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An Assessment of China's Ballistic and Cruise Missiles

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NATIONAL INSTITUTE OF ADVANCED STUDIES
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Executive Summary

The primary objective of this study is to provide an independent assessment of Chinese ballistic and cruise missile capability. The study also addresses the organisational, strategic and political links in China that impact upon its missile programme.

Our study on the Chinese Ballistic and Cruise Missiles uses images of these missiles available in the public domain to make an independent assessment of their capabilities. Length and diameter measurements on the images of these missiles are used to estimate propellant and stage masses. These estimates are used along with trajectory and range models to assess the performance of the missiles. This methodology has been applied to the DF-1, the DF-2, the DF-3, the DF-4, the DF-5, the JL-1 / DF-21, the JL-2 / DF-31, the DF-15 and the DF-11 ballistic missiles.

The scope of our study also included the longer range cruise missiles. Since there were not many images of these missiles available in the public domain we were not able to extend these methods to cover them. However, we have taken stock of developments in Chinese cruise missiles. As and when images become available we believe that our approach can be used to assess their performance as well.

The DF-1 and the DF-2 missiles that the Chinese had built with assistance from the Soviet Union have been retired from active service. Our measurements of the length and diameter of these missiles are in agreement with values quoted in the published literature.

The DF-3 was the first indigenous missile developed by the Chinese. It was also the first missile to use earth storable propellants – UDMH and AK-27. Though the chronology of the images is not exact, our analysis of the images shows a trend of increasing sophistication and performance. The analysis confirms the existence of at least two variants of the DF-3. We also see three warheads with the shortest of them possibly being a conventional warhead. The DF-3 has been exported by China to Saudi Arabia with a conventional warhead capability.

Our estimates of the lift-off weights of the DF-3 are lower than estimates available in the published literature though our lengths for the two variants are fairly close to the published values from different sources. Our estimates of the range for the DF-3 and the DF-3A with a 2200 kg warhead are 2636 and 2736 km respectively. These are fairly close to the values of 2500 and 2750 km quoted in the literature.

The DF-4 is a two-stage missile that uses the DF-three stage as the booster stage. We see two versions of this missile with lengths of 27.13 and 27.48 m respectively. These two versions are almost exactly the same except that for the longer missile the upper stage tanks have been stretched by about 0.42 m. According to publicly available information the Chinese ordered their missile engineers to increase the range of the DF-4 so that they could target Moscow. Our analysis independently confirms this.

As was the case for the DF-3 our estimates of the propellant masses and stage masses for the DF-4 are lower than the figures quoted in public information sources. Our length and diameter measurements match well with other publicly available information. The range for the DF-4 and the DF-4 variant with a 2000 kg payload is 4476 km and 4662 km respectively. These are once again fairly close to values available in the published literature.

The DF-5 is the largest missile available in the Chinese arsenal. It uses UDMH and nitrogen tetroxide as fuel and oxidizer. It is also the first Chinese missile to use an inertial platform for control and guidance. Our measurements indicated a large number of possible variants of this missile. These included variants in warheads, variants in the second stage as well as variants in the booster stage. Our estimates of the range with a 3000 kg warhead varied from 6300 km to 7800 km depending on the configuration. These ranges are significantly lower than the ranges of 12000 km and 13000 km reported for the DF-5 and the DF-5A in the literature.

We believe that the DF-5 is not a two stage missile as is commonly reported but actually a three-stage missile. We also believe based on measurements and analysis that the interface between the warhead portion and the second stage is sufficiently large to accommodate a small liquid rocket engine that would comfortably give the DF-5 and the DF-5A the range of 12000 to 13000 km reported in the literature. This is a finding that does not seem to be well-known. A possible configuration for this upper stage has also been worked out.

Our study also worked out a procedure for independently trying to estimate the number of DF-5 missiles produced by China.

The JL-1 is China's first Submarine Launch Ballistic Missile (SLBM). Our study revealed that there are at least four kinds of JL-1 (DF-21) missiles with different lengths. All of them use the same first and second stages but are equipped with different warheads. The literature only talks of two variants whereas we find at least four different configurations using our method. Though our measurements of length and diameter as well as liftoff weights match well with the published information our estimate of the range of the JL-1 / DF-21 is higher. The range that we get for the JL-1 is 3073 km with a 700 kg payload. Recent images of the DF-21 are those of the canister and not of the actual missile. Some of these images were also analysed to get some idea of some of the dimensions of the missile.

There are also many images of the advanced SLBM of China called the JL-2. A land based mobile variant of the JL-2 is the DF-31. Another variant reported in the literature is the DF-31A. There are also some reports of a missile termed the DF-41. These are all reported to be missiles fuelled by solid propellants.

We looked at some of the images of the JL-2 / DF-31 that are inside the canisters. Using these measurements and keeping in mind the length and volume constraints for designing a three stage missile we tried to look at possible configurations of the JL-2 that would give the Chinese the 8000 km Multiple Independently Targetted Reentry Vehicle (MIRV) capability for launch from a submarine. We got two measurements for the canister length – 13.4 m and 12.3 m. This would suggest that there are at least two variants of this missile. The canister diameter was approximately 2.2 m which would suggest that the missile diameter will be around 2 m.

Our study of the various configurations indicated that space limitation will not permit tandem staging of the third stage. For an approximately 8000 km range with MIRV the third stage has to be submerged inside the Post Boost Control Vehicle (PBCV). This would mean that the diameter of the third stage would have to be between 0.9 to 1.1 m. To accommodate the restrictions in length it is also quite likely that all the stages use multiple nozzles. Since the Chinese have developed such technology for their JL-1 missiles this may pose no special problems.

Our studies show that as long as the payload weight for the MIRV configuration lies between 1200 kg and 1350 kg a Post Boost Control Vehicle can be configured around the 0.9 m to 1.1 m diameter third stage. Our studies indicate that with such a payload a MIRV with three independent Reentry Vehicles can be configured. The propellant requirements for the PBCV to carry out the required trajectory changes can also be accommodated. The three stages that would comprise such a missile will have the following lengths and diameters:

- A first stage with a diameter 2m with a length of 6.6 m
- A second stage with a diameter of 2 m and a length of 2.58 m
- A third stage with a diameter of between 0.9 and 1.1 m and a length of 3.28 m.
- A overall length of 12.7 m that can be housed within the canister length of 13.4 m

A configuration like the one mentioned above with a MIRV and a suitably designed PBCV can give a range of between 7300 and 7700 km with a payload of 1200 to 1350 kg. This represents a major capability that brings China closer to the capabilities of the US.

It is our contention validated through our study that the other canister length of 12.3 m represents another version of the JL-2. This version will carry a single warhead with the warhead being mounted on top of the third stage as is the normal arrangement for most missiles. Such a missile will have a range of 12000 to 14000 km with a single 700 kg warhead. This can also be launched from the new submarine that the Chinese are building.

We also looked at the smaller DF-15 and DF-11 missiles. Both of them have a number of variants with different warheads and different rocket motor lengths. Our estimates of the range of these missiles match well with published information. In an earlier study we had clearly established links between images of these missiles and images of the Pakistani missiles.

Our analysis of China's long range cruise missiles was constrained by the non-availability of images. We believe that with a set of some images we will be able to extend our method to cover this emerging area of focus by the Chinese.

All technologies especially complex technologies require specialist organizations for carrying out assigned tasks. This requires many knowledge disciplines that cover both technology and science fields. The major problem for the successful completion of such tasks is the capability to integrate the different disciplines into a composite whole. The ability to differentiate and then to integrate these complex pieces into one system is a key organizational capability. Our study provides an overview of how the Chinese organized themselves for carrying out work on missiles. We also provide some idea of how the Chinese organization of the missile effort changed over the fifty year period as the scientists and engineers struggled to cope with the technical, economic, political and social problems they encountered in their quest for legitimacy. Details of work centres, facilities, procedures, routines and arrangements for integration within the missile complex are addressed.

The management of the various interfaces with other ministries for the development of various land and submarine based missiles is also covered in depth. The coordination mechanisms adopted by the political system to deal with the specialisation and integration problems arising from designing and building these major national capabilities are also addressed.

Our study of these organisational aspects suggests that the Chinese have truly built up a national level systems capability that is formidable. Personal, family and other social networks arising out of this high technology work reinforce these capabilities and facilitate decision-making on crucial issues. Understanding and mapping these networks is important for us to get an idea of how strategies and decisions are made within the national security complex of China.

China is poised to become a builder of almost any kind of large technology system that may be needed for preserving its national security. China has about 100000 people working directly on its missile and space programmes. Another 90000 to 120000 are associated with the Second Artillery Corps responsible for operations. China also has in place a very strong infrastructure and ranges for testing various kinds of missiles. Details of these have also been provided in the study.

The pioneers of the original missile effort were largely from the first Academy who built the liquid fuelled DF-3, DF-4 and DF-5 missiles. They were also originally responsible for the control and guidance systems as well as for the warheads. It is still the largest of the Academies under the seventh Ministry with 27000 people. Recent developments have taken away some of these responsibilities from the first Academy. The modernisation programme also involves a shift to solid propellant fuelled missiles, which is handled by the fourth Academy. This may result in the erosion of some of the power of the first Academy.

Our study also mapped in detail the deployment of the various missiles by the Second Artillery Corps – the organization that is responsible for operating all land based ballistic missiles. From bases in Qinghai and Yunnan provinces Chinese DF-3, DF-4 and DF-21 can reach all parts of India. These deployments reveal the changing nature of the threats that China is now confronting. From a US-centric focus that marked its original programme the current deployment would suggest that the nature of the threats facing China has changed. This reflects the changes in the China's threat perception as it seeks to become a global power over the next few decades.

The last part of our study looks at the links between the political, military and economic environment and the missile programme and how these have changed in response to the both internal and external challenges that China faced over the last fifty years. Current developments and how they will affect the Chinese missile programme are also briefly touched upon.

Background

Background & Rationale for the Chinese Missile Programme

The strategic rationale for the Chinese Ballistic Missile Programme can be traced back to the Korean War (1950) and the Taiwan Straits Crisis (1954). During both these conflicts China faced the threat of a nuclear attack from the US. These events convinced Mao Zedong that China must acquire atomic weapons and ballistic missiles for China to preserve its hard won territorial integrity. The US and its allies in the region were seen as the major threats to China's existence as an independent nation state. Though Mao Zedong talked about "Peoples War" he clearly recognized the role of atomic weapons and ballistic missiles as the currency of power in the world. This recognition of its importance ensured that a minimal level of support was always provided to these high technology endeavours as China grappled with a whole set of both internal and external problems in its transition to great power status.

The actual beginnings of the missile programme can be linked to the deportation of Qian Xuesen from the US to China in September 1955.[1] He became the head of the Chinese missile effort with the establishment of the fifth Academy in May 1956, which later on became the seventh Ministry of Machine Building that dealt with all missile development.

To speed up the process for acquiring nuclear weapons and missiles, China turned to the Soviet Union for help. One can say that the Chinese missile programme has its origins in the transfer of technology from the erstwhile USSR.[2]

Based on an agreement with the USSR two R-1 missiles (Soviet copies of the German V2 Rocket) were supplied in December 1956. According to various accounts Qian was disgusted with these copies and demanded that the Chinese needed something more advanced.

In October 1957 the USSR and China signed a New Defence Technical Accord under which the USSR would supply a prototype atomic bomb and two R-2 missiles. The Agreement also stipulated that the Soviet Union would provide China the necessary specialists, training and tooling for the licensed production of the R-2 – an improved version of the V2. Soviet engineers came to Beijing in December 1957 to set up the production line. Though the bomb never came, the two early Chinese missiles the DF-1 and the DF-2 were based on Soviet designs and technology.

[1] The circumstances under which Qian left the US and moved to China are well covered in the Iris Chang book "The Thread of the Silkworm", (New York: Basic Books, 1995).

[2] Most of the details are taken from: http://www.astronautix.com/articles/aboutica.htm which provides a comprehensive history of many things that have taken place in space and rocketry.

The Soviet Union also sold China designs, technical data and relevant equipment to make a liquid fuelled Submarine Launch Ballistic Missile (SLBM), codenamed the 1060 by the Chinese.[3]

While these discussions were going on with the Soviet Union, China began the construction of its Jiaquan launch site in June 1956.

The expansion of the fifth Academy also began in a big way with the addition of over 3000 engineers between 1956 and 1960. China ordered twelve more R-2 missiles which were delivered by the Soviet Union in 1958 and 1959.[4] By the summer of 1960 the Chinese had established a rail link between Beijing and Jiuquan the launch centre.

In September 1958 the fifth Academy finalised an indigenous missile development plan. The plan called for the development of an indigenous Dong Feng (DF) series of missiles. In early 1959 Soviet specialist arrived in China to assist them in the production of the R-2 missile. In September 1959 factories for the production of missile frames and engines were set up at Senyang and Nancheng respectively. Nie Rongzhen, a veteran of the Long March responsible for missile development, forced the fifth Academy to quit wasting time on leapfrogging Soviet technology and focus instead on developing a Chinese version of the Soviet R-2.

The missile programme ran into further problems with the launching of the Great Leap Forward (GLF) in 1958 which disrupted industrial production and scientific and technology programmes in China. The GLF also worsened relations between China and the Soviet Union.

By August 1960 relations between the USSR and China reached a low. According to one source the Soviets caught Chinese students at the Moscow Aviation Institute stealing restricted missile data. All Soviet technicians returned to the USSR and all projects with China were cancelled.[5]

On November 5th 1960 the first Chinese version of the Soviet R-2 was launched. This was followed by four further launches starting December 1960 and going on to 1964.

In September 1964 Qian orchestrated a new development plan, the *Banian Sidan* Plan, for the Chinese Missile Programme. The Chinese version of the Soviet R-2 was re-designated as the DF-1. A DF-2 missile – a stretched DF-1- was to be built to carry a nuclear warhead with a range sufficient to hit Japan. The DF-3 was to target the Philippines. The DF-4 and DF-5 were to be designed to hit Guam and the continental USA. This was the first baseline plan.[6]

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3 John Wilson Lewis and Xue Litai, *China's Strategic Seapower: The Politics of Force Modernisation in the Nuclear Age* (Stanford: Stanford University Press, 1994) p. 131

4 For details see, http://www.astronautix.com/lvs/df1.htm

5 Ibid

6 Robert S. Norris, Andrew S. Burrows, and Richard W. Fieldhouse, *Nuclear Weapons Databook: British, French, and Chinese Nuclear Weapons,* (New York: Natural Resources DefenceCouncil, Inc., 1994), p 384, cited in Nuclear Threat Initiative's Missile Chronology available at http://www.nti.org/e_research/profiles/China/Missile/5657.html

Following China's first nuclear test in 1964, China decided to revitalise the strategic programme through reorganisation of its infrastructure. The fifth Academy which had been responsible for the development of ballistic missiles was renamed the seventh Ministry of Machine Building. The seventh Ministry was reorganised into five Academies including the fourth Academy which was responsible for Solid Propulsion.[7]

In 1966, the Second Artillery Force comprising six ballistic missile divisions was created to direct China's nuclear forces. The same year China successfully tested the DF-2 and DF-3. One of the DF-2 rockets carried a live nuclear warhead that flew over the Chinese mainland and detonated in the nuclear test site at Lop Nor.[8] China also initiated a project to build an all solid fuel rocket to be launched from an indigenously developed nuclear power submarine in 1968.

Meanwhile China's relations with the Soviet Union were going from bad to worse. In 1969 Soviet and Chinese forces clashed over Damansky / Zhenbao Islands in the Ussuri River. While the crisis was contained, China and Soviet Union maintained increasing force levels at their border through the next 14 years. Given these worsening relations, the Chinese increased the range of the DF-4 missile so that it could reach Moscow from its Da Qaidam bases in Qinghai Province.[9]

Starting from 1966 China erupted into the Cultural Revolution that severely damaged the political, economic and S&T infrastructure of the country. The missile programme was also affected. However despite these political hurdles work on the development of the various missiles continued. In 1970 the DF-3 was tested for the first time from the Jiaquan test facility in Gansu and entered service the following year. The early development flights of the DF-5 took place in 1971[10] though it became operational only in 1981.[11] The DF-4 became operational only in 1980.

The 1970s saw a major strategic reorientation in China with the Sino-US rapprochement. This significantly downgraded the Chinese threat perception from the US. The Soviet Union replaced the US as its primary security concern.

After the death of Mao, China's military modernisation programme speeded up. In 1980 China finally tested the DF-5 missile to its full range.[12]

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7 In 1962, under a three year plan on solid propulsion, the Fifth Academy set up an independent institute at Hohhot in Inner Mongolia called the Solid Rocket Motor Institute under Xiao Gan. Through the next two years the SLBM programme was oriented firmly towards solid propulsion laying the foundation for expanded R & D on both the SLBM and the solid rocket. The JL-1 programme was named in 1964 when the Solid Rocket Motor Institute was made the Fourth Sub-academy under the Fifth Academy.

8 Nuclear Threat Initiative's Missile Chronology available at http://www.nti.org/e_research/profiles/China/Missile/5657.html. This is the only reported case where a live nuclear warhead has been tested along with a missile launch to verify the total chain from launch to nuclear explosion.

9 John Wilson and Hua Di, China's Ballistic Missile Programme: Technologies, Strategies, Goals, *International Security* Vo17. No. 2 Autumn 1992. p17.

10 Nuclear Threat Initiative's Missile Chronology available at http://www.nti.org/e_research/profiles/China/Missile/5657.html

11 John Wilson and Hua Di, China's Ballistic Missile Programme: Technologies, Strategies, Goals, *International Security* Vo17. No. 2 Autumn 1992. p19.

12 Nuclear Threat Initiative's Missile Chronology. 1980 - 1985 available at. http://www.nti.org/e_research/profiles/China/Missile/5657.html

The SLBM development also suffered several setbacks during the period of the Cultural Revolution. The first successful flight of the JL-1 from a Golf class (Soviet) submarine took place in 1982. The first flight of the JL-1 from an indigenous nuclear powered submarine took place only in 1988.

In the mid-1980's tensions between the superpowers eased. This period also saw a lessening in the tensions between China and its neighbours. This prompted China's military planners to declare that it was no longer necessary to prepare for "early war, major war, nuclear war with the Soviet Union".[13] By this time China had also built up a reasonable second strike capability to deter attacks. In 1983, China and the Soviet Union opened talks on normalizing relations which included Chinese concerns about Soviet missiles targeting China and Soviet forces deployed along China's borders.

The focus of defence preparation moved to building strategic capabilities in peacetime rather than responding to imminent threats. Technological advancement came to play an increasingly important role in the direction and pace of China's strategic programme. The focus on economic development also acted as a restraint on China adopting more militarily aggressive policies. China's defence policy moved from defending China's territorial frontiers to securing China's "strategic frontiers."[14]

The collapse of the Soviet Union and the end of the Cold War reshaped China's strategic environment in the early 1990s. The first Gulf war also revealed the increasingly important role of hi-tech weaponry. At this point in time, China's borders were the most secure since the establishment of the PRC. China's missile programme is now aimed at acquiring an all round capability that includes long and short range missiles of all kinds that have both strategic and tactical roles. Ballistic missiles and the newer types of cruise missiles will both be important. As the US moves towards the development and deployment of a Ballistic Missile Defence system, China may be forced to make appropriate changes to its development programmes in the missile area.[15]

The Chinese missile programme has made steady progress. The DF-31 / JL-2 missile will carry a MIRV payload that can be launched from a submarine. A successful launch of the JL-2 from a converted Golf class submarine has been reported in 2004. However reports mainly from US sources seem to suggest that China is facing technical difficulties with the development of the Nuclear Power Ballistic Missile Submarine (SSBN). The JL-2 may be deployed by 2008 – 2010[16] according to US intelligence estimates. A 3-stage all solid ICBM that can reach all parts of the US with a single warhead is also reported to be under development.

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13 Mark Burles and Abrams N. Shulsky, *Patterns in China's Use of Force: Evidence from History and Doctrinal Writings* (Santa Monica: RAND Corporation, 2000) p 29

14 Strategic Frontier was defined as "living space of a state and nation that contracts with the ebbs and flows of the comprehensive national strength of a nation", Nan Li, "The PLA's Evolving Warfighting Doctrine, Strategy and Tactics, 1985-95: A Chinese Perspective*", China Quarterly*, no. 146, June 1996. p 450

15 The recent Chinese ASAT test may be an example of changes that the Chinese may choose to adopt.

16 China Nuclear Forces 2006, *Bulletin of the Atomic Scientists* May / June 2006, p 61

Objectives of the Study

Though there is a lot of information on the Chinese missile developments there has been no independent Indian assessment of their missile capabilities. This study is an attempt to redress this shortcoming.

The primary objective of the study is to understand the strategic implications of the Chinese missile programme for India.

The secondary objectives of the research study would be the following:

- To critically evaluate the performance of all ballistic missiles in the Chinese arsenal.
- To assess and evaluate the Chinese development of cruise missiles.
- To examine in detail the evolution of Chinese organisational and infrastructure capabilities in the area of missiles.
- To understand the underlying strategic and military imperatives behind the development and deployment of various Chinese missiles.
- To study the current composition of the Chinese missile arsenal and evaluate Chinese "Threat Perceptions".
- To evaluate the "India factor" in China's strategic force planning.
- To address problems raised by the US deployment of Ballistic Missile Defence systems and the likely Chinese responses.
- To analyse and understand the strategic implications of China's ballistic and cruise missiles for India.

Approach and Methodology

- Look at all the literature and published material on China's missiles.
- Specially look at images that are published or available on the Internet.
- In view of the reported connections between China and the erstwhile Soviet Union in the early days of the Chinese missile programme also look at images and information on the relevant Soviet / Russian missiles.
- Use special image processing software to make measurements on the images.
- Interpret and use these measurements through an understanding of the basic characteristics of missiles, their underlying technologies and the demands of operational testing.
- Use the measurements to estimate major missile parameters like quantities of propellant, lift off mass. Use these measurements along with software for estimating the range, altitude, time-of-flight of the missiles.
- Put all of this together to get an integrated picture of the technological capability.
- Complement the technology part with an assessment of the organisation of the missile programme and its link with the other parts of the Chinese security system. Try and link the technical tasks the

organisation structure and the linkages of the missile system to the larger military and national security system in China. Try to use this understanding to look at what might happen in the near and medium term.

- Link these findings to what we deem to be the national security strategy of China.

In our study we refer to images of every missile type through numbers. These are based upon a library of images that we have created for each missile type.

Models for range estimations

Long range missiles lift off vertically. They then fly a trajectory during the powered phase that enables them to reach a certain cut off velocity at a certain altitude. For maximum range there is a certain optimum angle of injection. **Figure 1** depicts a typical trajectory for a ballistic missile.

