-31, which will have an operational life beyond 2025, will stabilise the Chinese deterrence for the next three decades.[14] Their *Ying Ji* missile, retro-engineered from the *Exocet*, equals/exceeds the parent missile in its anti-ship version. By 2020, China will produce an accurate long range land attack cruise missile equal to the *Tomahawk* and surface-to-air missiles equal to the S300. The People's Liberation Army Air Force (PLAAF) already has one indigenously produced beyond visual range missile and one air-to-surface anti-radiation missile. But in the field of counter measures and counter-counter measures, the Chinese tactical missiles will remain one generation behind the West by 2020, although by then China will be basically self-sufficient in all kinds of missiles.

C4ISR Systems[15]

A Chinese data exchange system, based upon digital maps, is thought to exist (2005) up to the Headquarters and Army Command levels. There is also some literature to show that the first intra command system, which has been data linked, is the Tibetan border with Chengdu. These are the only visual data exchanges that are known to exist.

It is easily assumed that by 2020, this system will have percolated down to the tactical levels, probably below Brigade levels. The information on the screens as of today includes electronic warfare and unmanned aerial vehicle information, but what is not yet available is information from satellite surveillance, a shortfall which will definitely be made up by 2020. All this information is carried on what is known as the Army Wide Public Data Exchange Network. This network is partly satellite, very/ultra high frequency (V/UHF), partly co-axial cable, and partly optic fibre, while towards the West of China, there is extensive microwave and tropscatter high frequency (HF) links of low capacity. The carrier network will definitely become broadband by 2020-25. At present, broadband connectivity is assumed to be available only over continental China.

Tactical Missiles

To get an idea of Chinese tactical missile capability, the best example of a tactical missile is the PL-12 or SD-10, which are the same missiles. Roughly equal to the US AIM-120 and the Russian R-77, this missile was expected to be operationally available in 2008-10, roughly 20 years after the US and Russian versions. By 2020, this 20-year gap will probably have narrowed to 10 years.

Chinese Power Projection

Satellite-based wideband connectivity is assumed to be available for a Chinese power projection fleet on a mission up to the limits of the South China Sea. Data linking for a Chinese task force in the Indian Ocean is today done using HF connectivity.

Strategic Technology Capabilities: Overall Assessment

Thirteen strategic capabilities, arising from a combination of civilian and defence S&T and defence R&D have been studied. These exclude two technologies, namely, a terminal homing ballistic missile meant to be used against large aircraft carriers and the development of an over the horizon targetting (OTHT) radar with allegedly huge ranges. Quite possibly these two developments are interrelated and meant to be the Chinese answer for anti-access technology. Doubts exist on the success of both ventures.

The technologies studied fall broadly into the following five categories:

- Mini and Micro satellites that will increase the backbone on which the PLA's command picture will ride.

- A whole generation of UAVs that will give Army formations the ability to generate accurate tactical pictures up to the Brigade level.
- A strategic ballistic missile submarine programme on which will be anchored, an assured second strike, along with a silent nuclear powered SSN.
- Various tactical weapons to be fitted into the next generation of warships to give the PLAN the edge when it encounters other fleets, including surface to air missiles, surface to surface missiles and torpedoes.
- A four and a half generation fighter aircraft to form the mainstay of PLAAF.

It is opined that these technologies will actually bring the PLA forces up to the levels of current weapons and sensor technologies. The doubt still remains whether, all these successes, achieved through reverse engineering can be repeated for another future generation which can only happen with a strong level of basic science and research.

Notes

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