THE TRAJECTORY OF A MISSILE

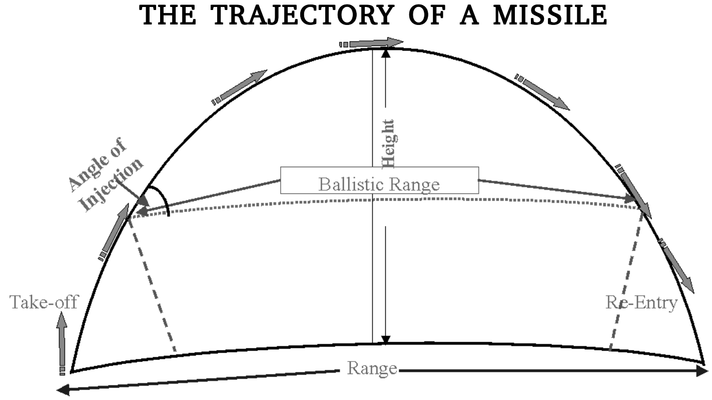

Figure 1

During the powered phase atmospheric drag as well as gravity induced losses reduce the theoretical velocity that a missile can achieve. While there are approximate estimates for these losses and we could have used them we have chosen to build an Excel spread sheet model that quantifies drag and gravity effects. Since the equations of motion of a powered rocket flight do not have explicit closed form solutions we have adopted a numerical approach where accelerations, velocities and distances are calculated at discrete time intervals along the trajectory.[17] In this study we have chosen a 1 second interval for these calculations.

The simulated trajectories for the lift off portion of the trajectory can be modeled in such a way that injection values are close to the optimum value of the injection angle. Through such a procedure we can get estimates of the drag and gravity losses. We can also get an estimate of the altitude of injection and a measure of the range covered during the lift-off and re-entry parts of the trajectory.

[17] Apart from a ballistic missile primer available on the net (the author prefers not to be quoted) we have also validated these from looking at the basic equations of motion for a thrusting rocket that includes atmospheric drag and gravity effects. See George P Sutton, "Rocket Propulsion Elements– an Introduction to the Engineering of Rockets", sixth edition John Wiley & Sons Inc, 1992

To get initial estimates of the thrust if this information is not readily available we use typical estimates of Thrust to weight ratios available in the literature on rocket propulsion. Specific impulse[18] values are also taken from the literature if they are not explicitly stated.

Once the powered phase is over and the missile is injected it follows a ballistic trajectory that has a closed form solution for the purposes of our study.[19] This part is once again modeled in an Excel spreadsheet.

Since the re-entry part of the trajectory closely replicates the lift off part in terms of range we can include the relevant results from the simulation of the liftoff into the range model to get estimates of the range. Other flight parameters like time-of-flight, altitude reached can also be estimated.

For each Chinese missile we have both a liftoff as well as a range model. These technical calculations along with measurements on the images of the missiles form the basis for much of our analysis.

Problems of Interpretation of Image Analysis Data

We have addressed these issues in an earlier study on Pakistan's missile programme.[20] These issues are relevant for this study also.

Structure of the Report

The first part of the report will look at the technology developments related to missiles. It will try and assess the performance of each missile. It will particularly look at the more recent developments and assess their implications in terms of missile performance.

The second part of the report will look at the organisation structures that China created in order to solve the technology problems associated with creating missile capabilities. It will specifically address the continuous changes that the Chinese made to the organisation system as they tried to develop this high technology capability under constraints of political and economic turmoil. To provide some understanding of the links between the technical tasks, the organisation structure and the delivery of missile products we will look at some illustrations of how the Chinese coped with the complex system integration tasks required for a successful missile development programme. In this section we also try to map some of the major research, development, testing and system integration facilities that the Chinese created. We will try and link this to the organisation structures and organisation routines that

[18] Specific impulse can be defined simply as the thrust per unit weight flow rate of the propellant. Its normal unit of measurement is seconds.

[19] See J.W Cornelisse , H.F.R.Schoyer, K.F.Wakker, "Rocket Propulsion and Spaceflight Dynamics" (London: Pitman Publishing Limited, 1979). Chapter 13 specifically addresses ballistic trajectories.

[20] S. Chandrashekar, et.al., "An Assessment of Pakistan's Ballistic Missile Programme", NIAS Internal Report, 2005

they established as they struggled with the various technological, political and economic problems that they encountered.

The third section will look at the arrangements for deployment of the missiles. It will look at the command and control structure and the specific organisational arrangements for routine operations. The threat to India will be specifically addressed. The impact of the modernisation drive and its implications will also be covered.

The fourth part of the report will look at China's strategic challenges and its responses to these challenges. A historical perspective of the changing nature of these challenges as China has evolved over the last 50 years and the implications of this legacy for the problems it faces in the future will be covered.

We will then summarise our findings and draw certain conclusions.

The Missiles

The DF - 1 missile

There is no doubt that the DF-1 missile built by the Chinese was a copy of the Soviet R-2 missile. The Chinese saw the DF-1 as competence building project rather than as a missile that had to reach a particular target. The Soviet R-2 itself had been developed from their earlier R-1 missile. The R-1 was a cloned copy of the German V2 missile. The chronology and details of the R-2 are widely available in the public literature on Chinese missile development. The R-2 also known as the SS-2 Sibling[21] was an improved version of the R-1.[22] The ethyl alcohol used in the R-1 and in the German V2 was replaced by methyl alcohol. The alcohol content was increased from 75% in the V2 to about 96% in the R-2 increasing the thrust to about 37 tonnes.[23] The oxidizer used was liquid oxygen. All these enabled the building of a bigger R-2 rocket as compared with the original R-1.

The basic data on the Soviet R-2 stage is available in the public domain.[24] Table 1 below provides details.

Table 1
R-2 parameters

Parameter	Value / Constituent
Gross Mass	19632 kg
Empty mass	4592 kg
Payload mass	508 kg
Specific impulse	237 seconds (vacuum)
Specific impulse	214 seconds (sea level)
Propellant / oxidizer	Methyl alcohol / Liquid oxygen
Length	17.65 m
Diameter	1.65 m
Span	3.56 m

The basic R-2 has been modified by the Soviets to produce several versions of the missile. There was a military production version; a version termed the Model R-2A used for scientific research up to altitudes of 200 km and an R-2E prototype version used for testing new technologies. The payloads and the lengths quoted in the literature for these various versions differ. Table 2 provides details of the different versions.

21 http://www.globalsecurity.org/wmd/world/russia/r-2.htm

22 Improvements in the V2 engine resulted in increased thrust. This enabled the R-1 (a Soviet copy of the V2) to be stretched resulting in a bigger rocket with a greater range. The R-2 also had an integrated fuel and oxidizer tank and the oxygen tank was placed below the fuel tank to improve stability.

23 This was done apparently to prevent the Soviet personnel from siphoning off the alcohol for drinking.

24 Technical details of the various versions are available in http://www.astronautix.com/lvs/r2.htm

Table 2
Details of Different Versions of the R-2 missile

Parameter	Basic R-2 version	Production version	Scientific version	Prototype version
Liftoff Thrust (kN)	~376.12 kN	364.90 kN	363 kN	363 kN
Total mass (kg)	19632 kg	19632 kg	20300 kg	20300 kg
Diameter (metres)	1.65 m	1.65 m	1.65 m	1.65 m
Length (metres)	17.65 m	21 m	17 m	17 m
L/D ratio estimated	10.7	12.73	10.30	10.30
Span / diameter ratio calculated	2.16	2.16	2.16	2.16
kN is Kilonewton L/D ratio is the length to diameter ratio, span is the total width from fin to fin				

Images of the DF-1, R-2 missiles

While there are many versions of the Russian R-2, there is only one image of the DF-1[25] that we could locate in the public domain. This is not a real rocket but the model of a rocket kept in an exhibition in Beijing.[26] There are some other pictures available of the R-2 – images 2, 3 and 4.[27] We could also locate some images of R-2 models at a third site[28,29].

Details of the analysis carried out on the various images are available in Appendix 1.

The measurements we can infer for the DF-1 (based on the second image of the R-2) are in Table 3.

Table 3
DF-1 Measurements summary

Parameter	Measurement
Length	17.84 m
Diameter	1.65 m
Warhead + interface length	3.71 m
Upper tank (Alcohol tank) length	4.17 m
Lower tank (Oxygen tank) length	4.90 m
Combustion chamber + nozzle + fin	5.16 m

[25] We could also find an image in Robert S. Norris, Andrew Burrows, and Richard Fieldhouse, “Nuclear Weapons Databook Series Volume V: British, French and Chinese Nuclear Weapons”, (Washington: NRDC), figure 7.2, p.360, 1994. However we did not analyse this image.

[26] The model is available at http://www.astronautix.com/graphics/d/df1beiji.jpg

[27] See the http://www.russianspaceweb.com/r2.html

[28] http://space.skyrocket.de/index_frame.htm?http://space.skyrocket.de/doc_lau/r-_2.htm

[29] http://space.skyrocket.de/index_frame.htm?http://space.skyrocket.de/doc_lau/r-_2_sci.htm

The first Chinese reverse engineered DF-1 missile was flight tested in November 1960. According to Norris et al production continued till 1964 and the missiles were handed over to the PLA for training. The range of the DF-1 with a nuclear warhead was reported to be 590 km.

The DF-2 missile[30]

Almost immediately after starting on the reverse engineering of the R-2 i.e. the DF-1 programme, the Chinese had initiated another technology effort to stretch the capabilities of the DF-1. The effort involved making improvements to the DF-1 in two ways. One was to stretch the tankage to accommodate more fuel and the other was to improve the engine thrust / performance.

Like the DF-1 it had graphite vanes in the rocket exhaust for attitude control during launch. Control during the launch phase was also exercised by radio command from the ground during the launch phase.

We analysed 6 images that were reported to be images of the DF-2. Details of the analysis on these images are available in Appendix 1

Since we have also made some measurements on the engine lengths, the tankage lengths as well as the warhead lengths for the R-2 as well as the DF-1 and the DF-2 we think it would be useful for us to look at all the measurements together. Table 4 below provides such an overview.

Table 4
Summary Measurements on the DF-1, DF-2, R-2

Missile	Image	Warhead + IF	Tankage	Engine + fin	Comments
R-2/ DF-1	Image 2	3.71 m	9.07 m	5.16 m	Soviet warhead smaller
R-2 / DF-1	Image 5	3.67 m	8.81 m	4.89 m	Soviet warhead smaller
R-2 / DF-1	Image 6	6.61 m	8.83 m	5.04 m	Longer Soviet warhead
DF-2	Image 1	4.46 m	11.45 m	2.39 m	Dummy engine?
DF-2	Image 2	4.64 m	8.02 m	4.95 m	DF-1 image
DF-2	Image 3	4.14 m	11.30 m	2.45 m	Dummy engine
DF-2	Image 4	4.45 m	11.40 m	5.30 m	Operational DF-2
Avg. DF-2		4.42 m	11.38 m	5.13 m	

[30] One website claims that the starting point of the DF-2 was the supply of the drawings of the DF-12 IRBM to China and a model that was given along with it. There is some problem with the DF designations which were changed sometime in 1964 after the adoption of the 8 year plan for missile development.

Findings on the R-2, DF-1 & DF-2 linkages

The exhibition model supposed to be the DF-2 (image 2 of the DF-2 data set) appears to be the DF-1 not the DF-2.

The diameter of the DF-1, DF-2 is independently validated to be 1.65 m.

Average warhead length for both DF-1 & DF-2 is 4.42 m. This is longer than the Soviet warhead of ~3.70 m for the fission warhead. This would validate the Chinese claim that they got no Soviet help with the warhead.

The average combined tank length (the fuel tank + the oxygen tank + the interface) for the DF-1 and the DF-2 are 8.02 m and 11.38 m respectively. This means that the tankage in the DF-2 is about 3.3 m longer than in the DF-1.

The average length of the engine + nozzle + fin for the DF-2 is 5.13 m. This length is nearly the same for both the DF-1 and the DF-2. This is also very close to the average engine + nozzle + fin length of 5.03 m for the Soviet R-2. There is therefore clear evidence of technology transfer of the R-2 engine from the Soviet Union to China.

The measurements are consistent with a DF-1 and DF-2 lengths of ~ 17.6 and 20.6 m respectively. We also get some images with a total length of about 21.2 to 21.5 m. This could be an improved DF-2 missile.

The image analysis results are in general consistent with published information on technology transfer from Soviet Union to China. It is also consistent with the claims that the DF-2 is a stretched version of the DF-1. There are some differences in the details.

Based on published information the range of the DF-2 with a 1500 kg nuclear warhead is 1050 km. The original target for the DF-2 was Japan. The range is just sufficient to reach Japan.

China is the only country to have tested its missile with a live nuclear warhead. On 27th October 1966 a DF-2 missile with a 1290 kg nuclear warhead flew 894 km in a westerly direction to the Lop Nor site. The 12 Kt nuclear device exploded about 569 m above the ground.[31]

Like their Soviet counterparts the Chinese have also retired their DF-2 missiles. The liquid oxygen alcohol combination creates many operational problems. It was not long before the Chinese gave up on this route and moved towards storable propellants for their missiles.

[31] Robert S. Norris, Andrew Burrows, and Richard Fieldhouse, “Nuclear Weapons Databook Series Volume V: British, French and Chinese Nuclear Weapons”, figure 6.22, 1994, P.355

The DF-3 missile

According to the publicly available information:

- The DF-3 was the first of the indigenous missiles developed and built by China.
- It is a 21.9 to 24 metre long (DF-3 and (DF-3A), 2.25 metre diameter missile. It uses UDMH and AK27 (nitric acid with 27% of nitrogen tetroxide) as fuel and oxidiser.
- With a reported liftoff weight of 64000 Kg it was originally conceived in a 1964 plan to target US bases in the Philippines. It has a range of ~ 2500 km with a payload of ~ 2200 kg. At the time of its design it gave China the ability to deliver a thermo-nuclear warhead to the Philippines.
- It has a strap-down inertial guidance system using accelerometers and gyroscopes.
- An improved version the DF-3A with a slight improvement in range to 2800 km has also been tested and deployed.

3 tests have been reported between December 1966 and May 1967. It entered service in 1970.

The development of an improved DF-3A was started in 1981 with test flights reported in 1985 and 1986.

There are a number of images of the DF-3 available in several website references. Our study was able to locate at least 20 such images. The same image is of course available in several data bases. In our study we have tried to look at all the images and used the analysis of these images as a baseline for looking at the performance of the DF-3. We have also tried to use the analysis to speculate about the likely trajectory of development of the DF-3 missile.

Details of the analysis on each of the images are separately reported in Appendix 1.

Even though we have 20 images of the DF-3 in the public domain many of them are duplicates of the same missile. Only 9 different missiles were available for measurements and of course we tried to make measurements on all nine of them. Though measurements have been made and in some cases repeated on the same image from different sources many of the measurements because of inherent scale and rotation effects may not give accurate measurements of all parts of the missile.

The images give us a good idea of the lengths of various elements of the missile. The warhead lengths, the length of the interface between the warhead and the stage, the upper tank length, the inter-tank interface, the lower tank, the lower tank engine interface and the length of the engine including the nozzle and fins have all been measured and through comparison best estimates have been obtained for these very important lengths. We were also able to measure the fin area and use this measurement to refine our liftoff and range calculations.

Findings on the DF-3 / DF-3A

Our analysis independently validates the diameter of the DF-3 as around 2.25 m.

The measurements confirm the existence of two different DF-3 configurations. In the later versions the upper and lower tank lengths have been stretched by about 0.5 m each. This would increase the propellant loading and also increase the range. These increases in tank lengths that we have measured are in accordance with published data on the DF-3 and the DF-3A.

One feature that we discovered through our measurements is a major increase in inter-tank length in some of the later images. The inter tank length in early images (0.4 m and 0.52 m) are much lower than the 1.94 m inter tank length we get from the more advanced image 9. One plausible explanation for this increase is that it is a design hangover from the Chinese experimentation with the reverse engineering of the Soviet R-12 which also had such an inter tank interface to accommodate additional control elements. The other possibility is that it is linked in some way to the Chinese use of the DF-3 as a platform for conducting some MIRV tests.[32]

Through our measurements we see the following versions of the DF-3 missiles:

- A version with a length of 21.91 m (7.73 m warhead + 5.07 m upper tank + 0.46 m inter tank length + 5.67 m lower tank + 3 m engine & interface) .

- A second version with a length of 23.41 m (7.73 m warhead + 5.07 upper tank + 1.94 m inter tank length + 5.67 m lower tank and 3 m engine & interface). All the elements of this version are the same as version 1 except for the length of the inter-tank interface which shows an increase in length from 0.46 m to 1.94 m.

- We also see a third version with a length of about 24 m (7.18 m + 5.65 + 1.94 + 6.03 +3). In this version the warhead length has been reduced and both the tanks have an increase of ~ 0.5 m in length.

- We also see a fourth version with a possible length of ~ 20 m (4.3 m warhead + 5.07 m upper tank + 1.94 m inter-tank area + 5.67 m lower tank + 3 m engine +fin). The 4.3 m warhead could be a conventional warhead. The Chinese have exported a large number of DF-3 missiles to Saudi Arabia in the late 1980s.

[32] Both these are possible explanations. Although we cannot date these images we believe that the MIRV experiments appear to be a more plausible reason.

Our conclusions are that versions 1 and 2 and 4 are the DF-3 and version 3 is the stretched version of the DF-3 which is called the DF-3 A in the published material on the DF-3. The following table summarises our best estimates of the various elements of the DF-3 and DF-3A.

Table 5
Summary Measurements on the DF-3

Element	**DF-3**	**DF-3A**
Warhead + IF	7.73 m or 4.3 m	7.18 m
Upper Tank	5.07 m	5.65 m
Inter-tank IF	0.46 or 1.90 m	1.90 m
Lower Tank	5.67 m	6.05 m
Engine + fin	3.0 m	3.0 m
Length	21.93 - 23.37 m (3 versions)	23.76 m

Based on the measurements we have estimated the propellant loading and the stage weight for the DF-3 and the DF-3A. These are given in Table 6 below.

Table 6
Estimated Propellant, Stage & Liftoff Masses for the DF-3

Propellant mass (kg)	Stage mass	Payload mass	Total liftoff weight
46504 kg DF-3	49682 kg	2200 kg	51882 kg DF-3
50661 kg DF-3A	54122 kg	2200 kg	56322 kg DF-3A

Our estimate of the liftoff weight is lower than the liftoff weights mentioned in the public domain by 7000 to 11000 kg

We have also used a liftoff and trajectory model for estimating the various performance parameters of the missile including its range. We have cross checked this with publicly available information on the DF-3.

Most of the literature that we saw indicated that the liftoff weight of the DF-3 / DF-3A was 64000 kg or 64 tonnes.[33] Our estimates for the DF-3 and the DF-3A from our sample images are ~51882 kg and ~ 56322 kg (51.88 and 56.32 tonnes) respectively. Our lengths of 21.91 m for the DF-3 and 23.7 for the DF-3A are reasonably close to published values from different sources. Our measurements independently confirm the diameter as 2.25 m.

[33] Some of the sources are http://www.sinodefence.com/strategic/missile/df3.asp, http://www.globalsecurity.org/wmd/world/china/df-3a.htm.

If we look at the first stage weight of the CZ-1 series of space launchers (which are based on the DF-3) the liftoff weight is given as 64100 kg with a stage length of 17.84 m.[34] The tank lengths that we get from our measurements are shorter than the tank lengths we would get from a 17.84 m, 64 tonne stage. This should account for some of the differences. We believe our approach provides a more accurate and realistic estimate of the liftoff weight of the DF-3 and the DF-3A.

It is also clear from the literature that the DF-3 and DF-3A stages use a cluster of 4 YF-2A engines. Lewis & Di in their report[35] on Chinese ballistic missiles talk of a 96 tonnes thrust for the DF-3. They also talk of increasing this thrust to 104 tonnes in the engine cluster the Chinese may have used to power the first stage of their DF-4 two stage IRBM.

The literature we have seen especially from one site[36] talk of a vacuum level thrust for the CZ-1-1 (the first stage of the CZ -1 launcher) of 125 tonnes which translates into a sea level thrust of about 112 tonnes. This is higher than the 96 or 104 tonnes talked about by Lewis & Di in their landmark study on Chinese ballistic missiles. This higher value of thrust that we have used may give us range values that are likely to be higher.

Our liftoff and range calculations based on our measurements for the DF3 and the DF-3A show the ranges of these missiles (with a payload of 2200 kg) as 2636 km and 2734 km respectively. These are reasonably close to the values of 2500 km and 2750 km quoted for the DF-3 and the DF-3A respectively in the public domain.

The flight times and the maximum height reached for the DF-3 and the DF-3A are 928 seconds, 957 seconds, 649 km and 668 km respectively

The DF-3 was used as the first stage of the 2-stage DF-4 missile. It uses the YF 2A engine in a 4-engine cluster to provide the required thrust. The YF 2A is also used in the second stage of the DF-4 as a single engine.

The basic DF-3 / DF-4 combination was also used to launch the first and the second Chinese satellites in 1970 and 1971.

The number of DF-3 deployed as reported range from 100 – 150 missiles. About 36-60 missiles were also sold to Saudi Arabia. One report talks about 40 DF-3 re-fire launchers being seen in China in 2002. Flight tests have been reported even in 2001.

[34] One could infer that some analysts have used the CZ-1 first stage data for estimating the DF-3 performance. Actual measurements indicate a smaller liftoff weight.

[35] John Wilson Lewis & Hua Di, “China’s Ballistic Missile Programme: Technologies, Strategies, Goals”, International Security Vol. 17 (Autumn 1992), pp. 16-17.

[36] For details on engines and stages flown on the commercial launchers of China see http://www.astronautix.com/lvs/cz1.htm

From the images and the measurements we see progressive change in capabilities as the programme has evolved and matured. Though there has been speculation that all the DF-3 missiles will be retired this has not yet happened. One would expect the DF-3 to be phased out and replaced by the DF-21.

The DF-4 Missile

The DF-4 was originally designed to hit US bases at Guam. It is a two stage missile using the DF-3 as the first stage and a YF2 engine-based second stage. The propellants used are UDMH and AK27 (nitric acid with 27% of nitrogen tetroxide).

It uses the same strap down gyro system for attitude control as the DF-3.

The length of the DF-4 is given as 28 m in the literature with a diameter of 2.25 m. The liftoff mass reported is 80,000 to 82,000 kg. The reported Range is 4500 to 4750 km with a ~2000 kg 3 MT warhead.

The development of the DF-4 began in 1965 with development flights taking place in 1969, 1970 and 1971.

As it was being developed China's relations with the Soviet Union worsened and the Chinese leadership wanted the DF-4 to be able to target Moscow. By increasing the thrust of the first (DF-3) stage and by extending the length of the upper stage by 0.42 m this was achieved according to one version of the DF-4 development. Tests of the DF-4 have been reported even in 2002.

The DF-4 missiles are supposed to be stored in underground missile storage complexes built beneath caves in mountains.

There are 17 images of the DF-4 that we have identified from various locations on the Net. One of them is actually a DF-5 image another is a DF-2 or DF-1 image. There is yet another image which appears to be a two stage missile but whose diameter does not match the 2.25 metre diameter of the DF- 4.There are also duplicates of the same missile available in different web sites. Taking all these facts into account there are not more than 6 images that are useful. Out of these 6 images some have other problems of scale and orientation. This leaves us with very few images that gave us useful measurements.

The details of the image analysis for the DF-4 are provided separately in Appendix 1.

Findings on the DF-4 Missile

The analysis shows that the diameter of the DF-4 as measured in the various images is consistent with the diameter of 2.25 m cited in the literature.

The best measurements of the warhead length are from Images 3, 5 and 7. The average of the 3 measurements of the warhead portion that we get from these 3 images is 6.07 m. This is the value we will assume as the best estimate of the warhead dimension.

Image 4 gives us an upper stage tankage measurement value of 4.73 m. The average upper stage tankage measurement from Images 3 and 5 is 5.08 m. According to one authoritative source[37] the Chinese wanted to increase the range of the DF-4 in order to attack targets in the erstwhile Soviet Union including Moscow. They did this by increasing the thrust of the first stage (a DF-3) to 104 tonnes and by lengthening the upper stage by about 0.42 m. The upper tank measurements seem to validate this.

The length of the first stage upper tank, the first stage inter-tank length and the length of the lower tank can be obtained as an average from Images 3 and 5. These lengths are 5.32 m, 0.45 m and 6.50 m respectively.

The best estimate of the length of the engine + the fin + the interface with the tank of the first stage is obtained from Image 1. This works out to be 2.75 m.

If the upper stage tankage length is only 4.73 m one measure of the overall length of the DF-4 missile would be 6.07 (warhead) + 4.73 (upper tankage) +1.31 (inter-stage) + 5.32 (first stage upper tank) +0.45 (first stage inter-tank interface length) +6.5 (first stage lower tank length) + 2.75 (engine +fin +nozzle) = 27.13 m.

If the upper stage tank length is 5.08 m the overall length of the missile from the data is = 6.07 + 5.08 + 1.31 + 5.32 + 0.45 +6.50 +2.75 = 27.48 m.[38]

One of the images (Image 5) shows a number of DF-4 missiles being taken out of their underground storage shelters and assembled possibly for a parade or an exercise.

Table 7 below provides a summary of our average estimates of the different lengths based on our analysis of the images.

[37] John Wilson Lewis & Hua Di, "China's Ballistic Missile Programme: Technologies, Strategies, Goals", International Security Vol. 17 (Autumn 1992), p17.

[38] This is not too far away from the length of 28 m reported in the published literature.

Table 7
Summary Measurements on the DF-4

Element	DF-4 Version 1	DF-4 Version 2
Warhead + IF	6.07 m	6.07 m
Upper tank	4.73 m	5.08 m
Inter-stage	1.31 m	1.31 m
First stage upper tank	5.32 m	5.32 m
Inter-tank IF	0.45 m	0.45 m
First stage lower tank	6.5 m	6.5 m
Engine + fin	2.75 m	2.75 m
Total length	27.13 m	27.48 m

Using these dimensions which have been validated we can then estimate the amounts of propellants and oxidiser carried by the DF-4 and estimate its performance. Table 8 gives us these estimates.

Table 8
Calculations of propellant, stage and liftoff weights

Element	DF-4 version 1	DF-4 version 2
Propellant mass kg upper stage	16151 kg	17666 kg
Stage Mass kg upper stage	17945 kg	19629 kg
Propellant mass lower stage	48799 kg	48799 kg
Stage mass lower stage	52472 kg	52472 kg
Payload mass kg	2000 kg	2000 kg
Liftoff mass kg	72417 kg	74101 kg

Table 9 compares the elements common to the DF-3 and the DF-4 missiles.

Table 9
A comparison of the DF-3 and the DF-4

Element	DF-3 / DF-3A	DF-4
Warhead	7.73 m or 7.18 m	6 m
Upper tank	5.07 m or 5.65 m	5.32 m
Inter tank interface	0.46 or 1.94 m	0.45 m
Lower tank	5.67 or 6.05 m	6.50 m
Engine + fin +interface	3 m	2.75m

The DF-4 warhead is shorter. The upper tank of the first stage of the DF-4 is slightly bigger than the upper tank of the DF-3 and slightly lower than the length of the tank of the DF-3A. The lower tank of the first stage of the DF-4 is longer than the tanks of the DF-3 and the DF-3A.[39] The engine of the DF-4 also seems to be slightly shorter.[40]

The range of the DF-4 that we get with a 2000 kg payload is 4476 km. With a larger upper stage derived from our measurements the range increases to 4662 km with a 2000 kg payload. This range comes about only if the thrust of the booster (DF-3) stage is increased somewhat. If this is not done there seem to be no major differences in the range between the two configurations. The thrust of the 4 engine YF2 cluster from the literature is more than the 96 tonnes and the 104 tonnes specified in the article by Lewis and Di.[41] The thrust we have used is the higher value.

How do our estimates compare with other sources?

The requirements for the DF-4 changed after the border clashes between China and the Soviet Union in 1969.The Chinese political establishment apparently ordered the Missile establishment to increase the range of the planned DF-4 to hit Moscow and other Soviet cities. The engineers increased the range through the following changes:

- Increased the length of the upper stage by 0.42 m so as to be able to add more propellant.
- Raised the thrust of the lower stage engines (DF-3) from 96 tonnes to 104 tonnes.

Our measurements show two upper stage lengths from the rather limited data that we have vindicating to some extent the stretching of the upper stage. The engine for the DF-4 as compared to the DF-3 seems to be shorter. Many sources report a liftoff weight of 82 tonnes.[42] Our estimates are lower - one configuration with a total liftoff weight of about ~72.4 tonnes and the other with a liftoff weight of ~74.1 tonnes. This is lower than the 80000 to 82000 kg reported in the literature. However in spite of these differences our estimate of the range with a 2000 kg payload compares reasonably well with other range estimates in the public domain.

[39] Is this indicative of a change in the mixture ratio from the DF-3 to the DF-4.

[40] According to Lewis and Di the DF-4 went through some changes in order to be able to reach targets in the Soviet Union. The thrust of the first stage was increased from 96 tonnes in the DF-3 to 104 tonnes in the DF-4 in 1970 after its first flight. The upper stage of the DF-4 was lengthened by 0.42 m to accommodate another 2 tonnes of propellant. The DF-4 also had a fibre glass reinforced nozzle with a large expansion ratio for the upper stage.

[41] John Wilson Lewis & Hua Di, "China's Ballistic Missile Programme: Technologies, Strategies, Goals", International Security Vol. 17 (Autumn 1992), p17

[42] See http://www.globalsecurity.org/wmd/world/china/df-4.htm and http://www.sinodefence.com/strategic /missile/df4.asp

Getting a Bit of History Right

One other issue raised by our analysis is actually to set right a bit of history. Two sources that we had looked at talked about a link between China and Soviet R-12 rocket technology.[43] The R-12 was an early Soviet design to use the R-1 and R-2 configurations but replace the alcohol liquid oxygen combination with an earth storable combination of oxidizer and propellant (kerosene and nitric acid). One of the unique features of this design was the inclusion of two oxidizer tanks one on top of the other. This feature can actually make a single stage vehicle look like a 2-stage vehicle. Image 15[44] of our DF-4 set of images raised this issue – since a first cut look would suggest that the image we had was a two stage missile.[45] Our independent check of the diameter revealed that the diameter was not 2.25 as it should be for a DF-4 but was 1.65 m which would put it into and DF-1 or DF-2 class. Since there were references in the literature to the Chinese pursuing the R-12 design we looked at the details of the R-12. Fortunately there was a good picture of the R-12 in the astronautix web site. We compared Image 15[46] with this image and also made some measurements. We feel strongly based on this that Image 15 is actually a Chinese copy of the R-12. If this were so then it establishes that the Chinese did experiment with the reverse engineering of the R-12 before they moved on to the DF-3.[47] The measurements to justify this are in Table 10 below.

Table 10
Comparison of Image 15 and the Soviet R-12 Missile

Item length	Image 15 of DF-4 Set	R-12
Warhead	3.004 m	3.75 m
Upper part	1.036 m	1.85 m
Interface	0.788 m	
Tank	1.822 m	2.4 m
Interface	0.599 m	
Tank	4.679 m	4.75 m
Interface	0.838 m	0.95 m
Lower tank	7.536 m	7.30 m
Engine +nozzle	1.034 m	1.80 m

[43] For details and a picture of the R-12 please see http://www.astronautix.com/lvs/r12.htm Lewis and Di also talk about the R-12. See John Wilson Lewis & Hua Di, "China's Ballistic Missile Programme: Technologies, Strategies, Goals", International Security Vol. 17 (Autumn 1992), p13 who cite some Chinese awareness of the R-12 design. In our discussion of the DF-2 we encountered the same image and classified it wrongly as the 2–stage DF-4.

[44] http://www.globalsecurity.org/wmd/world/china/images/df-4_p6-1.jpg

[45] Some sources also list it as a DF-2 missile. Image 3 of our DF-2 set of images is exactly the same as this image and has been classified as a DF-2 because it has a diameter of 1.65 m

[46] The same image is seen under both the DF-4 and the DF-3 by different web sites.

[47] One other thing that we see in the sequence of analysis of the DF-3 missile is that we see an increase in the inter-tank length from about 0.4 m to 1.94 m. The R-12 apparently had this increased inter-tank length to house additional control systems. It was possibly one of the earliest systems to do so. This establishes fairly firmly a clear link between the R-12 and the DF-3 in more concrete terms

The DF-5 Missile

According to publicly available information the DF-5 missile was designed to target the continental United States.

Unlike the DF-3 and the DF-4 which used UDMH and AK-27 as the fuel and oxidizer the DF-5 used a more advanced combination of fuel and oxidizer – UDMH and nitrogen tetroxide. The DF-5 was also the first Chinese missile to use an inertial platform instead of a strapdown guidance system.

The DF-5 is reported to be a 3.35 m diameter and 32.6 m long missile. There are apparently 2 variants termed the DF-5 and the DF-5A. The ranges reported in the literature for these two variants with a single 3000 kg thermo-nuclear payload of between 3 and 5 Megatonne yield are 12000 and 13000 km respectively.

Its liftoff weight is reported as 183000 kg.

The reports also state that the DF-5 is silo-based with the silos being hardened against a nuclear attack. The silos are inter-connected through a network of tunnels and a number of dummy silos are also meant to confuse the enemy and ensure retaliation. Though estimates vary the number of deployed DF-5 are ~ 24 missiles.

The DF-5 is also the basic booster for the CZ-2 and CZ-3 series of space launchers. The same production facilities are meant to cater to both requirements.

There are 15 images that are available in the public domain. These have been analysed. Details of the analysis of each missile are provided in Appendix 1.

We get 4 warhead lengths based on our analysis:
1st warhead length: ~ 5.27 m (Images 3 and 10 substantiated by Image 5)
2nd warhead length: ~5.79 m (Image 11 weakly substantiated by Image 2)
3rd warhead length: ~ 6.14 m (Image 4, 6 and 8)
4th warhead length: ~ 6.7 m (Image 13)

These may represent different types of thermo-nuclear weapons.[48]

[48] Unfortunately we have not had the time to look into this aspect in some more detail. Though measurements indicate 4 types of warheads one issue to raise and ask is whether there are really 4 types of warheads and would all of them need to be deployed in the DF-5.

Using similar logic we get 4 upper stage lengths:

1st upper stage length:	6.70 m
2nd upper stage length:	7.23 m
3rd upper stage length:	7.73 m
4th upper stage length:	8.20 m

We also see 4 variants of the first stage tankage:

Variant 1:	12.1 m
Variant 2	13.6 m
Variant 3	14.8 m
Variant 4	15.23 m

The best estimate for the engine + nozzle length from the data is 5.11 m.

Data on tank lengths and interface lengths for both stages are also there in the data base and can be used for assessing performance.

Table 11 summarises these variations.

Table 11
Possible Variants of the DF-5 Missile

Warhead	5.27 m(C1)	5.79 m(C2)	6.14 m(C3)	6.7 m(C4)
Upper stage	6.7 m(B1)	7.23 m(B2)	7.73 m(B3)	8.21 m(B4)
Lower stage tankage	12.1 m(A1)	13.6 m(A2)	14.8 m(A3)	15.23 m(A4)
Engine + interface	5.11 m	5.11 m	5.11 m	5.11 m

In principle we can see that there are a total of 4x4x4 = 64 configurations of the DF-5 that seem possible based on our analysis of the images in the public domain.[49] This does seem to be a large number.[50] The sample of images that we have analysed reveal 5 different variants of these 64 configurations.

[49] There are possibly two different design groups that were given the mandate to develop the engines and the stages for thee DF-5. Public information seems to show at least two organisations one in Shanghai and the other in Beijing responsible for liquid rocket engine development.

[50] Though there are 64 possibilities, we see only a few of these combinations in the pictures we have analysed. The following variants are seen (A1, A2, A3, A4 are the lower stage Options, B1, B2, B3 and B4 are the upper stage options and C1, C2, C3, C4 are warhead options) – A1 – B3 – C1, A2 – B2 –C2, A2 – B3 – C4, A3 – B2 – C2, A4 – B1 – C1. B4 – C1 is also seen though we do not know what the lower stage would be.

Based on the measured lengths of the upper stage and the lower stage tanks we estimated the quantity of propellants (nitrogen tetroxide and Unsymmetrical dimethyl hydrazine) that the rocket would carry for the different variants. We used some engineering knowledge based on discussions with experts to convert the propellant weight into stage weights. Based on a survey of the available literature we also assumed that the weight of a thermo-nuclear payload of the 5 Megatonne class would be around 3000 kilograms. This data was used to run a typical trajectory and based on the final velocity reached we estimated the range.

Ranges achieved by the different combinations of upper and lower stages (with a payload of 3000 kg) are shown in Table 12 below.

Table 12
Range of the various configurations of the DF-5 missile

Upper stage length	Lower tank lengths			
	12.1 m (A1)	13.6 m (A2)	14.8 m (A3)	15.23m (A4)
	Range in km	Range in km	Range in km	Range in km
6.7 m (B1)	6656 km	6539 km	6426 km	6330 km
7.23 m (B2)	7184 km	7038 km	6910 km	6795 km
7.73 m (B3)	7607 km	7444 km	7299 km	7168 km
8.21 m (B4)	7760 km	7589 km	7438 km	7302 km

We can see that the range of the variants of the DF-5 including the DF-5A may lie between ~6700 km and ~7800 km.

How do we explain the Major Anomaly in Range

These values of range are much lower than the ranges reported - 12000 km for the DF-5 and 13000 km + for the DF-5 A - in the published literature.[51] One obvious explanation would be that our measurements and the derivations of mass and range from engineering considerations could have been erroneous. Even though there could be differences between the values we have used and the values others may have used it still cannot explain the large difference in ranges that we see in the published literature and our own estimates.

[51] John Wilson Lewis & Hua Di, "China's Ballistic Missile Programme: Technologies, Strategies, Goals", International Security Vol. 17 (Autumn 1992), http://www.globalsecurity.org/wmd/world/china/df-5.htm, and many other sources state that the range of the DF-5 and the DS-5 A are 12000 kms and greater than 13000 kms respectively. This obviously implies that the DF-5 has to have another smaller stage on top of its second stage to impart additional velocity and range to the DF-5.

The only logical explanation would be that the Chinese have put another smaller stage on top of their second stage. Though most published sources say that the DF-5 is a two stage vehicle there are some sources who also talk of three stages in the details.[52]

To resolve this issue we further investigated the various possible configurations of the DF-5 that may have been the source of the information put out by various entities. Since the same stages with modifications were used for the CZ-2 series of space launchers we looked at both the engines[53] and the stage details provided. Information in the public domain is also available from Chinese sources.[54]

Most sources give the liftoff weight of the DF-5 as 183 tonnes. Our assessment of the smallest configuration of the first two stages gives a liftoff weight with a 3000 kg payload as ~175 tonnes. The largest configuration would have a liftoff weight (with a payload of 3000 kg) of 222 tonnes. Most of the sources do not provide the stage weights separately. One argument could be that the difference of 8 tonnes between the 183 tonnes cited in the literature and our estimate of 175 tonnes could be the third stage that would provide the additional velocity required to get the 12000 km range for the DF-5 to reach the United States. As we shall see we do not believe that such a large stage is required.

The engines used in the first stage are a set of 4 clustered YF20A engines. Our estimates of the length of the stage are lower than the first stages flown on various CZ 2 and CZ 3 configurations. This could maybe also account for the mass differences we get for our configuration.

The engine used in the second stage is possibly a YF-22/23 engine which has a set of 4 vernier engines for attitude control.[55] This engine has been configured as a second stage for the CZ 2A launch vehicle. Our sizing derived from the measurements is in reasonable agreement with this second stage configuration.

We would therefore per se have to admit that unless there is a third stage to the DF-5 the achievement of a range of 12000 or 13000 km is not possible.

One way to check the veracity of our methodology is to compare it with other comparable two stage ICBMs. The closest in configuration and size that we could compare the DF-5 with was the Titan 2 ICBM.

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[52] See for e.g http://www.globalsecurity.org/wmd/world/china/df-5.htm which talks of three stages for the DF-5. A number of blog sites on the Net also talk about the range being less.

[53] The technical data used in our analysis is largely from http://www.astronautix.com/alpha/alpndexy.htm

[54] One source of information is in http://www.cgwic.com/launch/vehicle-3.htm

[55] Portions of a Thor rocket that had crash landed in Cuba including the vernier engines were apparently sold by the Cubans to the Chinese. This according to one source quoting a Chinese source was used to design the second stage of the DF-5. Please see Scott. D. Sagan "The Limits of Safety", Princeton Studies in International History and Politics, footnote 26 of Chapter 3 page 127.

Our trajectory analysis of the Titan 2 reveals that the range of the Titan 2 with the payload of 4080 kg is 6867 km. With a 3 tonne payload similar to the DF-5 the Titan 2 range is 8565 km.

The incremental velocity provided by the first stage of the Titan 2 is more than that provided by the DF-5. This is because the Mass ratio of the Titan 2 first stage is much better.[56] This provides a clear 0.76 km per second advantage to the Titan 2.

This superior performance of the Titan 2 first stage is compensated by the second stage of the DF-5 which seems to be better.[57] The DF-5 second stage has a velocity advantage of 0.771 km /sec compared to the Titan 2.

Thus overall the DF-5 has a marginal advantage. Of course if the Titan 2 payload is reduced to 3000 kg (the payload of the DF-5) its range increases to 8565 km. For the Titan 2 each MIRV warhead may have some additional propulsion that will be able to impart the additional velocity to give it its 10000 km + range. The DF-5 according to the information available does not seem to have MIRV capability though the Chinese are reported to have tried this.[58] The estimated range is of course quite far away from the 12000 and 13000+ kms range that is claimed for the DF-5.

One of the questions that we asked ourselves was whether it would be feasible to put a third stage on the existing DF-5 configuration to take it to a 12000 km range. The answer seems to be that it is indeed possible to do this. From measurements on Image 8 the interface between the warhead and the second stage is conical in shape with a measured length of between 2.25 and 2.5 m. The diameter of the cone that interfaces with the warhead is about 2 to 2.2 m.[59] The volume available would be enough to accommodate a small liquid rocket stage that could propel the warhead to its destinations of 12000 or 13000 km.

In the volume of 2.2 by 2.5 m we should be able to accommodate a small liquid engine within about 1.3 m including the nozzle. This still provides us with a space of about 1.2 m by about 2 m for accommodating the fuel and oxidiser tanks. The volume of 3.77 cubic m can contain about 3800 kg of propellant. The stage mass would be 4220 kg. With a payload of 3000 kg this translates into an initial mass of 7220 kg. This can provide an additional velocity of about 2.2 km per second – more than enough to provide the required range.

[56] The mass ratio of the Titan 2 first stage is 3.94 as compared to a mass ratio of 2.48 for the first stage of the DF-5. This gives the Titan a + 1.2 km / sec velocity advantage

[57] The mass ratio of the upper stage for the DF-5 is 6.98 as compared to 4.84 for the Titan. This gives the DF-5 an advantage of 0.771 km / sec.

[58] The Chinese are reported to have experimented with a Fractional Orbit Bombardment System (FOBS) system under a three stage DF-6 variant. So they do have three stage configurations available. There are also reports that the DF-3 was used to experiment with MIRV. The diameter of the DF-5 is sufficiently large to accommodate several smaller 600 to 700 kg nuclear warheads similar to what may be used on some of the shorter range missiles like the M9 or the M11.

[59] A spherical tank of 1.5 metre diameter would provide about 2 tonnes of propellant. This would provide an additional velocity of 1.44 km per second. An incremental velocity increase of 1.1 km per second is enough to give the DF-5 a range of 12000 km. An increment of 1.25 to 1.3 km per second would increase the range further to 13000 km plus. It may also be possible to accommodate a cylindrical tank

The Chinese also have an YF-40 engine with a thrust of about 49 Kilo Newtons.[60] Two of these engines are used as the upper third stage of the CZ-4A launcher. A stage with just 1 engine may be adequate to deliver the required performance. Just using the data on the engine, a stage with about 2500 kg of propellant appears very realistic. This gives an additional velocity of about 1.5 km / sec.- enough to get it to the 12000 or 13000 km range. Even a solid stage could do the job and there are enough candidates. We believe it is most probably a small liquid stage.

If we look at the information on testing available in the public domain – most tests were confined to within China during the period from 1971 to 1979. In 1979 four to five firings took place mostly confined to within China.[61] These could have most probably been the two stage versions.

The first tests over a long range took place in 1980 when the impact point is supposed to have been an area bounded by the Gilbert islands, the Solomons, Fiji, and the New Hebrides. Launch is reported to have been from Shuangchengzi. The range as we measured it is ~ 8000 km.

From Xichang (Base 27) the range to Washington, New York, Los Angeles and Chicago are 12545 km, 12329 km, 11916 km and 12166 km respectively.

From Tong Dao (location of the 405 Brigade) the ranges to Washington, New York, Los Angeles, Chicago are 12739, 12578, 11645 and 12262 km respectively.

If one goes to a location in the south east section of China the range to Washington would be around 13200 km.

A two stage vehicle like the DF-5 does not have this range to target the continental United States.

To hit targets in the US it is necessary for the DF-5 to have another stage.

Descriptions in the public domain largely but not solely from US sources seem to suggest that the DF-5 is a two stage missile. The Chinese have however only claimed inter-continental capability These provide some additional corroboration to the three stage hypothesis. The additional velocity required to achieve a range of 12000 km is ~ 1 to 1.1 km per second and this can easily be achieved with a small third stage. The Chinese had been developing another rocket for a Fractional Orbit Bombardment System (FOBS). This project called the DF-6 was cancelled in 1973. It involved putting a third stage on top of the DF-5. So a three stage configuration for the DF-5 has always been a part of the programme.

[60] This engine could even be a pressure fed engine. This could also provide some kind of terminal control and guidance and improve the accuracy during the re-entry phase.

[61] Apparently many upper stages do have thrusts that are lower than the stage weight. So this may not be a major problem

It is clear that if the reports of the DF-5 range are indeed true, the Chinese do have a third stage on it. This stage could be based on a YF40 [62]engine and should have a minimum propellant loading of about 2 to 2.5 tonnes. Such an addition would easily give the 12000 to 13000 + km range for the DF-5 and the DF-5A reported in the public domain. Alternatively it could be a separate small stage configured for the DF-5. The 2.5 m by 2.2 m warhead interface area could easily accommodate such an engine. Figure 2 below provides a possible configuration for a third stage that will provide the required range. We can have a two engine cluster also as a possible configuration just as we have on the PSLV Indian launcher

A possible configuration for the 3rd stage of the DF-5

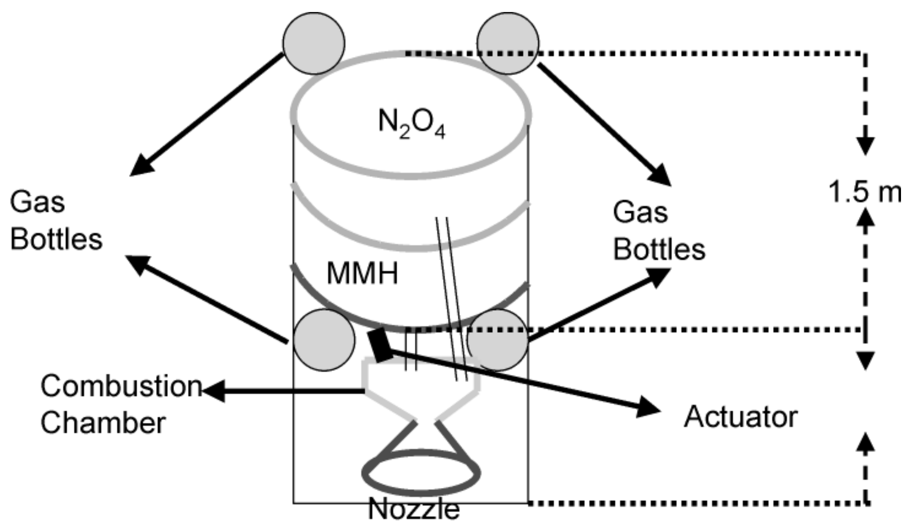

Figure 2

Estimation of the number of DF-5 Missiles

Our analysis also tried to estimate the possible number of DF-5s that the Chinese may have produced. Such an exercise is possible since the DF-5 is the basis for the CZ-2, CZ-3 and the CZ-4 launchers.[63] Some information on DF-5 testing is also available in the public domain.[64] The Figure below provides some details of the space launchings for the period 1973 to 2005. From this assessment we can estimate the number of DF-5s produced.

[62] See http://www.astronautix.com/engines/yf20a.htm

[63] For the launch log of all Chinese Space missions please see http://www.geo.cities.com/Cape Canaveral/launchpad/1921/launch.htm?20068

[64] http://www.globalsecurity.org/wmd/world/china/df-5.htm

In 1979 there were 5 test launches of the DF-5. There was also 1 CZ-2 launch.

This indicates that there was the inherent potential to maybe make and launch about six DF-5 type launchers. If we assume that this was the capacity we can roughly estimate the number of DF-5 that were produced – the total of space launches + the additions to the missile stockpile – launches of missile = 6 nos. every year.

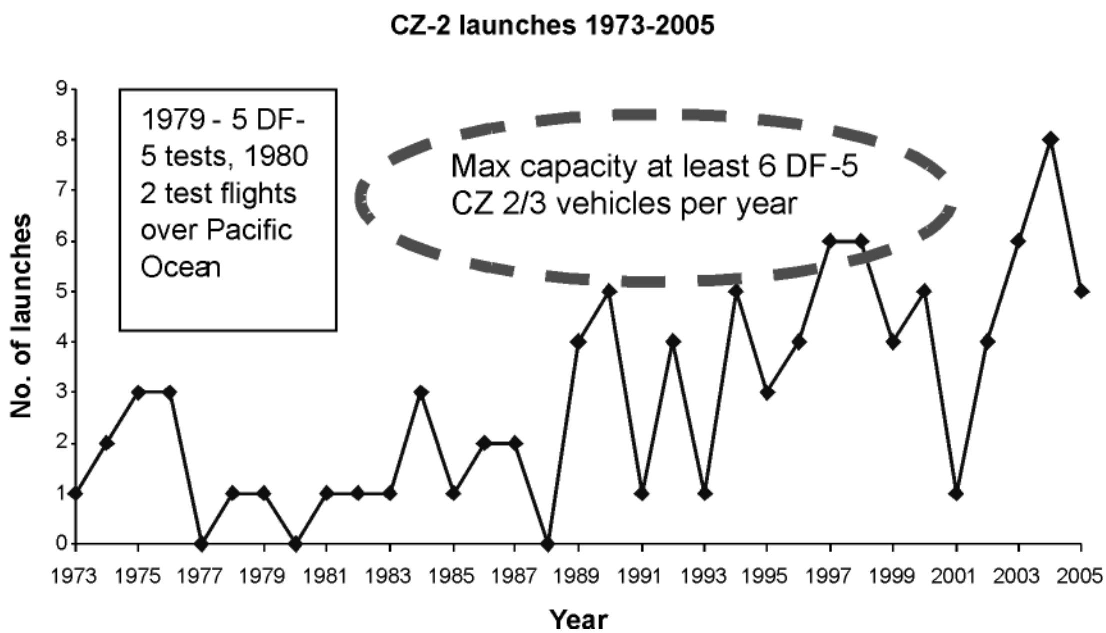

Figure 3

Using this approach one would surmise that in the period from 1980 to 2005 the number of DF-5s that could have been produced assuming a capacity of around 6 DF-5 / CZ-2, CZ-3 CZ-4 is around 67. This is much higher than the 24 reported in the publicly available information. This would seem to indicate that the Chinese may have a stockpile of at least 60 to 70 DF-5s.

Maybe only 24 DF-5s as reported are operationally deployed. There may another 50 or so in inventory that could be deployed at short notice.

Knowing that the DF-5 is meant to target the United States as well as Western Europe, 24 missiles appear to be a deceptively small number. The Chinese seem to have the infrastructure to produce at least six DF-5 type missiles / launchers a year.

The JL -1 & DF-21 Programme

Lewis and Litai[65] have written an outstanding account of the development of the Submarine Launched Ballistic Missile the JL-1 and the political, technology and other problems faced by Chinese scientists and technologists during its development and subsequent deployment.

The problems of control and guidance, rocket motor development, re-entry, stage separation, the testing sequence especially the part related to acquiring control immediately after ejection from the submarine, the creation of the ground Telemetry Telecommand & Control (TT&C) for monitoring of the test launch from a submarine are well presented in the Lewis and Litai book.

It is now well-known that the Chinese first launched their SLBM - the JL-1 –from a Soviet Golf class submarine in 1982. This was followed by successful launch from a Chinese built nuclear powered submarine in 1988.

The period between these two launchings witnessed a number of unsuccessful launchings as the Chinese struggled with mastering the technologies associated with a successful launch after igniting the rocket under the water. The Chinese finally appear to have given up the underwater route for initial ignition in favour of ignition after the rocket clears the sea surface.

In spite of these rich accounts on the development of the JL-1, technical details on the JL-1 in the publicly available literature are rather sparse. Explicit details on parameter like thrust, specific impulse, burn times are not readily available.[66] Some limited literature on Chinese solid rocket motors used as upper stages is available.[67] For our calculations of range and other parameters we have had to extrapolate from this limited data set.

Summary Measurements on the JL-1 / DF-21

There are a number of images of the JL-1 available in the public domain. We looked at 22 images of the JL-1 and its land based equivalent the DF-21. After taking into account the suitability of the image for providing accurate measurements and duplication of the images from different sources we had 6 images that provided accurate measurements of the various parts of the missile. Though some of the images were not suitable for measurements they did provide some information that complemented the understanding we obtained through measurements. The diameter of the JL-1 has been independently validated as being ~ 1.4 m. The details of the analysis of each image are available separately in

[65] John Wilson Lewis and Xue Litai, "China's Strategic Seapower – The Politics of Force Modernisation in the Nuclear Age", Stanford University Press, 2004. Part 1 deals with the development of the submarine and part 2 deals with the development and launch of the JL-1 missile.

[66] Some details are available on the solid rocket stage used to launch China's first satellite at http://www.astronautix.com/lvs cz1.htm

[67] The development of space solid rocket motors in China - Huang J; Ye D, Acta Astronautica, Volume 40 Number 2 January 1997

Appendix 1. Table 13 below summarises the measurements from the 6 images of the JL-1 / DF-21 missile.

Table 13
Summary of Measurements on the JL-1 / DF-21

Image	Warhead	Upper stage	Stage Interface	Booster rocket motor	1st stage Engine	Total Length
Image 2	3.60 m	N.A	N.A	N.A	N.A	N.A
Image 9	3.80 m	1.62 m	0.32 m	4.36 m	0.88 m	10.98 m
Image 14	5.13 m	1.58 m	0.28 m	4.11 m	0.80 m	11.98 m
Image 18	2.3 m	1.46 m	0.22 m	4.43 m	0.76 m	9.17 m
Image 21	3.21 m	1.4 m	0.29 m	4.28 m	1.11 m	10.29 m
Image 22[68]	3.7 m	1.52 m	0.24 m	3.79 m	0.71 m	9.96 m
Average		1.52 m	0.27 m	4.3 m	0.89 m	

Findings on the JL-1 / DF-21

We can see from the Table that there are at least 4 different warheads with lengths of 2.3 m, 3.21 m, ~ 3.7 m and a very long warhead of 5.13 m. The shortest of them with a length of ~ 2.3 m could be a conventional warhead. The others may represent different kinds of nuclear warheads.[69]

There is reasonable consistency in the length of the upper stage (an average of 1.52 m), the length of the stage interface (0.27 m), the length of the lower stage (4.3 m) and the length of the engine (0.89 m).

One can assume that subject to some small variations in the stage lengths the same combination of the first and second stages of the JL-1 / DF 21 caters to different warhead requirements that may serve different strategic objectives. The variability in stage lengths that seem to be so characteristic of the liquid fuelled missiles do not appear in the solid propellant fuelled missiles.

Based on the reliability of the various measurements (determined by the nature of the image and the kind of corrections we need to make) we see 4 possible JL-1, DF-21 configurations. These configurations have lengths of 12.1 m, 10.7 m, 10.2 m and 9.3 m respectively. The literature mentions configurations with lengths of 12.3 m (reasonably close to our value of 12.1 m) and a configuration with a length of 10.7 m (reasonably close to another of our values of 10.7 m).[70] These differences in lengths are largely if not solely determined by the kind of warhead that the missiles carry.

[68] Measurements on the engine length are likely to be inaccurate because of the nature of the image.

[69] http://www.aeronautics.ru/archive/wmd/ballistic/ballistic/css5-01.htm mentions several types of warheads that the Chinese may have on the DF-21.

[70] http://www.aeronautics.ru/archive/wmd/ballistic/ballistic/css5-01.htm

Warheads can be of two possible types – a heat sink kind of warhead design or an ablative type of warhead.[71] Our analysis makes it fairly clear that the warheads we see on both the JL-1 and the DF-21 are ablative type warheads. This is consistent with published accounts of their warhead and re-entry vehicles development.[72] The diameter of the JL-1 which is 1.4 m may make it difficult to MIRV this missile. The differences we see in the warhead shapes may be because of their use in both land based and sea based platforms as well as for different missions.[73]

Based upon the measurements from the images we estimated the mass of the propellant, the masses of the two stages and the liftoff weight of the missile. The estimated liftoff weight for the JL-1 with a 700 kg payload is 14627 kg. This is fairly close to the Liftoff weight values in the published literature.[74]

Our estimate of the range of the JL-1 / DF-21 with a 700 kg nuclear warhead of the boosted fission type is 3073 km. This is much higher than the range quoted in the literature for the JL-1 which varies from values of 1500 km to 2500 km for the enhanced version.[75] Given the fact that the physical dimensions we have measured match the publicly available information on parameters like length, diameter, liftoff weight etc we believe that the range of the JL-1 with a 700 kg payload is indeed greater than 3000 km and not either 1500 km as some published sources say or 2500 km or 2100 km as yet other sources say.

The JL-1 or the DF-21 which is its land version can clearly substitute for the DF-3 and DF-3A. It can provide a somewhat higher range than the DF-3 with a smaller nuclear payload. With a 2-tonne payload it will match or do marginally better than the DF-3A with a range of about 2800 km.

Canister based DF-21 missiles

As a part of the modernisation drive China is moving all its land-based missile assets from being fuelled with liquid propellants towards solid fuels. The DF-21 improved missiles are now stored inside closed canisters and towed by mobile launchers. This approach has been derived from the successful ejections of their submarine launched missiles from under the water. These developments improve the readiness

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71 Re-entry vehicles deal with the heat of re-entry in two ways. They reflect or absorb the heat in one type of arrangement. In the other they have coatings which vaporize and draw away the heat. All the warhead shapes we have seen indicate that they are all of the ablative type.

72 All Chinese missiles have ablative warheads. For some details please see John Wilson Lewis and Xue Litai, "China's Strategic Seapower – The Politics of Force Modernisation in the Nuclear Age", Stanford University Press, 2004 pp178 - 180

73 Different warheads with different capabilities and ranges will result in different re-entry conditions. Some differences in the way the warheads are shaped should be expected because of this.

74 Lewis and Di talk of a 1.4 m diameter, a length of 10.7m and a liftoff weight of 14.7 tonne. See John Wilson Lewis and Hua Di, "China's Ballistic Missile Programmess: Technologies, Strategies, Goals", International Security, Vol. 17, No. 2 (Autumn 1992), p 10. Other sites such as the sinodefence.com and the global security site also provide the same parameters. The Russian site talks about two variants - the DF-21 and the DF-21 A. The DF-21 A has a liftoff weight of 15200 kg as against the lift off weight of the DF-21 which is reported to be 14700 kg. See http://www.aeronautics.ru/archive/wmd/ballistic/ballistic/css5-01.htm

75 The range values quoted differ widely. Lewis and Di state the range to be 1700 to 1800 km. At the global security site the range is reported to be 1700 km with a 600 kg re-entry vehicle mass, the sinodefence site talks of a 2150 km range for the JL-1 and 2500 km for the JL-1A. Please see http://www.sinodefence.com/strategic//missile/jl1.asp

and http://www.globalsecurity.org.wmd/world/china/jl-1.htm of their arsenal for reacting to any threat by reducing the response time. The solid route will also simplify the logistics of moving the missiles around and in the long-run reduce operating costs. We have collected images of the JL-1 / DF-21 that are inside these canisters. There are 15 such images in our data set.

We analysed a few of them to see what we can derive from them. Details of the analysis of each of the 5 images we studied are in Appendix 1.

For the 1.4 m DF-21 the diameter of the canister estimated independently is 1.70 m.

We also got 3 reliable measurements of the canister length. One value of the canister length was 12.1 m. The other length of the canister that we got was ~ 10 m.

Credibility of the Submarine based Deterrence

Doubts have been expressed by many about the credibility of the submarine launched capabilities of China. According to many sources, China only has one indigenously built nuclear powered submarine. Even this has not been operationally deployed in waters far away from the Chinese shores. China is in the process of building a more advanced nuclear powered submarine, which may not yet be operationally ready for deployment. Till such time China's sea-based deterrence capabilities are possibly suspect.

Even if China has in place only 1 nuclear powered submarine, it still has some deterrence value. To assume it is not operational or not capable of being operated during a crisis would be too big a risk to take. There is no doubt however that China is developing a more advanced submarine to deploy its more advanced 3-stage JL-2 missile. Even if there are some operational problems, the Chinese missile and submarine building entities have the technical, organizational and system engineering resources to address them. The robust infrastructure that China has created will ensure that they have in place all the elements of a guaranteed submarine based deterrence very soon.

None of the images that we have analysed provide a clear view of the 4 nozzle cluster of the first stage booster of the JL-1 / DF-21. Lewis and Litai talk about the many technical difficulties that the Chinese missile engineers encountered in its development.[76] There is one image published in their book.[77] This image is also available in the public domain.[78] An analysis of this image indicates that the diameter of the rocket motor with the 4 visible nozzles is only 1 m. If this was really the booster stage of the JL-1 its diameter should be 1.4 m and not 1 m. Our view is that this could represent the third stage of the

[76] John Wilson Lewis and Xue Litai, "China's Strategic Seapower – The Politics of Force Modernisation in the Nuclear Age", Stanford University Press, 2004, image 30

[77] http://www.globalsecurity.org/wmd/world/china/images/jl-1-7.jpg

[78] John Wilson Lewis and Xue Litai, "China's Strategic Seapower – The Politics of Force Modernisation in the Nuclear Age", Stanford University Press, 2004 pp 157 - 158

new JL-2 / DF-31 missile that the Chinese are reportedly developing.[79] Alternatively it could be a new configuration for the booster of the M-9 (DF-15) missile. If it were the upper stage this raises the issue of what additional capabilities could be provided by such an upper stage.[80] Understanding the technical logic for such a development is an issue which we have not been able to address in our study.[81]

Number of JL-1 / DF-21 Missiles

Based on our analysis we have tried to estimate the number of JL-1 / DF-21 missiles that the Chinese may possess.

According to Lewis and Litai the JL-1 / DF-21 missile was tested in three batches.[82] The first, second and third batches involved a production of 8, 11 and 8 missiles respectively. Their account also makes it clear that development difficulties not related to production of propulsion systems or their integration were the major reasons for the delays they encountered in the period form 1982 to 1988. The major delays actually came about from the problems they may have had with respect to underwater ignition.

Once these development problems have been resolved it would appear that the Chinese would be able to produce about 8 to 10 JL-1 / DF-21 missiles in a year from the above data. This would mean that the rocket motor production for the JL-1 / DF-21 would be about 20 grains which is consistent with the casting curing cycle for typical rocket motor grains.

From 1989 to 2006 this would translate into a production of 170 missiles. The DF-31 development and testing may require some common facilities and specialized skills. At about 1 DF-31 test a year[83] this may reduce the production of the JL-1 / DF-21 missile by about 20 missiles. This would mean that about 150 JL-1 / DF-21 may have been produced in the period 1989 to 2006. 12 of these would be the JL-1 required for the operational submarine and another 12 may be the back up inventory. This would result in about 125 DF-21 missiles being available as of 2006. Since these will be replacing the DF-3 one should assume that most of them would be deployed.

79 This would suggest that the upper stage of the JL-1 could also have a 4 nozzle configuration. Lewis and Litai briefly mention this. John Wilson Lewis and Xue Litai,, “China’s Strategic Seapower – The Politics of Force Modernisation in the Nuclear Age”, Stanford University Press, 2004, p 158.

80 According to Lewis and Litai the second stage uses secondary injection of a fluid into the 4 nozzles of the second stage. In principle the same degree or even a greater degree of control can be achieved by rotating the nozzle as they any way do in the booster.

81 Robert Hewson, “Dragon’s teeth - Chinese missiles raise their game” provides some details of how the DF-21 can be used against ships. See http://www.janes.com/defence/news/jni/jni061219_1_n.shtml

82 John Wilson Lewis and Xue Litai, “China’s Strategic Seapower – The Politics of Force Modernisation in the Nuclear Age”, Stanford University Press, 2004 pp 184 - 205

83 Even if the casting and curing facilities are separate there could be some common use of resources like skilled manpower that could take away some capacity. This is the assumption. To validate the DF-31 number of an average of 1 test a year please see details provided in http://www.globalsecurity.org/wmd/world/china/df-31.htm

The Submarine Bases

The submarines are located in a protected underground harbour that has been hardened to withstand any attack. This major facility is located at Qingdao in Shandong province. The Submarine Training Institute is also located here. A second submarine base is reported at Lushun in Liaoning Province.[84]

The JL-2 / DF-31 Missile

Lewis and Litai in their book discuss some of the details of the JL-2 / DF-31 development. They state - quoting a Chinese reference - that the first two stages of the 3-stage JL-2 have 2 m diameter solid rocket motors and the third stage has a 1 m diameter solid rocket motor.[85]

Another reference talks about both the DF-31 and an improved DF-31 A. The DF-31 A according to this source uses the same first two stages as the DF-31 but adds a different third stage to increase the range from about 8000 km for the DF-31 to 10000 km + for the DF-31A. The DF-31A will replace the liquid fuelled DF-5 missiles. This same reference provides some details of the DF-31 / DF-31A.[86]

The project to build the JL-2 and the advanced submarine was apparently delayed due to Deng Xiaoping who wanted a greater focus on economic development. In 1986 the priorities apparently shifted towards the development of the land-based version of the JL-2 called the DF-31. So unlike the JL-1 which converted a missile developed for launch by a submarine to a land based DF-21 launcher, the JL-2 / DF-31 programme envisages a movement from a land-based platform towards a sea-based submarine platform.

Though Lewis and Litai claim that the JL-2 cannot be launched from a Golf class submarine another report suggests that the Chinese did conduct some pop up tests using the Golf class submarine. This same report quoting Bill Gertz suggests that China conducted JL-2 tests in 2002 and 2003 and that a test failed in the summer of 2004. The Chinese are reported to have successfully tested the SLBM JL-2 on 16 June 2005.[87]

Based on the reports it would appear that the development and testing phase of the DF-31 is almost over and deployment on land will start soon. If the report on the successful JL-2 test is presumed to be true it would suggest that the advanced larger nuclear submarine is also becoming operational. If this were so we should see operational deployment of these weapon systems soon – by 2008 to 2010.

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[84] John Wilson Lewis and Xue Litai, "China's Strategic Seapower – The Politics of Force Modernisation in the Nuclear Age", Stanford University Press, 2004 p 123 and footnote 123 p 293.

[85] John Wilson Lewis and Xue Litai, "China's Strategic Seapower – The Politics of Force Modernisation in the Nuclear Age", Stanford University Press, 2004 footnote 107 p 292

[86] http://www.sinodefence.com/strategic/missile/df31.asp talks about a launch weight of 42000 kg, a length of 13 m and a diameter of 2.25 m

[87] http://www.globalsecurity.org/wmd/world/china/jl-2-7.htm

We could find about 24 images of the JL-2 / DF-31 missiles in the public domain. However all of them were inside canisters.[88] This makes it difficult to make measurements on them. We have catalogued these images by source.

Though the new Chinese nuclear-powered submarine is much bigger, the launch of the JL-2 from a submarine would put some constraint on the length of the missile. It cannot be very much longer than the 10.7 m length reported for the JL-1.

From the publicly available information the JL-2 / DF-31 will have a lift off weight greater than 20 tonnes and a range of about 8000 km with a 700 kg payload. It will have an MIRV capability and could carry 3 or 4 small 90 KT re-entry vehicles or a larger 250 to 1000 kilotonne nuclear warhead.

We looked at a few of the 24 images of the JL-2 / D-31 that we had collected. We tried to estimate independently the length and the diameter of the canister using benchmarks available in some images and extending it to other images in which there were no benchmarks. Details of the analysis on each of the images are in Appendix 1.

The analysis suggests that there are at least two versions of the DF-31.[89] One version has a canister length of about 13.4 m and the other a canister length of 12.3 m. Are these the DF-31A and the JL-2 / DF-31?

The canister diameter in all the 4 images we analysed was in the range of 2 to 2.2 m – closer to 2.2 m.

Can we get some idea of the performance of the JL-2 / DF-31?

We have studied in detail the possible ways in which the Chinese could have configured the JL-2 to fit it within the constraints imposed by the submarine platform that has to launch it. The details of this are in Appendix 2.

We believe that a critical element that would affect the performance of the overall missile would be how the upper stage and the Post Boost Control Vehicle (PBCV) with MIRV can be accommodated within the length and diameter constraints. One approach would be a PBCV carried on top of the third stage. We call such a configuration a tandem configuration. The other approach would be to carry most of the requirements of the PBCV around the third stage as is done in the case of the US Trident D-5 missile. We call such a configuration a submerged configuration since the third stage of the missile is carried inside the PBCV.

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88 http://www.sinodefence.com/strategic/missile/df31.asp and http://www.sinodefence.com/strategic/missile/jl2.asp and http://www.nti.org/db/china/df31.htm and http://www.globalsecurity.org/wmd/world/china/jl-2.htm and http://www.globalsecurity.org/wmd/world/china/df-31.htm

89 This would assume that the TEL wheel base dimensions would be the same.

Our studies show that the tandem configuration performance may not be adequate given the uncertainties in development. Our configuration studies also indicate that a multiple nozzle submerged upper stage of ~3.2 m length, a diameter of 1 to 1.1 m along with a 2m diameter second stage of length ~ 2.58 m and a 2 m diameter first stage of length of ~6.6 m can match the range of the Trident if the 3 MIRV total payload is between 1200 and 1350 kg. The submerged configuration with multiple nozzles is the more likely configuration.

The range with such configurations will be between 7300 and 7800 km with a 3 MIRV payload. To get to this range the total weight of the PBCV should be between 1200 and 1350 kg. The realization of a PBCV within this weight and within the volume constraints is the major challenge facing China's missile designers.

We believe that the propulsion for the PBCV will be provided by a bipropellant pressure fed system with either one or two nozzles. The tanks and the gas bottles can be accommodated in the annular space available around the 1 to 1.1m third stage. Since inclination changes will be needed to individually target each re-entry vehicle the PBCV must be able to provide an additional velocity of at least 700 to 1000 m per second.

The 13.4 m long canister most probably houses the MIRV configuration. The other canister which has a length of 12.3 m most probably has a JL-2 missile that carries a single warhead. Our studies indicate that several configurations within the available length and diameter envelope will be able to take a single 700 kg warhead to a range of 12000 to 14000 km. This missile may be easier to develop than the MIRV version. This is most probably the DF-31A or the DF-41 missile that is reported in the literature.

The key technology elements involved in the realization of the JL-2 / DF-31 are:

- A four nozzle configuration is essential for containing the nozzle length and achieving a reasonable expansion ratio.
- Contouring of the nozzle and submergence will bring down the nozzle length.
- It is also necessary that the rocket motors for the 3 rocket motor stages are state-of art motors. All of them including the upper stage may be 4 nozzle configurations.
- The propellant fractions in these rocket motors need to be of the order of 90 to 92 percent.

This also would involve significant technology and development challenges. The Chinese by now have possibly solved most of these challenges

It is our view that the Chinese are almost there. When the JL-2 / DF-31 become operational, the Chinese may be able to launch a MIRV from a submarine with a range of about 8000 km. While they may be able to launch only 3 MIRV compared to the 8 MIRV from a US Trident missile it is still a substantial capability. It would possibly put China almost on par with the US when this happens. We think this may happen soon.

With a Megaton warhead launched from a submarine they would be able to reach any part of the world. One would expect these missiles to replace the liquid fuelled DF-5 missiles as and when they enter service. Further details are available in Appendix 2.

The DF-31A / DF-41 Missile

This is reported to be the replacement for the liquid fuelled long range DF-5 ICBM targeted at the continental US and Western Europe. The shorter variant of the DF-31 that we saw in the earlier section is most probably the DF-31A which will eventually replace the DF-5 liquid fuelled missile.

The DF-15 or the M9 Missile

We have provided details of the M9 missile in a separate study.[90] We summarise the measurements we made on images of the M9 available in the public domain in Table 14 below. Details of the analysis of each image is separately provided in Appendix 1

Table 14
Measurements on M9 images

Image	L/D ratio	Warhead	Motor + nozzle	Length	Comment
Image 9 (M9)	8.86	4.41 m	4.45 m	8.86 m	New TEL. Different from MAZ 543 TEL
Image 10 (M9)	8.89	4.08 m	4.81 m	8.89 m	Diameter 1 m verified using MAZ 543 TEL dimensions
Image 11 (M9)	9.70	5.08 m	4.62 m	9.70 m	Longer warhead. New configuration
Image 12 (M9)	8.40	3.53 m	4.87 m	8.40 m	Short warhead. Early configuration?
Image 13 (M9)	8.84	4.29 m	4.54 m	8.84 m	Similar to image 9.

Images 9, 10, 11 and 12 are of the Chinese M9 missile. Images 10 and 12 are images of the launch of the missile from a mobile MAZ 543 derived TEL. Images 9 and 11 are pictures of the M9 being carried on a Chinese built TEL.

[90] S.Chandrashekar, Arvind Kumar, Rajaram Nagappa, "An Assessment of Pakistan's Ballistic Missile Programme", NIAS Internal Report, 2006

Images 9, 10 and 12 have lengths ranging from 8.4 to 8.9 m. These differences are due to differing warheads (conventional warhead and a nuclear warhead) with some differences in rocket motor dimensions too. Image 11 has a length that is greater by nearly 1 metre – 9.69 m. It has a longer payload. This could be the M9 with a more advanced nuclear payload.[91]

The stage (rocket motor + nozzle) length varies from ~ 4.5 m to about 4.8 m. It is quite possible that what we are seeing is reduced version of the original M9.

Based on our measurements the propellant weight and stage weight of the M9 have been estimated as 3541 and 4426 kg respectively. With a payload of 700 kg or 1000 kg this translates into a lift off weight of 5126 and 5426 kg respectively.

The maximum range of the M9 that we get is 219 km and 279 km for a 1000 kg and 700 kg payload respectively. The time of flight and the apogee height for these 2 cases are 241 seconds, 281 seconds, 63 km and 84 km respectively. The range of the M9 as estimated is lower than the range of the smaller diameter M11 missile. This lends credence to the view that the publicly revealed capabilities of the M9 conceal much more than what they reveal.[92] The real capabilities of the M9 are likely to be significantly more. The M9 as originally conceived was supposedly a part of the 2-stage M18 missile.[93]

Images 10 and 12 are carried on a MAZ 543 derived TEL. The diameter measurements based on a tyre diameter of 1.5 m gives a missile diameter very close to 1 m.[94] Images 9 and 11 do not use the MAZ TEL but another version of the TEL which seems to have a shorter wheel base and a smaller diameter tyre. A wheel base of about 1.35 m and a tyre diameter of about 1.05 m would be compatible with a 1 m diameter M9 missile.[95]

Though there are references in the literature to the German origins of the TEL or to the TEL being based on a Mercedes Benz or Iveco technology[96], the Chinese TEL seems to be different. Their version resembles the MAZ 543 in outward shape with the dimensions being different. The TEL on which later M9 missiles are carried is also a Chinese made TEL.[97]

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91 The D15 A is supposed to have a more advanced and more accurate nuclear warhead. See http://www.softwar.net/df15.html. Also see http://www.sinodefence.com/nuclear/df15.asp for the sources of the images.

92 If they were developed as tactical missiles in the context of Taiwan and if the M11 and M9 were developed by separate groups for carrying a much smaller tactical warhead the shorter lengths are understandable. M9s were tested during the Taiwan Straits crisis of 1995-96 as a show of Chinese strength and intentions to act if Taiwan moved towards declaring independence. Both the M11 and the M9 may have been used to test an improved more accurate tactical nuclear warhead targeted at Taiwan

93 See http://www.aeronautics .ru/archive/wmd/ballistic/ballistic/css6-01.htm which actually is sourced from Jane's Strategic Weapons System. According to this the M18 is a larger 2-stage version of the M9. Another source http://www.globalsecurity.org/wmd/world/china/df-11.htm claims that the M18 is a two stage version of the M11.

94 Values obtained using the tyre diameter for Image 10 and the width of the TEL for image 12 were 1.03 and 1.07 m. If wheel base measurements were used these values changed somewhat. These would change depending on where the standard is located and where on the image the measurement is made.

95 If we assume a diameter of 1 m we can work out the other measurements.

96 http://www.aeronautics.ru/archive/wmd/ballistic/ballistic/css6-01.htm

97 The Taian 5380 heavy duty vehicle is the base for the M9 TEL. For some details see http://www.sinodefence.com/army/transport tas5380.asp. There is also known transfer of MAZ 543 TEL technology from Ukraine to the Chinese.

There is little doubt that the Chinese M9 is the source of technology for Pakistan's Shaheen 1 and Shaheen 2 missiles. A separate publication expounds on this connection in greater detail.[98]

The DF-11 or the M-11 Missile

According to many reports the Chinese M11 was supposed to be a solid propellant replacement for the liquid propelled SCUD B[99] Russian (Soviet) missile. The missile was meant to cater to both the domestic and export markets. Due to MTCR considerations, the Chinese were reported to have reduced the length of the missile by about 2 m to meet the 300 km 500 kg payload limit. These reduced length M11 missiles were the ones exported to Pakistan and de facto became the Ghaznavi missile.[100] Measurements were made on 4 images of the DF-11 missile available in the public domain. The details of the analysis on each of the images are in Appendix 1. Table 15 below summarises the measurements made on this missile.

Table 15
Measurement Summary M11 Missiles

Image	Warhead	Rocket motor	Total length
M11 image 1	N.A	N.A	**11.34 m**
M11 image 2	3.81 m	5.76 m	**9.57 m**
M 11 image 3	4.09 m	6.54 m	**10.65 m**
M 11 image 4	4.80 m	6.17 m	**10.97 m**

The available evidence from the images of the M11 seems to indicate that there are 3 warheads – 3.81 m, 4.09m and 4.80m. There are also 3 incremental versions of the Chinese M11 rocket motor with lengths of 5.76m, 6.17m and 6.54 m. There are 2 (maybe 3) warheads and 3 rocket motor lengths that seem to be part of the Chinese M11 arsenal. In principle that would give rise to about 2x3 = 6 or 3x3 = 9 possible configurations of warheads and rocket motors each of which would have a different total length. Of course even though these combinations may be possible some of them may not be feasible because of some technical problems like stability or because the particular combination of warhead and rocket motor gives no specific practical advantage in terms of range or payload over other combinations that have already been proven.

98 S.Chandrashekar, Arvind Kumar, Rajaram Nagappa, "An Assessment of Pakistan's Ballistic Missile Programme", NIAS Internal Report, 2006.

99 For data on the SCUD see "R-17 rocket tech dossier" at http://www.russianspaceweb.com/r17.html. There is also information from French sites.

100 There are several sources that talk of the connections. The M11 Chinese missile is supposed to be a solid version of the Soviet / Russian SCUD B missile. See http://www.fas.org./nuke/guide/china/theater/df-11.html and http://www..aeronautics.ru/archive/wmd/ballistic/ballistic/css77-01.html. Most of the information may be sourced in part from Janes Strategic Weapon Systems. A more elaborate presentation of the origins and exports is available at http://www.sinodefence.com/nuclear/df11.asp. Another site that provides similar information on origins and exports is http://www.globalsecurity.org/wmd

The M11 is compatible with the Russian MAZ 543 TEL mobile launcher. Since there is a lot of information available on the SCUD[101] we can make some reasonable assessments of the lift-off weights and propellant weights of a solid propellant SCUD substitute missile.[102] Based on our measurements the propellant weight carried by the DF-11 is 5151 kg and the stage weight can be estimated as 6690 kg.

The range of the M11 with a 1000 kilogram payload is ~384 km with a time of flight of 332 seconds and an altitude of 109 km. With a payload of 700 kg it has a range of 463 km. As we can see this range is greater than the range of the larger 1 m diameter DF-15 missile.

Cruise Missiles

China has been active in the development and deployment of cruise missiles for the past forty years. While the early missiles were of short range with main application for anti ship and coastal defence applications, recent development centre around long range attack missions. China is reported to have acquired the Soviet Styx missile technology in 1959[103] and based the development of its Silkworm missile on this technology. Similarly their anti ship missile is stated to be based on reverse engineering of the French Exocet missile[104]. China has also deployed land attack cruise missiles and is also developing long range versions. In this development, China appears to have benefited from the procured Russian Raduga Kh 55 (Kent) as well as the 'captured' Tomahawk missiles obtained from Pakistan.

Assessment

An approach similar to the ballistic missile capability of China is not possible on account of the paucity of imagery. The few available images do not have a calibrating dimensional measurement. In the absence of these a survey of available literature and an approach methodology for sizing the cruise missile is suggested. The Chinese cruise missiles with a range higher than 80 km is shown in table 16 [105]

[101] A lot of information from various sources are available. See the R17 Rocket dossier at http://www.russianspaceweb.com/r17.html. Also see "DOD: Information Paper – Iraq's Scud Ballistic Missiles" http://www.iraqwatch.org/government/US/Pentagon/dodscud.htm

[102] There are many estimates of the propellant and stage masses of the SCUD B missiles. Most of them are reasonably close to each other. We take a value of 3700 kg for the propellant carried by the SCUD B as the basis. Since the SCUD B was designed for a propellant oxidizer combination of UDMH and IRFNA whose average density we know to be 1220 kg per cubic metre we can estimate a volume for the liquid propellants. If instead of liquids we use a solid propellant whose density is about 1700 kg per cubic metre we get a solid propellant mass (3775 kg in our case) that can be carried in the same volume as the SCUD B liquid fuel.

[103] http://www.fas.org/man/dod-101/sys/missile/row/hy-1.htm

[104] http://www.globalsecurity.org/military/world/china/c-801.htm

[105] http://www.missilethreat.com

Table 16

Cruise Missiles Overview

Designation	Mission	Propulsion	Launch Platform	Range	Payload	Remarks
HY – 1	AS	LR	G/S	80 Km	400 Kg	Operational
HY - 2	AS	LR	G/S	95 Km	513 Kg	
HY – 3	AS	RJ	A/G/S	100 Km	500 Kg	
HY – 4	AS	TJ	A/G/S	150 Km	500 Kg	
YJ - 6	AS	LR	A (H6D bomber)	100-110 Km	500 Kg	Can cruise at altitudes of 50-100 at M 0.9
YJ - 62	AS	TJ/TF	S	280 Km	513 Kg	Improved YJ 6
YJ - 82	AS	TJ	A/G/S	120 Km	165 Kg	YJ 83 is an improved version with range of 150-200 km
HN – 1	LACM	TJ	G	600 Km	400 HE / 90 kT	HN 1 operational; HN 2/3 under development. KH 55/ Tomahawk technologies inputs are presumed.
HN - 2	S/LACM	TF	S/G	1800 Km	HE? Nucl.	
HN – 3	S/LACM	TF	S/G	3000 Km		

Key to abbreviations used in the table:

HY:	*Hai Ying*	*LR:*	*Liquid Rocket*
YJ:	*Ying Ji*	*RJ:*	*Ramjet*
HN:	*Hong Niao*	*TJ:*	*Turbojet*
AS:	*Anti-ship*	*TF:*	*Turbofan*
S/LACM:	*Ship/Land Attack Cruise Missile*	*HE:*	*High Explosive*
Nucl.	*Nuclear*		

From the above table and information available in the public domain, the following inferences can be drawn regarding Chinese cruise missile capabilities.

- From coastal defence and anti-ship versions of missiles, they have advanced to long range attack configurations
- They are in a position to use all varieties—land, sea, air—of launch platforms
- In terms of propulsion from the easy to do/adapt solid and liquid rockets, their present missiles use turbo-jet or turbo-fan propulsion. They have also tried ramjet propulsion.
- Inertial navigation aided with GPS guidance (derived from the ballistic missile programme) is perhaps a standard feature.
- The land attack versions are bound to be fitted with terminal guidance using TERCOM (Terrain Contour Matching) and television imaging.
- Resistance to jamming by fitting the missiles with frequency agile radar seeker systems.

Methodology for Performance Assessment

The reported launch weight, performance and subsystem description has come from western sources, based on displays in parades, air shows and their own assessment. It is further reported that China obtained unexploded warhead Tomahawk missiles through Pakistan and procured the KH 55 through Ukraine. This perhaps lends credence to the fact, that many technology inputs especially in the HN series have been derived from these missile systems. The Tomahawk and KH 55 missile systems have many common features and from the available image of YJ 62 it will not be wrong to surmise that similar features are incorporated in the HN series of cruise missiles.

The reported details of HN[106] missiles in comparison with the Tomahawk[107] and KH 55[108] are shown in table 17.

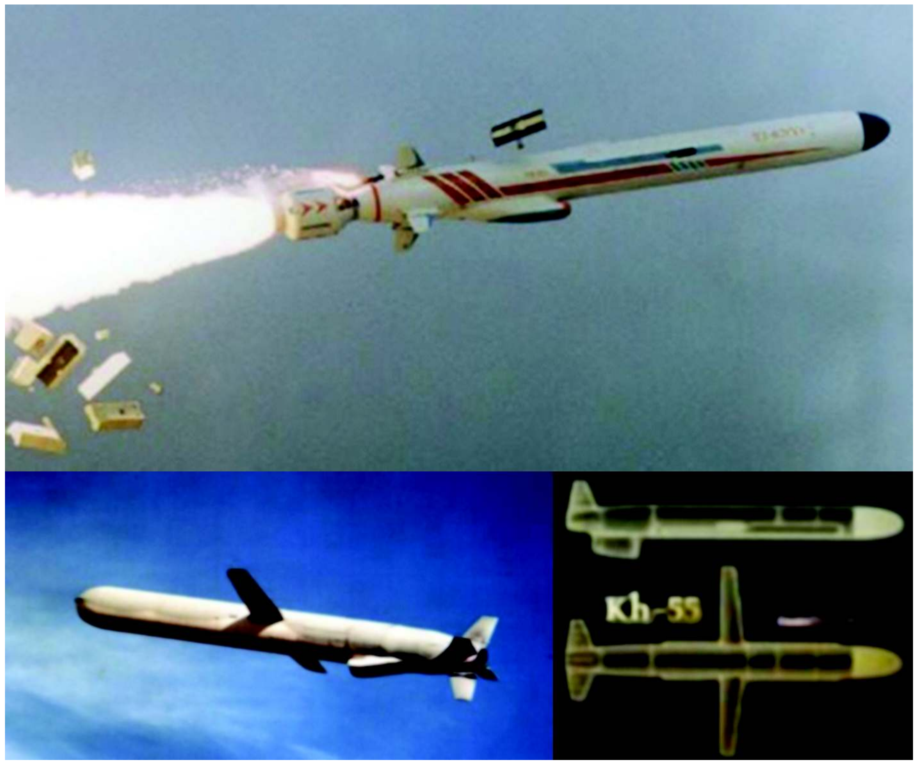
Table 17
Details of the HN Series of Cruise Missiles

Parameter	HN 1	HN 2	HN 3	Tomahawk RGM/ UGM109A	KH 55SM
Length	6.4 m	6.4 m	6.4 m	5.56 m	6.04 m
Diameter	0.5 m	0.7 m	0.75 m	0.531 m	0.514 m
Wing span	2.50 m	2.50 m	2.50 m	2.62 m	3.10 m
Weight	1200 kg	1400 kg	1800 kg	1450 kg	1185 kg
Warhead yield (kT)	90 kT	—	—	5-200 (W-80-0) kT	200 kT
Speed (Mach No)	0.8 M	—	—	0.9 M	0.77 M
Cruise Altitude	20 m	—	—	Very low	<110 m
Range	600 km	1800 km	3000 km	2500 km	3000 km
Cruise Propulsion	Turbojet	Omsk OKB TRDD50 T/fan		Williams F 107-WR-400 T/fan	R 95-300 T/fan
Guidance	INS/GPS/ TERCOM/Radio Altimeter		—	INS/TERCOM	Inertial with Doppler Radar/ Terrain Map Updates
Status	Operational*		Develo-pment	Operational	Operational

**HN 1A and HN 1B are the ground and air launched versions of HN 1. For HN 2, HN 2A is the ground launched version with a range of 1800 km, HN 2B is the ship launched version with a range of 1800 km and HN 2C is the submarine launched version with a range of 1400 km .The HN 2 was reportedly tested in 1995 with 4 additional tests reported in 1997and operational evaluation started in 1998.*

106 http://www.missilethreat.com/cruise/hn_1/2/3/.html
107 http://www.astronautic.com/lvs/tomahawk.htm
108 http://kh55quickseek.com/

YJ 62



Some level of extrapolation regarding the HN series of cruise missiles can be drawn from the details and imagery of YJ 62 anti-ship cruise missile. The missile launcher[109] was seen for the first on board the PLA Navy's Lanzhou class destroyer in 2004. An internet picture of the missile was posted soon after and can be seen in figure 1. The Tomahawk[110] and the KH 55[111] missile pictures are also reproduced below the YJ 62 missile and it is evident that the missiles share common features.

From an examination of the images, the following similarities can be seen:

- All have Cylindrical fuselage with pop out planar wings approximately at the mid body region. (In the YJ 62 picture, the wings are not deployed, but one would assume the wings to be located in the blue painted strip in the mid-body region).
- Tail fins are cruciform configuration for YJ 62 and Tomahawk. The KH 55 has a 3 fin configuration.
- The Control surfaces are kept folded and deployed after launch.

[109] http://www.sinodefence.com/navy/navalmissile/yj62.asp

[110] http://www.designation-systens,net

[111] http://www.aeronautics.ru

- Solid booster is used for the starting phase of flight (The pictures of Tomahawk and the KH 55 are during the post-boost phase of flight).
- Cruise propulsion uses Turbofan/Turbojet engine.
- In the case of Tomahawk the engine inlet is deployed, while in the case of KH 55 the whole engine is deployed. The YJ 62 seems to have adopted the Tomahawk model by deploying only the inlet.
- The lengths of Tomahawk, KH 55 are 5.56 and 6.04 m (without the solid booster) respectively. The length of YJ 62 is reported to be 6.1 m.

The YJ 62 diameter is not reported. One would guess the diameter will be of the same order, i.e., 0.5-0.6 m. However, the range of YJ 62 is 280 km as compared to 2500 and 3000 km for the other two. The shorter range could be a design requirement. Also the design may not be optimized and may involve heavier structural and avionics mass as well as employ an engine with higher fuel consumption.

It is well within the Chinese capability to extend and improve upon the technology to achieve the reported features and performance of the HN series of cruise missiles. China is also reported to have procured the technology for manufacturing the OMSK turbofan engine from Russia and these are reported to be fitted on HN 2/3 and will help in performance improvement. Unfortunately, there are no images of these missiles in the public domain to corroborate this.

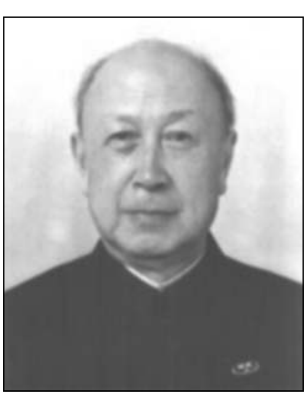
The first cut performance estimation methodology is indicated Appendix 3.

Organisations, Infrastructure & Networks

China's ballistic missile programme is now five decades old. In spite of many ups and downs including major societal upheavals such as the Great Leap Forward and the Cultural Revolution, China has been able to build an advanced and robust ballistic missile capability. The programme began in 1956, in a very small and modest way. The current organisation and structure of their ballistic missiles and space programme suggests that they have been able to integrate technology with organisation routines and practices that provides them with significant national system engineering capabilities characteristic of an advanced industrial economy. This national system capability is reinforced with a fairly closely knit informal network of people that span the political, military, technology and academic domains. This enables the decision-making system to bridge many gaps that come about from the organisation and development of complex high technology national security systems. We will try and map some of these inter-linkages between various organizations. We will also see how the movement of the people from one organisation to another created networks of influence that facilitate system engineering and decision-making. Many scientists and engineers from the missile and other strategic programmes are now moving into and occupying important positions in the political and decision making system of China. The historical path through which China has achieved these major capabilities in missile systems that it now possesses is crucial for understanding current trends that will affect China as it moves towards becoming a major player in the global geopolitical arena.

The Dynamic Evolution of the Missile Infrastructure

This section will study the organisations involved in China's ballistic missile programme. It would also look into the circumstances under which the programme started and the various phases it went through over the years. The infrastructure created for both solid & liquid rocket motors, guidance and control systems and for system integration in the last five decades reveals that they have worked systematically and built capability not only in the domain disciplines but more importantly in systems design, development and integration.


Qian Xuesen

China has a large, well established infrastructure for the development and production of ballistic and cruise missiles. In the early days, Mao himself directed R&D relating to aircraft and missile delivery systems.

Qian Xuesen was the central figure in Mao's plan. Xuesen has been regarded as the father of China's rocketry and ballistic missile programme. He was the driving force behind the first generation of nuclear missiles and satellites in China. His credentials were very high. Xuesen had worked with the great Theodore Von Karman an aerodynamicist and a well known expert in aerospace systems at the Jet Propulsion Laboratory in California.

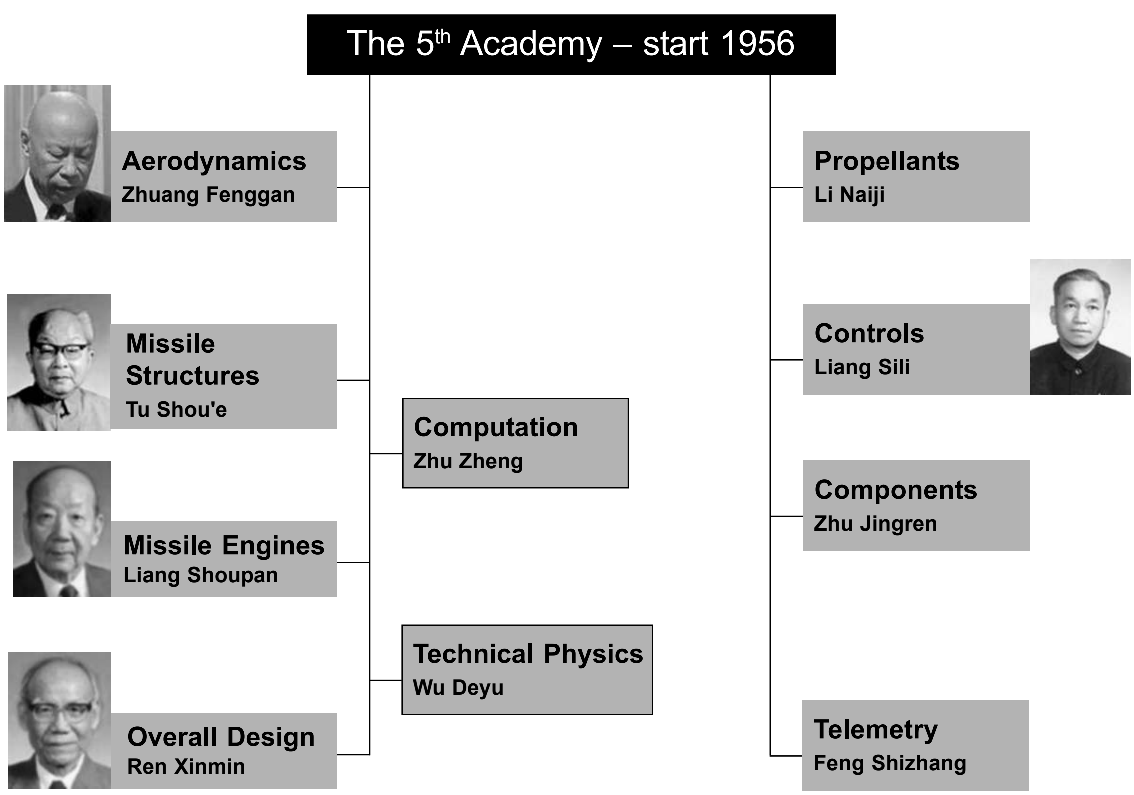
In 1956, Qian had submitted a report on Defence aviation to the Central Military Commission (CMC). The CMC accepted Qian's main recommendations and organized the Aviation Industrial Commission under Marshal Nie Rongzhen to manage the programmes for guided missiles and military aircraft. The management of important programmes through special purpose high level commissions directly linked to the PLA and the Politburo has always been a feature of many of the high technology programmes and projects that China has undertaken. During the same year, Nie approved a proposal to create a unit for developing surface to surface strategic missiles.

During the initial years of China's ballistic missile programme, the Soviet Union helped China by providing training in ballistic missile technology to Chinese students. It also delivered two R-1 rockets to China as per the commitment made in the Soviet-China assistance accord. The CMC had already formed the Fifth Academy under the Ministry of National Defence before two Russian R-1 rockets arrived in China. Qian Xuesen was made the Director of the Fifth Academy in November 1956 where he continued to Head the organisation until April 1960.

Within months of the Fifth Academy's creation in October 1956, it had formed ten research sections, each headed by a senior scientist. Chart I shows the organisation of the activities of the fifth Academy.

A network of factories was built in the interior of the country under the assumption that a full scale war was likely. The Chinese began to reverse engineer the Soviet R-1 missile which was renamed the

CHART - I



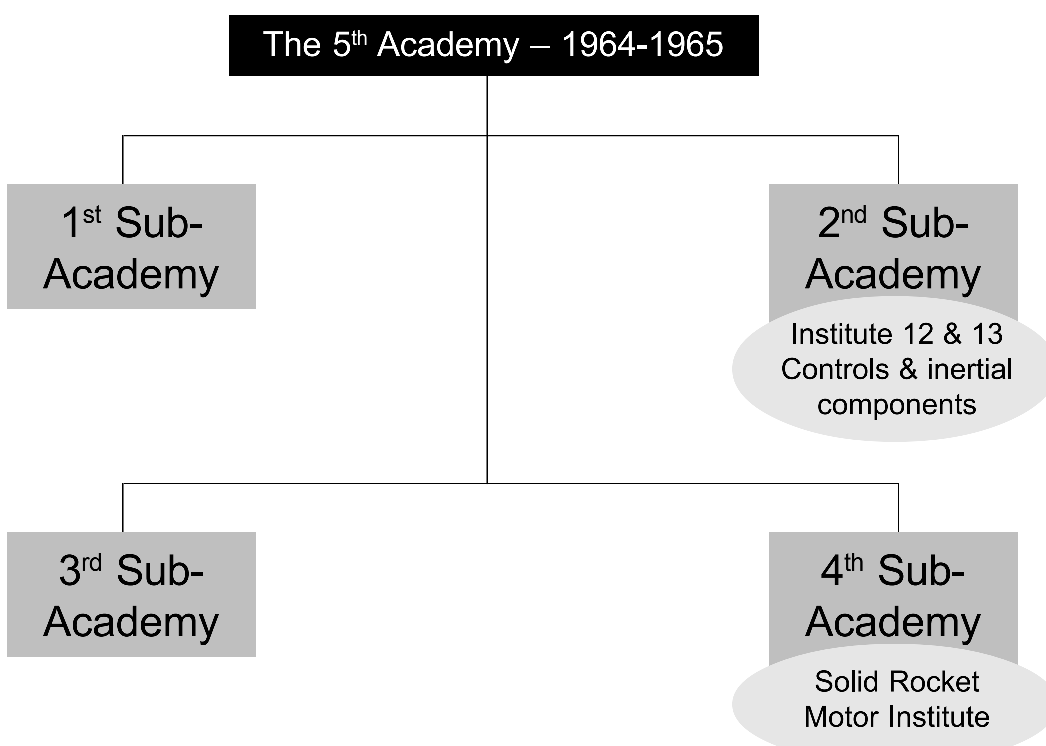
DF-1. The Soviet Union also supplied China with twelve R-2 missiles and one R12 liquid fuelled missile that they had used in their submarines. The Sino-Soviet bonhomie did not last for a long period. During the Great Leap Forward, Sino-Soviet ties began to strain. By 1960, the former Soviet Union stopped technical cooperation with China.

Chart II depicts how the fifth Academy functioned during 1964-1965 just before the fifth Academy became the seventh Ministry of Machine Building (MMB).

Initially, the Fifth Academy dedicated their R&D efforts to surface-to-surface missiles powered by liquid fueled engines. The transfer of the R-1, R-2 and the R-12, provided an initial impetus to the liquid rocket programme. Though a small solid propellant rocket programme existed, it received much lower priority. The Soviet Union did not provide any help for the solid rocket programme. The Fifth Academy also designated its Institute of Mechanics to coordinate the missile work. The dominant feeling among the key people in the establishment was that the Chinese should have what the enemy had.

In January 1961, the Defence Science and Technology Commission debated ways to promote R&D on all propellants. The Commission thereafter formulated a three year plan of research on solid composite propellants. Institute 3 and Plant 845 were established at Xian province to perfect solid propellant grain casting techniques.

CHART - II

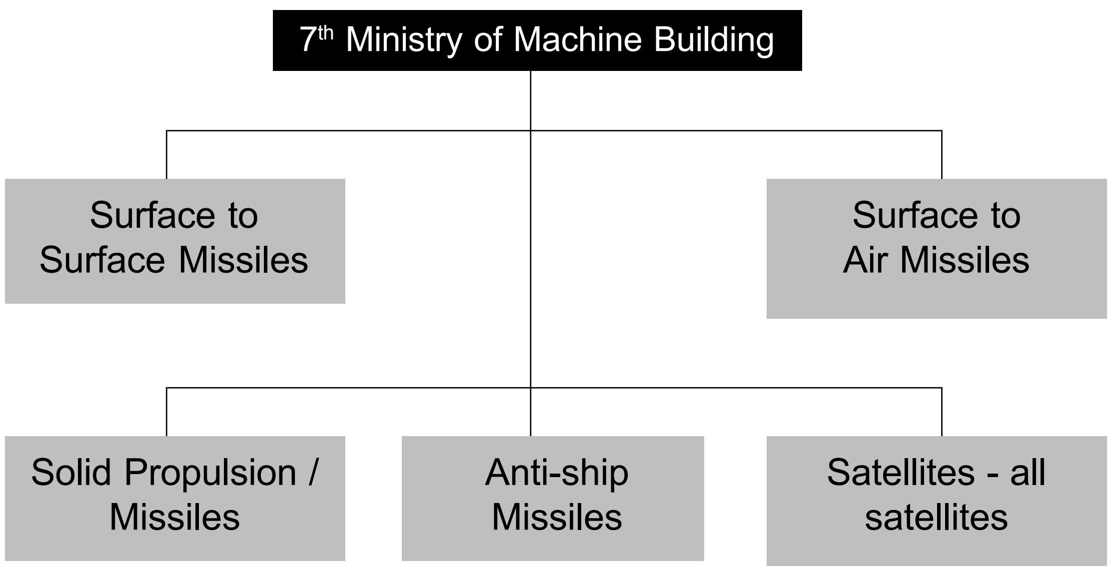


In 1962, China established the Solid-fuel Rocket Engine Research Institute in the Fifth Academy. The Fifth Academy transferred the specialists working on solid propellants from Institute 3 to the new facility established at Hohhot in Inner Mongolia. From 1962 onwards, the Chinese began to give some importance to the solid rocket programme. In 1963, Shanghai Mechanics and Electricity Design and Research Academy was placed under the Fifth Academy. As seen in the Chart II, the solid rocket motor institute became the solid rocket motor sub-academy (Fourth Sub-Academy) of the Fifth Academy.

In January 1965, the Chinese reorganized themselves once again. The Fifth Academy became the Seventh Ministry of Machine Building. Chart III depicts the structure of the Seventh Ministry of Machine Building and its various Academies in 1965.

CHART - III

The Chinese Missile Programme -~1965



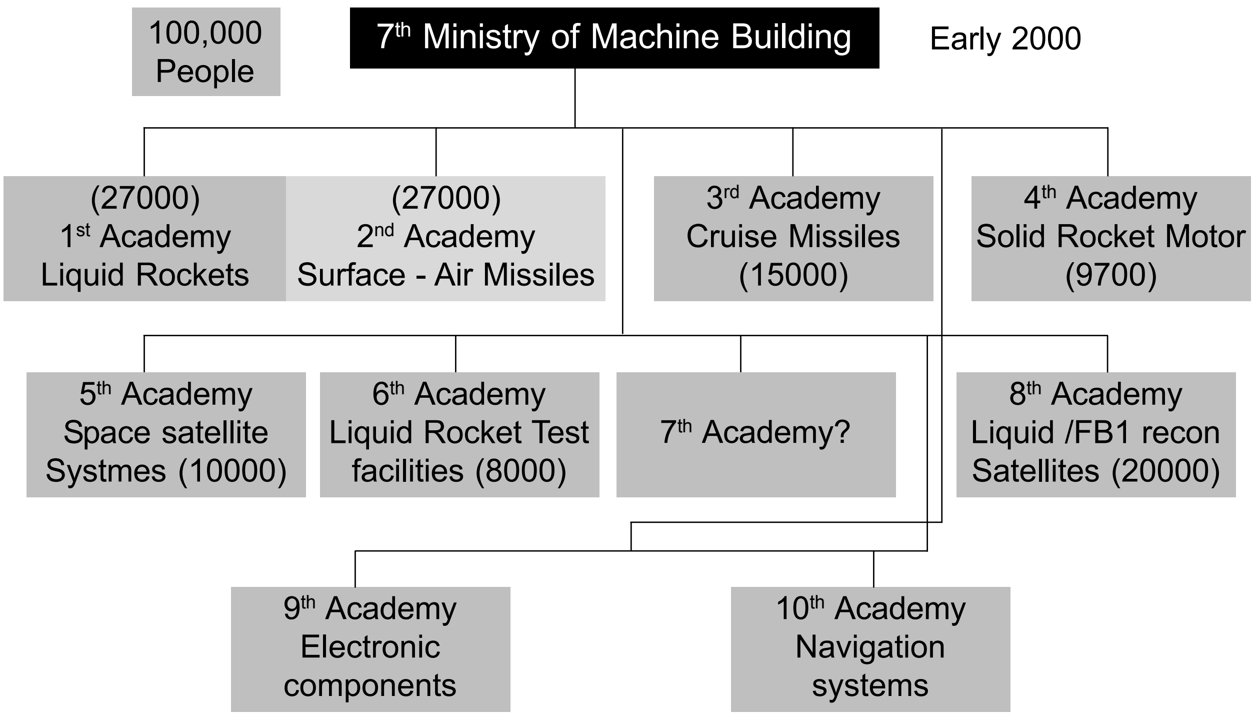
Under this reorganisation the Fourth Sub-Academy became a full fledged Academy and was called the Fourth Academy. It became solely responsible for the design and development of all solid rocket motors. Though liquid fuelled missiles received maximum attention during the early phase, the decision taken to develop a modern navy and to put missiles on nuclear powered submarines was eventually to trigger stepped up research on solid propellants.

Chart IV depicts the formal organisation structure of the seventh Ministry of Machine Building in early 2000. It provides details of the number of personnel working in each Academy. The evolution of the seventh Ministry of Machine Building in the last four decades suggests that the Chinese have been able to expand their programmes and infrastructure in a well-planned phased manner.

Chart IV explains the systematic creation of various academies and the allocation of different and definite task to each one of these. The First Academy was entrusted with task of building liquid rockets.

CHART - IV

The Chinese Missile Programme 2000



It was largely responsible for the execution of the Chinese *Banian Sidan* Plan of conceptualizing the DF series liquid propellant missiles. The plan was that the DF-2 would target Japan, the DF-3 the Philippines, the DF-4 Guam and the DF-5 the Continental US. These identified targets of each category of the DF series missiles represent a solely US directed focus for China's missile programme. Historically many of the key figures worked in this Academy before they moved on to other locations within the missile establishment. With 27000 people it is still the largest Academy. Originally it also dealt with the development of both the electronics and various control systems including gyros and platforms for all missiles. More recently Electronic Systems including the development of on-board computers and Navigation Systems have been separated out and placed under the more recently created 9th and 10th Academies. As the focus in missiles shifts towards solid propulsion under the modernisation initiative one would expect the power of the first Academy to diminish.

The Second Academy was entrusted with the task of building Surface to Air missiles. The famous scientist Chai Zhi was one of the Heads of this Academy. There is not much information on this Academy. In 1979 because of the emphasis on the DF-5 and other liquid programme the management of the SLBM Project was moved out of the first Academy and transferred to this Academy. Ostensibly the Chinese did have a major programme that looked at both air and missile defence systems. Somewhere in the late 1970s they seemed to have moved away from working in missile defence. Recent developments may force them to revisit some of these technologies.

The Third Academy of the Seventh Ministry of Machine Building dealt with cruise missiles and it had about 15,000 employees. Its original mandate was for the development of tactical short range missiles for the navy. The Chinese Navy has had a long history of successful association with the missile builders. The Lewis and Litai account of the development of the JL-1 SLBM and the nuclear submarine gives us an insight into how the missile system interacts with its user agencies and develops processes and routines for dealing with complex technical and organizational problems encountered during development.

The Fourth Academy is the designer of solid rocket motors. One of its early motors was used as the third stage of the CZ-1 space launcher that launched China's first satellite in 1970. It also developed China's first generation Submarine Launch Ballistic Missile (SLBM) JL-1 and its land based variant the DF-21. It is currently working on the second-generation SLBM the JL-2. In addition, the Fourth Academy is also the designer of China's other solid ballistic missiles including the DF-11 (M-11), DF – 15 (M-9), DF-21, DF-31 and the escape rocket on China's Shenzhou spaceship. Lewis and Litai once again provide a detailed account of the development of the SLBM and the solid rocket motors used in these missiles.

The Fifth Academy was set up in February 1968 with the responsibility for the management of satellite development projects. It is also called the China Academy of Space Technology (CAST) and it develops and manufactures most of Chinese spacecraft, including recoverable, communications, and scientific research satellites. It operates a number of institutions and factories to meet satellite development and testing requirements.

CAST has been the designer of China's first satellite DFH-1, which was launched on 24 April 1970. CAST has a total staff of around 10,000 personnel. Scientists at CAST have developed and manufactured spacecraft, ground support equipment and facilities for various satellite applications. It has also developed technologies for satellite recovery, multiple satellite launches from a single launch vehicle and various operations for geosynchronous communications satellites.

The activities of the research institutes and factories under CAST include the development, design and production of application satellites, sounding rockets and related technical engineering projects. These units also supply technology and equipment in the fields of vacuum, low temperature, automatic control, remote sensing, radio and precision machinery.

The Sixth Academy was founded as an R&D base for testing liquid engines. It is also called the China Academy of Propellant Technology (CAPA). It is located in Xi'an in Shaanxi Province and Hohhot, Inner Mongolia. The Sixth Academy oversees 11 research institutes and factories with more than 8,000 employees. Prior to its creation most of the activities of the sixth Academy would have come under the first Academy.

Our research and literature survey did not tell us anything about the Seventh Academy of the Seventh Ministry of Machine Building.

The Eighth Academy was founded in 1961 as the second Shanghai Bureau. The second Bureau initially concentrated on the development of tactical missile systems. The second Bureau later became the Shanghai Bureau of Astronautics. In 1993 this was renamed the Shanghai Academy of Space Flight Technology (SAST). SAST is a research and production complex headquartered in the Shanghai Area. The Shanghai Academy cooperates and occasionally competes against the other five aerospace academies in launch vehicles and air defence systems. SAST designs, develops and manufactures various spacecraft, as well as launch vehicles. It is the system integrator for the CZ-4 family of space launchers, the now defunct FB-1 launch vehicles, and also provides subsystems and other help for the CZ-3 and CZ-2D launch vehicle programmes.

The FB-1 was China's first dedicated military purpose space launch vehicle developed by the Eighth Academy in the 1970s. SAST had also engaged in pioneering the design of China's Shen Zhou spaceship and the Feng Yun series of meteorological satellites. The other activities of Eighth Academy include research and development on satellites, tactical missiles, civilian products, and the components and instruments for rocket inertial guidance and stabilization systems.

SAST has 20,000 employees with 40 research institutes and 11 factories.

The Ninth Academy, also called as the China Academy of Space Electronics Technology (CASET), is headquartered in Beijing with sites in Nanyuan and the suburbs of Xi'an city. It has specialized in the development of computers, integrated circuits and other microelectronic devices for use in rockets and satellites since its establishment in 1993.

The Tenth Academy was established in July 2001 by integrating space navigation R&D institutes and factories distributed in different academies and companies located at Beijing, Xi'an, and Guilin.

The Chinese Government restructured organisations and academies in 1999. In an effort to reform the defence industry and make it more market oriented the Chinese brought in some additional coordination mechanisms into the Academy structure. A corporate superstructure has been added to the technology driven Academy structure of the seventh Ministry of Machine Building. The most recently formed structure comprises the China Aerospace Science and Technology Corporation (CASC). The new CASC has adopted over 130 organisations including the following eight primary research and design academies:

- China Academy of Launch Vehicle Technology
- China Academy of Rocket Motor Technology
- China Academy of Space Technology
- China Aerospace Propellant Technology Academy
- Shanghai Academy of Space Flight Technology
- China Academy of Space Electronic Technology
- China Academy of Aerospace Navigation Technology

This additional layer of cross functional networking is expected to make these missile industries more market oriented. The commercial sale of products and services now seems to have become more important for the missile complex of China.

Infrastructure for Missile Development

Chart V provides details on the various facilities and organisations created by the first Academy for managing the development and production of liquid fuelled ballistic missiles.

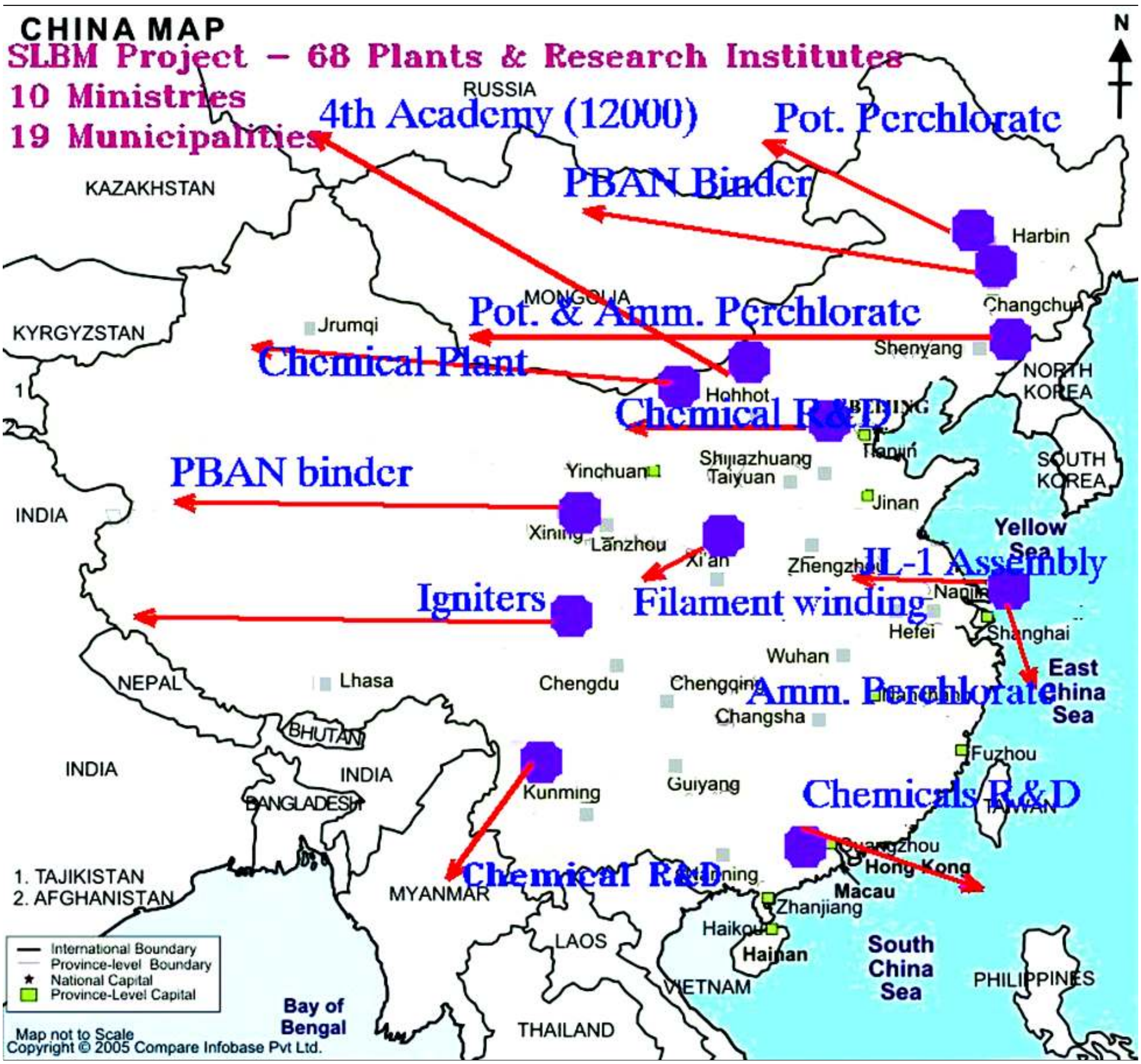
Most of the facilities seem to be clustered around Beijing and Xi'an. The warheads for the DF-3, the DF-4 and the DF-5 were also developed under the aegis of the first Academy in Institute 14.

Chart V

Lewis and Litai in their book dwell in detail about how a number of materials problems were resolved for the re-entry warheads of the DF-3, DF-4 and the DF-5. Institutes 12 &13 were responsible for the development of gyros and accelerometers. The locations of the liquid engine test stands and the aerodynamics Institute are also shown. All of them played a major role in the development of the liquid fuelled missiles of China.

Solid propulsion is the key technology for the missile modernisation programme of China. The development of the JL-1 missile for use on China's indigenously developed nuclear power submarine has been well documented by Lewis and Litai. The development of an intercontinental range single warhead missile and an 8000 km range MIRV missile to be launched from China's larger nuclear power submarine is also in an advanced stage of development. These advanced missiles need state-of art

Chart VI



solid propulsion capabilities. Chart VI provides details on the various organisations and facilities set up by the Chinese for the work related to solid propulsion.

As we can see from the above Chart the facilities and material supply centres for the production of solid rocket motors are widely dispersed. The Main centre of the fourth Academy is located at Hohhot. Lewis and Litai document in detail the development of the rocket motors and the propulsion systems for the JL-1 missile.

System Integration

System Integration is one of the most challenging and difficult tasks in the development of complex high technology systems. The Chinese have managed to couple the domain knowledge organisations with high quality system integration skills. They do this through various organizational processes that cut across the structure of the traditional academies. While these may not be very different from approaches adopted by other countries and organisations there is certainly a Chinese flavour to their efforts. A strong capability development is a hall mark of most of their efforts in this area. A top down no-nonsense approach which is result oriented seems to be at the centre of this effort. The Lewis and Litai account provides a lot of detail and considerable insights on how the Chinese have managed their system integration efforts.

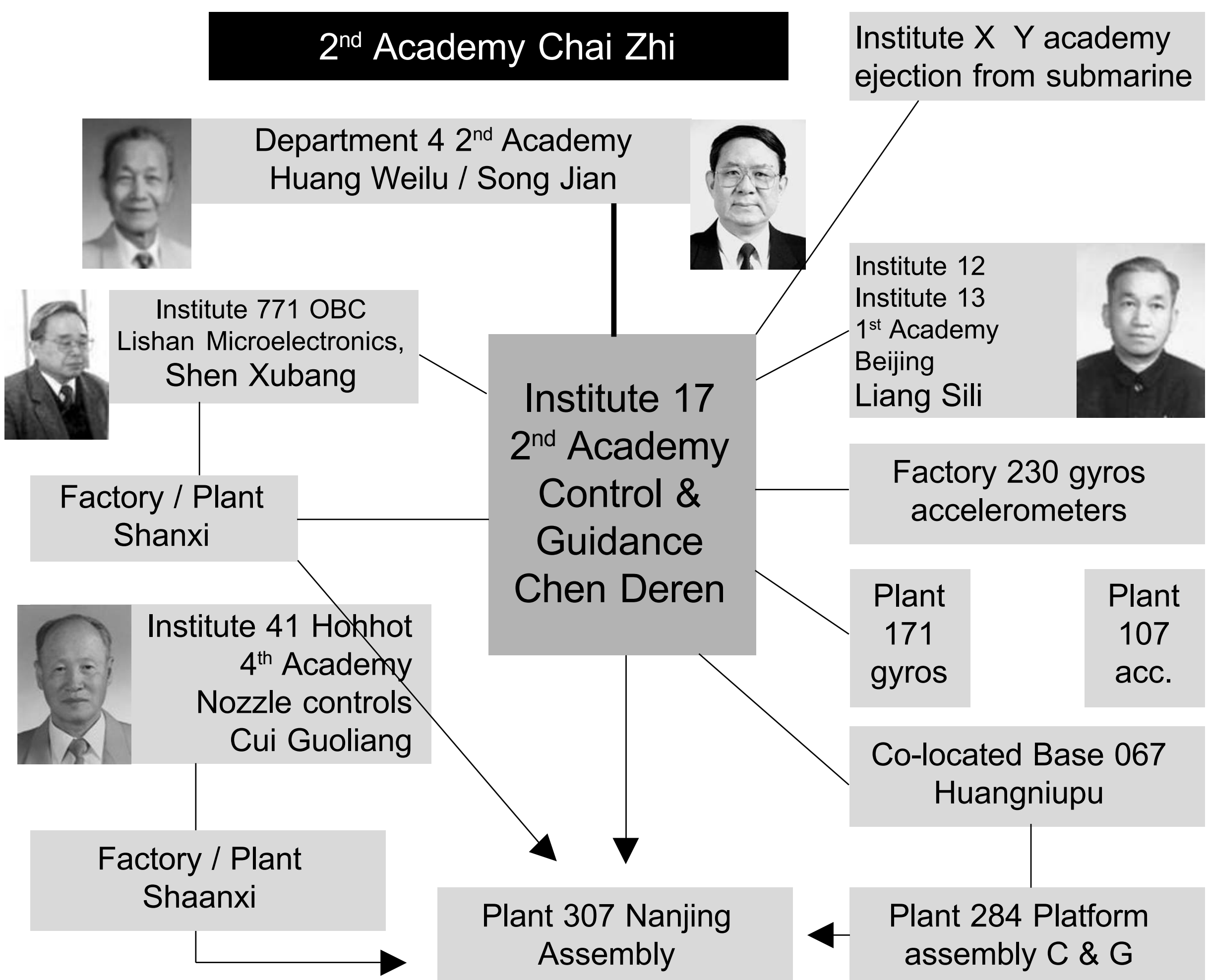
The control systems for a submarine launched missile are particularly difficult to develop and integrate. Apart from the technical components it involves a multi-organisational effort for the solution of various design and development problems. The learning associated with their development also includes various soft skills such as organizational routines and practices many of which are path dependent. They also involve a large component of learning by doing – knowledge that is difficult to acquire through explicit formal systems of learning. Chart V11 provides a flavour of how the Chinese dealt with such problems for the development of the control and guidance system for the JL-1 SLBM Project..

In 1965, the Fourth Academy had established Department 4 for design and development of the control systems for the JL-1 and Institute 41 for the development of the solid rocket propulsion systems including their controls. Lewis and Litai in their account of the SLBM control systems development document the many changes that happened and the way the control systems for the JL-1 were developed. Department 4 was moved to the first Academy and in 1979 was moved to the second Academy. Huang Weilu was made the Department Head.

As we can see from Chart VII the integration of the control systems involves both complex technology and complex organizational coordination mechanisms. Ejection from the submarine, sensing of the attitude and velocity, initiation of the booster ignition, the corresponding management of the attitude and orientation, acquisition of the attitude followed by the major powered flight sequence involve many difficult inter-related design, hardware and software problems. As soon as the rocket clears the water it is subject to large disturbances that have to be corrected for immediately. The solutions to these problems involve sensing, computation, correction in very short intervals of time. The Chinese approach for control during the powered phase involved the development of rocket motors with multiple nozzles that could be rotated or swiveled for getting the required control forces.

Both Huang Weilu and Song Jian who were responsible for these complex activities went on to become fairly big figures not only in the missile and technology establishments but also in the political system. Such career growth ensures sympathetic hearing of various causes within the top decision-making bodies in the country. Ding Henggao the son-in law of Marshal Nie Rongzhen was the head of the Plant 171 responsible for the manufacture of gyros. He is currently a major figure in the Chinese National Security Establishment. One could speculate that as these closely connected technocrats moved into higher positions the ties they developed between themselves would perpetuate and make a major impact on the various elements of the national security system. These informal networks of family and personal connections may be a major factor in how decisions are made by the Chinese system.

CHART - VII



Managing the Interfaces with Other Ministries and the Armed Forces

Chart VIII shows the areas of activities of the various Ministries of Machine Building within the Chinese Government. The Chinese Nuclear programme which comes under the second Ministry and the seventh Ministry which is responsible for the missile and space programmes have to work together in several areas. The reactor for the submarine has to come from this ministry. Though the warheads would be designed by Institute 14 under the first Academy of the seventh Ministry the weapon part has to come from the second ministry. The propellant casting technology was developed according to Lewis and Litai through cooperation between the fifth Ministry responsible for ordnance and the fourth Academy of the seventh Ministry. The interface between the submarine and the JL-1 involves close coordination between the sixth Ministry under whose direction the submarine would be built and the seventh Ministry. Development of various electronic components including onboard computers as well as reliability issues in electronics involves coordination with the fourth Ministry which deals with Electronics. It is clear that the development of nuclear weapons and their associated delivery vehicles like missiles especially submarine based missiles involves complex inter-ministerial co-ordination.

China does not clearly separate out civilian and military activities. The Peoples Liberation Army is a major power and would have a key role to play in the national security related activities of the various ministries. The dual use nature of the S&T infrastructure may make it easy for the Chinese to efficiently organize their activities. The DF-5 missile for example is also the booster for the CZ-2, CZ-3 series of civilian launchers. The PLA and the top brass of the PLA would play an important liaison role. Marshal Nie Rongzhen's role in the development of the atomic bomb and the missile illustrates this well.

The development of various test facilities and ranges would also involve major coordination and joint work with various services. The network of test ranges, ship based and land based tracking and telemetry stations, the submarine launch missile test range are some of the obvious areas where active cooperation and coordination would be involved.

Lewis and Litai in their book provide a wealth of detail on how the Chinese have created the organizational infrastructure and evolved processes and routines to monitor and manage them.

Though at times they have encountered many difficulties the Chinese now seem to have a good handle on how they can handle the increasingly complex interfaces between various organisations. Such learning is path and context dependent. This would suggest that China can in principle deal with the organisation and management of complex high technology systems that cut across discipline, organisation and ministerial boundaries. This is a powerful national capability.

CHART - VIII

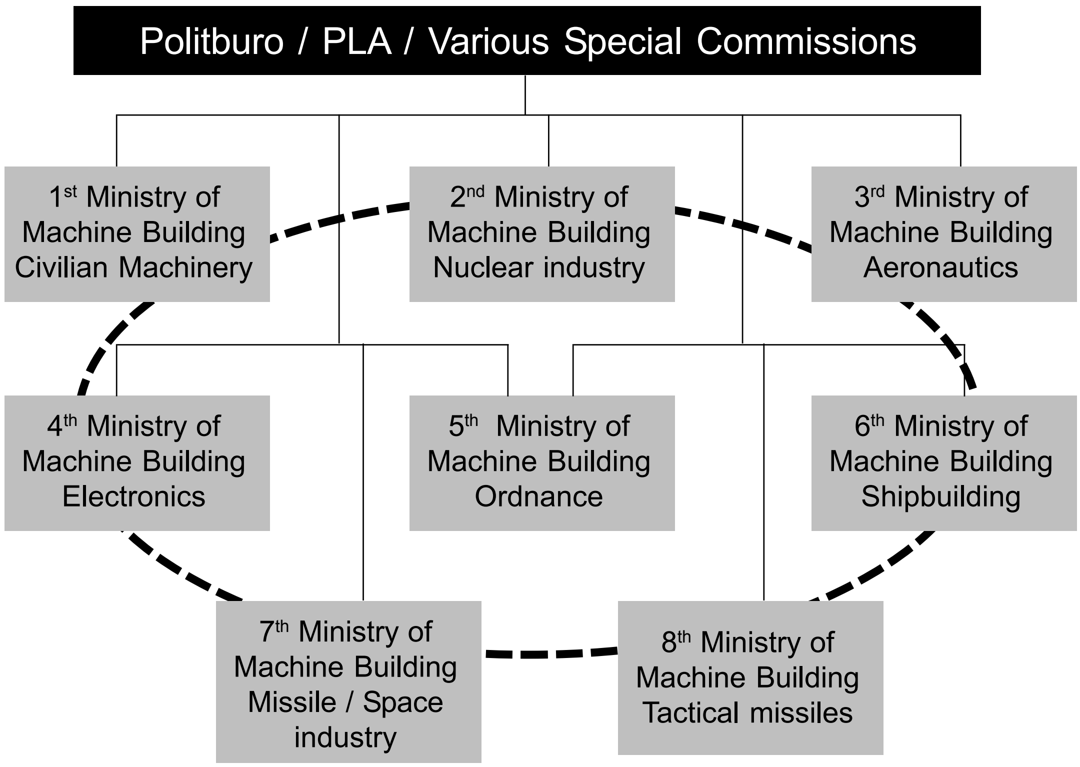
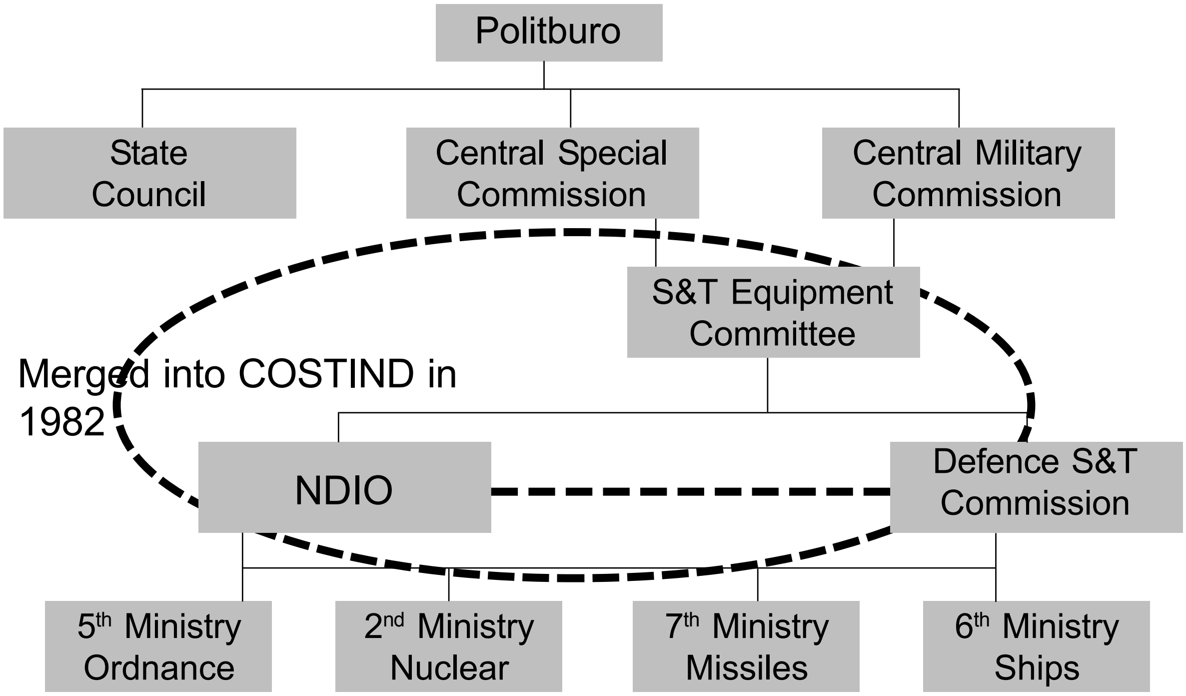


Chart IX provides an understanding of the link between the SLBM project, other ministries with whom the project needed to work with and the link with the political system through a variety of Commissions. The Chinese also kept changing the Commission structure through which they oversee these major projects of national importance. Chart IX shows some of the changes in this oversight management structure of the Chinese SLBM project during the period 1979 – 1982. It portrays the liaison between the political and technical system of the SLBM Project. In 1982, the many separate commissions that supervised the SLBM were merged into one Committee – the Committee on Science, Technology & Industry (COSTIND). This is just one of many examples of continuous changes made in the way the political system managed their important projects.

CHART - IX

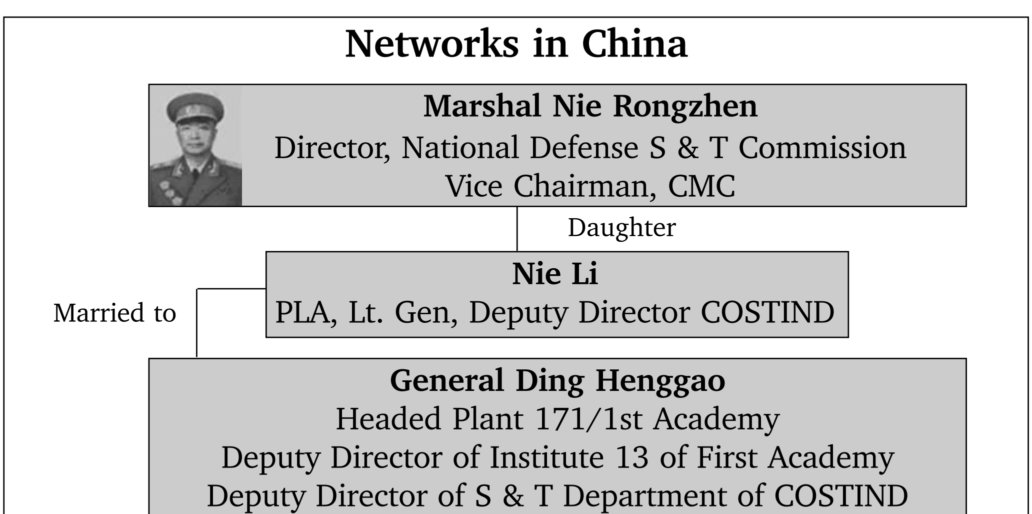
Management structure - SLBM Project - 1979 to 1982



Networks & Careers

In Chart 1 we saw some of the founding fathers of the missile programme. We saw some of the same people supporting the system integration problems in Chart VII. Others went on to head major centres within the missile complex. Liang Shoupan for e.g. became the head of the third Academy responsible for cruise missiles.

Networks are very powerful in China especially family connections. One such powerful network is shown below.



Marshal Nie Rongzhen, a veteran of the Long March, headed China's strategic weapons programme. He was powerful both within the military and the S&T institution and held high ranking positions in both fields. His daughter Nie Li, followed his footsteps reaching high positions within the PLA and China's S&T setup. She was married to yet another powerful figure in both the military and the strategic programmes, General Ding Henggao

There was a reorientation in the post-Mao period to evolve a broader national technological base that was not purely weapons-oriented or weapons-driven. During this time, technological advancement in China's strategic programme was linked to the goal of economic modernisation. However, China's weapons scientists and top technologists in its strategic programmes continued to play a key role in the diffusion of high technology R & D from a weapons-oriented to a components-and- critical-technologies-oriented approach. [112]

With horizontal movement of experts from strategic programmes to high technology areas, China has established a strong policy and institutional links between its goals of strategic modernisation, S & T advancement and economic modernisation. As an illustration we provide below the career path of one of the current leading lights of the missile programme Song Jian

Song Jian
Deputy Chief Designer of SLBM

Vice Minister & Chief Engineer of 7th Ministry

Director, State S & T Commission

Vice Premier and State Councillor

Chairman, 863 Plan Leading Group

Member S & T Leading Group of State Council

Some of the scientist and engineers involved in China's strategic programme reached high positions in government and were actively involved in S&T policy making. For example, Song Jian, who supervised China's SLBM programme, under Huang Weilu, went on to serve in many important policy positions in China's S&T institutional hierarchy. He finally became a member of the country's leading policy group in the State Council. The above figure traces Song Jian career path from his technical to his political role.

Programme 863

In the 1980s, conscious of China's backwardness in high technology industries, a group of strategic weapons experts headed by Wang Deheng, Chinese space program's leading optical physicist, proposed a plan to upgrade China's strategic, industrial and S&T infrastructure from the nuclear age to the

[112] For a detailed discussion of this theme See Evan A Feigenbaum, "Who is Behind China's High Technology Revolution? How Bomb Makers Remade Beijing's Priorities, Policies and Institutions", *International Security*, Vol 24, No. 1, Summer 1999. pp. 95-126 and *China's Techno-Warriors: National Security and Strategic Competition from the Nuclear to the Information Age.* (Stanford: Stanford University Press, 2003)

information age.[113] They proposed modernisation of China's strategic and high technology arenas linked to China's economic modernisation. Their recommendations were dubbed Programme 863.[114] Under this programme, they identified seven areas critical to China's long-term security and economic competitiveness.[115] These were; automation, biotechnology, energy, information technology, lasers, new materials, and space technology.

They urged for the civilianization of China's weapons infrastructure to foster innovation and competition while keeping intact the vital horizontal policy and institutional linkages with its strategic programme. This was done through "elite diversification" wherein the elite leadership of the strategic programme, including missiles, "spread from the military science and industrial complex to other important bureaucratic systems" taking with them the knowledge of the objectives and technological challenges of the weapons programme. They also took with them their unique management style that privileged informal networks amongst the strategic weapons elite to foster greater cooperation towards shared objectives of national security, technological innovation and economic growth.

Civilianization of the strategic programme laid the basis for creating a competitive environment for technological innovation that benefited China's strategic programmes while diversifying China's technology advancement from being solely focused on its strategic to long term economic growth and competitiveness.

Engineers are the Elite in China

It is a telling fact that the current membership of China's top decision making body, the Standing Committee of the Politburo, is made up entirely of engineers. Four of nine of them are from Qinghua university which is China's top technical and engineering university attracting the best talent in the country.

[113] Feigenbaum, 1999. pp. 109-126. Other members of the group were Wang Ganchang, nuclear physicist. Chen Fangyu, leading radio electronics engineer and Yang Jiachi, a leading electrical engineer. Ibid. p. 109

[114] See Feigenbaum for a detailed discussion of Programme 863.

[115] Ibid.

Member	Discipline	Institution
1. Hu Jintao 	Water Conservation Engineering	Qinghua University
2. Wu Bangguo 	Radio Electronics	Qinghua University
3. Wen Jiabao 	Geological Structures and Engineering	Beijing Institute of Geology
4. Jia Qinglin 	Electric Motor & Appliance Design	Hebei Engineering College
5. Zeng Qinghong 	Control Systems	Beijing Institute of Technology
6. Huang Ju 	Electrical Machinery Manufacturing	Qinghua University
7. Wu Guanzheng 	Thermal Systems	Qinghua University
8. Li Changchun 	Industrial Enterprise and Automation	Harbin Institute of Technology
9. Luo Gan 	Mining Engineer	Freiburg Institute of Mining and Metallurgy, Germany

A Strong Organisational Backbone

We can see from this assessment that China has been able to create a strong infrastructure which couples hard and soft skills to realize complex technologies. The building blocks are the specialist organisations within each Ministry. In the case of missiles this ministry is the seventh Ministry of Machine Building. Projects and programmes provide the cross functional links for delivery of hi tech products. The organisations of the seventh Ministry also work successfully with other specialist organisations in other ministries as in the case of the SLBM Project. The technical interfacing at working level is complemented by suitable arrangements at the inter-organizational level. Suppliers and users within the government set up are also connected via a Commission structure to the Politburo. There also seems to be a merit system in play. Many key people who have delivered value to the system are rewarded and moved to higher positions within the system. Over time this has created a system level network capability that has been very successful in the delivery of hi tech systems. The Chinese are now trying to find ways and means to leverage these competencies developed in the national security system complex into the commercial arena as well. We expect that this would mean an increasingly important role being given to the developers of weapon systems. Powerful networks of family ties and linkages shared during the difficult times of weapons development we believe will be the major factor in decision-making at least within the strategic community. This is an area that is poorly understood in Indian circles. Engineers within the Chinese system play an important role. We can clearly see that in the current composition of the Politburo.

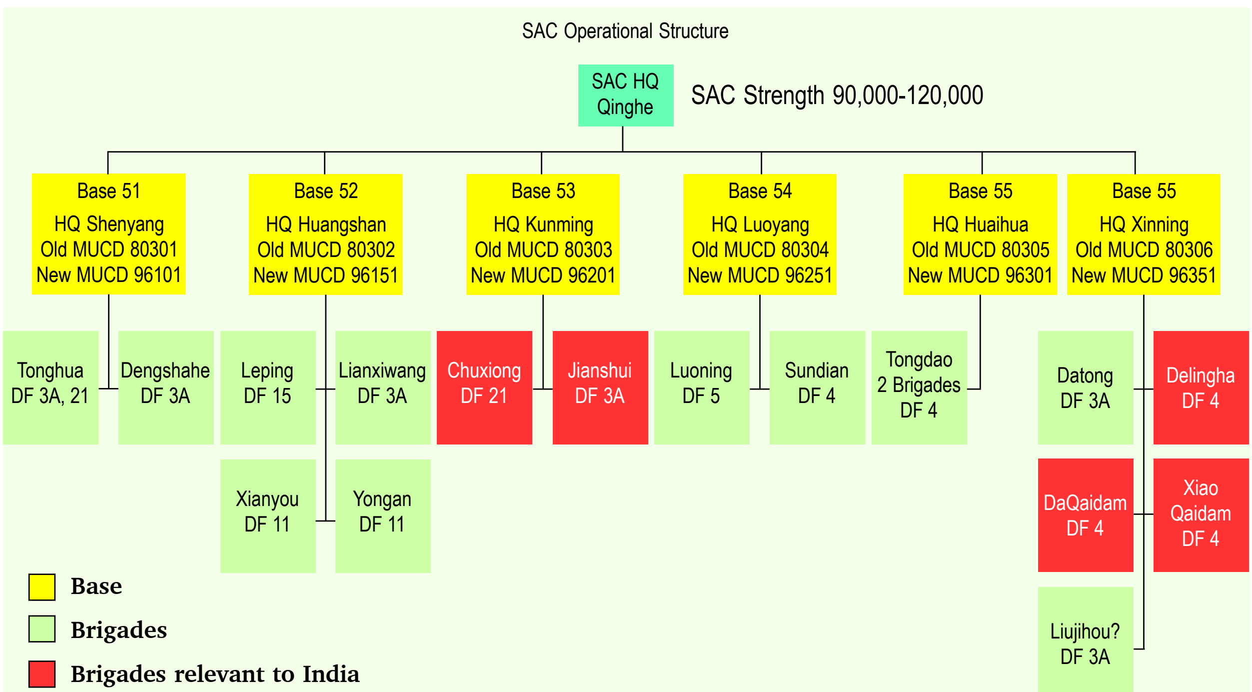
Our study of the organizations, processes, people networks and personal careers makes it clear that China has in place a robust capability for the development of all types of missile systems or for that matter any weapon system. They are possibly second to none in terms of national level competence. The question before them however is whether they would be able to leverage these competencies and extend them into the civilian sphere. This is possibly their great challenge.

Deployment, Command and Control of China's Missile Forces

Organisation of China's Second Artillery Corps (SAC)

China's Missile Forces are organized into a separate military organisation called the Second Artillery Corps that is not part of the PLA Army, Navy or Air Force. It is possible that the SAC commands the land based missiles of the Chinese Missile Force and the command for its sea based missiles is separate. The SAC is operationally organized as depicted in the Chart X below.[116]

CHART X



The SAC, comprising six ballistic divisions was created in 1966 to lead China's nuclear forces. Over time, the SAC has evolved into a force that also has conventional missile forces alongside the nuclear missiles.[117] This suggests a tactical dimension to SAC's role moving from a deterrent force to a war fighting force. It is also possible that in future China may include its Land Attack Cruise Missiles (LACMs) into the SAC force structure.[118] This would strengthen the war fighting role of the SAC.

The SAC or the Strategic Rocket Forces, as it is also known is headquartered at Qinghe near Beijing. It is estimated to consist of more than 90,000 people.

[116] Adapted from James C. Mulvenon and Andrew N.D. Yang eds, *The People's Liberation Army as Organization, Reference Volume* 1, Santa Monica: RAND Corporation, 2002. p. 541-2.

[117] Bates Gill, James Mulvenon, and Mark Stokes, "The Chinese Second Artillery Corps: Transition to Credible Deterrence" in James C. Mulvenon and Andrew D. Yang (Eds) *The People's Liberation Army as an Organization: Reference Vol. 1* (Santa Monica: RAND Corporation, 2002) p. 511

[118] Ibid p. 555

The SAC consists of an early warning division, a communication regiment, a security regiment, a technical support regiment, and six ballistic missile Divisions.

The Second Artillery headquarters complex consists of headquarters, political, logistics, and equipment technology departments, each headed by a PLA major general.[119]

The SAC is headed by a General and consists of 6 Bases, commanded by a Major General each. There are a total of 15 missile brigades under these six bases. Each missile brigade is headed by a Colonel. Each brigade operates one type of missile. The details of the Missile Brigades are provided in Appendix 4.

The SAC reports to the General Staff Department (GSD) of the PLA which in turn reports to the Central Military Commission (CMC). Though the SAC reports to the GSD, the organisation of the PLA into its seven military regions is separate and distinct from the operational organisation of the SAC at the regional level. The SAC HQ directly commands the missile bases which in turn directly command the missile brigades.

During Wartime, the GSD however is empowered to directly command the warfront command, skipping the SAC HQ. This, however, applies only to the conventional missile forces. The nuclear forces are commanded at all times by the national command authority in Beijing.

The authorization to use nuclear weapons must come directly from the Standing Committee of the Politburo and the CMC.[120] Traditionally, China's supreme leader who also heads the CMC is also a member of the Politburo.

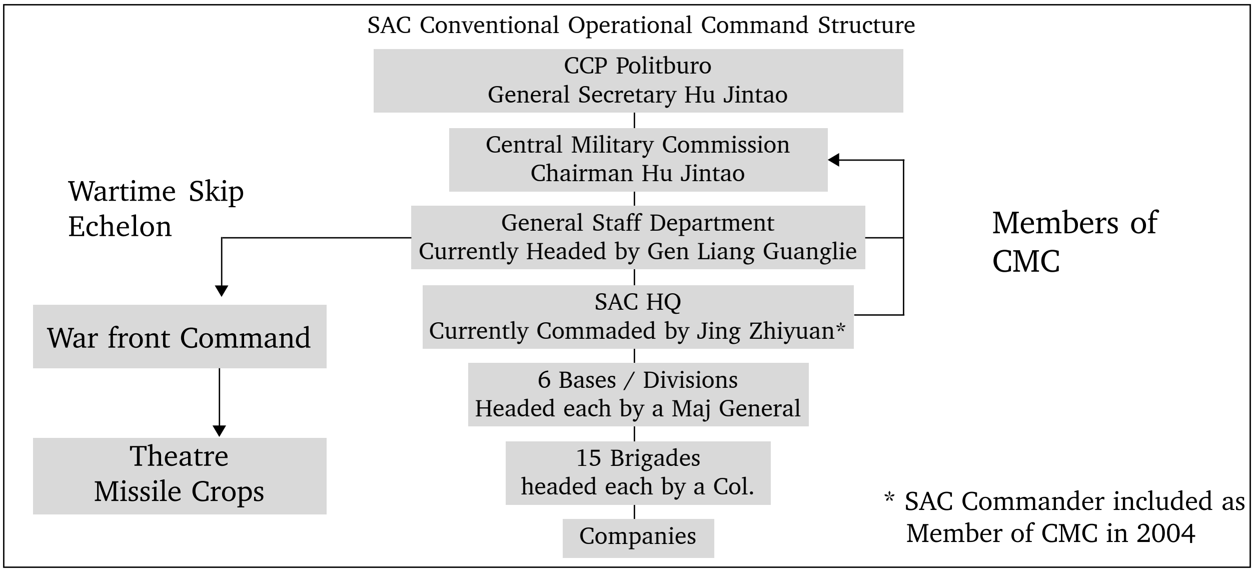
The SAC currently is headed by General Jing Zhiyuan who is also a member of the CMC. The CMC is China's top military policy and planning body with membership overlapping with the Chinese Communist Party's Politburo. The head of the SAC was recently included as a member of the CMC in 2004, providing a larger role for the SAC in the military and strategic planning process.

[119] http://www.fas.org/nuke/guide/china/agency/2-corps.htm

[120] Bates Gill, James Mulvenon, and Mark Stokes, "The Chinese Second Artillery Corps: Transition to Credible Deterrence" p. 522

The structure of the National Command Authority is shown in Chart XI below

CHART XI



Deployment of the SAC

The latest information available estimates the current Chinese nuclear arsenal to be around 130 nuclear warheads to be delivered by a triad of land, air and sea delivery systems comprising missiles and bombers.[121]

Table 18 provides details of the Chinese missiles that are currently deployed.

Table 18

Details of Chinese Missiles Deployed

Missile	Type	Nuclear Payload	Range (NIAS Estimate)
DF-3	Liquid	2200 kg	**2636** km
DF-3A	Liquid	2200 kg	**2734** km
DF-4	Liquid	2000 kg	**4476** km
DF-4A	Liquid	2000 kg	**4662** km
DF-5[122]	Liquid	3000 kg	**>12,000** km
DF-5A	Liquid	3000 kg	**13, 000 +** km
DF-21/JL-1	Solid	700 kg	**3073** km
DF-11	Solid	700 kg	**463** km
DF-15	Solid	700 kg	**302** km

121 China Nuclear Forces 2006, *Bulletin of the Atomic Scientists,* May/June 2006 p.60-63

122 According to the available literature on DF-5 and DF-5A, this is a two-stage missile. We have independently analyzed that a two-stage DF-5/ DF-5A would only have a range of 6656 km to 7760 km respectively. With this range, the DF-5A would not be capable of reaching continental United States from its currently deployed locations in China. For the DF-5A to achieve intercontinental range, it has to have third stage. It is our conclusion that the DF-5A is a three stage missile with range of 13, 000 + km.

The Missiles under development are listed in Table 19 below.

Table 19
Chinese Missiles Under Development

Missile	Type	Payload	Range
DF-31/JL-2	Solid	1200-1350 kg (MIRV)	~ 7200-8000 km
DF-31A	Solid	700 kg (Single Warhead)	~ 12,000-14,000 km

China's Land Based Deployment

China's deployment of its various land-based missiles is shown in Chart XII. This deployment shows that the original threat that China faced – largely from the US and its allies – now includes not only the US and its allies but other countries. Despite improved relations with almost all its neighbours including India and Russia, China continues to deploy missiles that target these countries. The deployment shows that Taiwan followed by Japan are the two most immediate and urgent threats for China.

Targeting United States

China's current strategic environment makes it necessary for China to contend with the US military presence in the Asia-Pacific region. This US presence has a direct impact upon China's major security concerns, Taiwan and Japan. The DF-5/5A targets continental United States. As indicated in the map above, the DF-5A is currently deployed at the Luoning, Wuzhai, Xuanhua and Tongdao missile bases. (See Appendix 3 for more details on missile bases.) From these locations, a **three stage** DF-5A can reach the United States. A two-stage DF-5/5A, as widely reported in the literature, launched from these locations will not reach the continental United States. It is also technically possible for the DF-5A to be equipped with MIRV though US intelligence estimates that China has yet to achieve this capability.

Taiwan

Taiwan continues to remain China's major security concern. China's considerable Short Range Ballistic Missile (SRBM) force is deployed in the Chinese province of Fujian along the coast targeting Taiwan. Nanping and Yong'an are the two major bases for these missiles. In 2006 it was estimated that 650-730 DF-11 and DF-15 SRBMs are deployed against Taiwan and that this number is increasing by 100 each year.[123] Latest reports put the total number of missiles at 980 of which 100 are cruise missile and 880 are ballistic missiles.[124]

[123] China Nuclear Forces 2006, *Bulletin of the Atomic Scientists,* May/June 2006. p. 62
[124] Bradley Perrett, Multiplying Missiles, *Aviation Week & Space Technology,* January 29, 2007. p.27

Chart XII

A potential conflict in the Taiwan Strait continues to be the focus for China's military modernisation. The 2005 Pentagon report on the Chinese military, states that China is looking at capabilities beyond a Taiwan scenario. According to the report China also wants to protect its sea lines of communication and to expand its "maritime defensive perimeter further seaward".[125]

Given the state of US-China relations and Taiwan's economic dependence on the Mainland, the chances of a Chinese led attack on the continental United States, in absence of serious provocation by Taiwan or the US, are remote.

[125] *The Military Power of the People's Republic of China 2005*, Annual Report to the Congress. P. 12

Japan

Relations between China and Japan have been plummeting over the last five years and there is a growing concern about strategic stability in the region. China has deployed DF-3 and DF-4 missiles to target Japan. The DF-3 is also in the process of being replaced at many locations by the solid fuelled DF-21. The DF-21 is a more survivable missile. The DF-21 can target all of Japan, North and South Korea, and parts of Taiwan from the Chinese bases of Tonghua and Lianxiwang. The DF-4 can also target US bases in Guam.

Added to a protracted struggle over wartime history, China and Japan also have a maritime territorial dispute over Diaoyutai / Senkaku Islands and a competition over energy resources in Northeast Asia. The Chinese and the Japanese economies are interlinked through a web of economic interdependence that connects the US, Japan, China, Taiwan and ASEAN. This acts as a stabilizing factor in dealing with hostile political relations.

Southeast Asia

China's other major security concern lies in the South China Sea where it has disputes with Vietnam, the Philippines, Malaysia and Brunei over the ownership of the Spratly Islands.

The DF-3 based at Jianshui, the DF-4 based at Tongdao and the DF-21 based at Chuxiong can reach targets in Southeast Asia from their currently deployed locations. The JL-1, solid fuelled SLBM when deployed in China's home waters in the South China Sea can also reach targets in this entire region.

The Chinese strategy of the creeping occupation of marine features in the region since the beginning of the 1990s is prompting fears of an aggressive Chinese policy in the resolution of this dispute. The official Chinese policy in this region is of shelving competing sovereignty claims and joint development of marine resource by the involved parties. However, growing Chinese military strength and its increasing economic clout is causing concern to other contenders in the dispute. US military presence in the region is seen as a stabilizing force in this region.

India

At present Sino-Indian ties are stable with little chance of a military conflict between the two countries. The border dispute continues to be unresolved though negotiations to resolve the issue are going on. India's threat perception from China, continues to be high. Among strategic thinkers in India, the indirect threat to India arising from Chinese help to Pakistan's nuclear and missile programmes are perceived to be a more likely source of concern than a direct military conflict with Beijing.

China has deployed the DF 3, the DF-4/ 4A and the DF-21 to target India. The DF-3 is deployed at the Jianshui and Kunming bases in Yunnan province.

The DF-4 is deployed at Da Qaidam, Delingha and Xiao Qaidam bases in Qinghai. Delingha and Xiao Qaidam are reported to deploy nuclear tipped missiles.

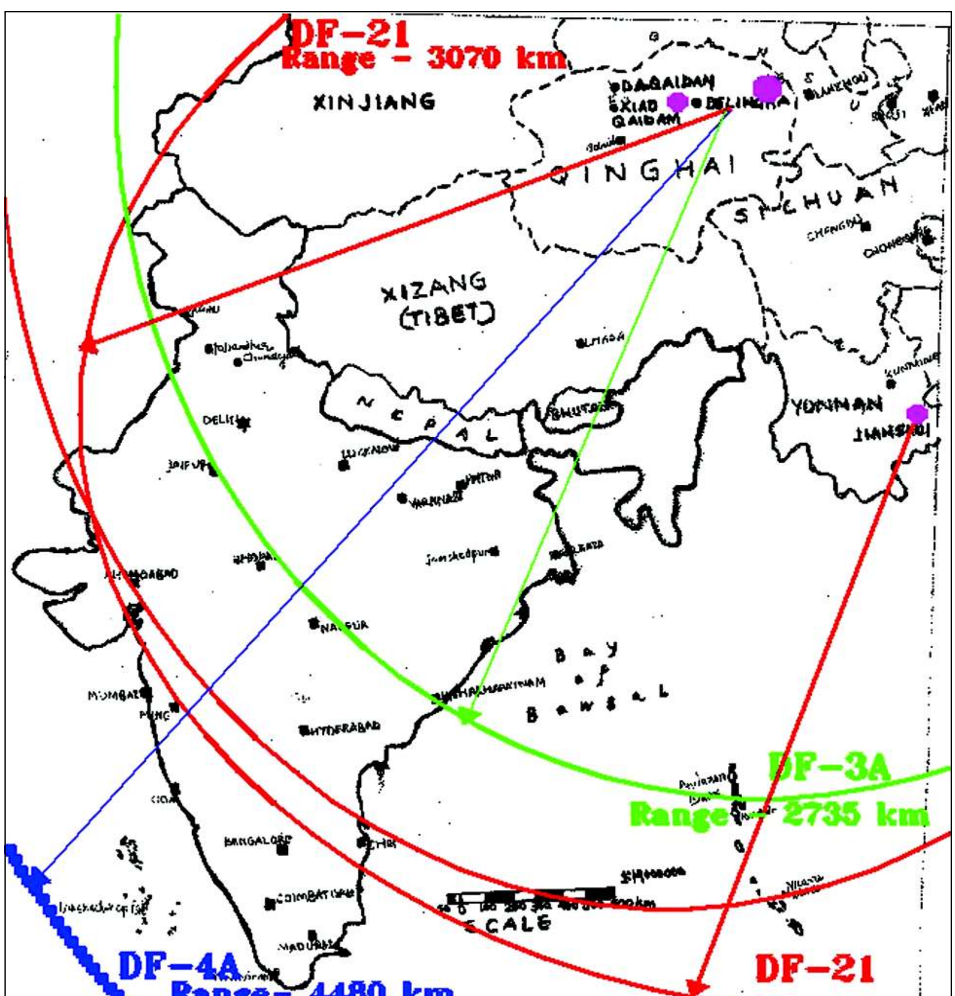
The DF-21 is deployed at the Chuxiong base, approximately 100 km west of Kunming in Yunnan. At the Jianshui base DF-3 is being replaced by the DF-21.

From these locations China can target all of India as indicated in Chart XIII.

We have found no evidence in the available literature of missiles stationed in Tibet. However, China does not necessarily need to deploy missile in Tibet to target India. It can comfortably do so from its bases in Qinghai and Yunnan.

Chart XIII shows the range of the Chinese land based missiles that are targeted at India.

CHART XIII



Sea-based Deployment

China's nuclear submarine bases are at Qingdao in Shandong province and Lushun (Port Arthur) in Liaoning province. (See the Missile Facilities Map for locations.) Qingdao also has a submarine training institute. According to the 2006 Pentagon report the North Sea Fleet based at Qingdao has all of the five Chinese nuclear submarines.

Currently China has one type of SLBM, the JL-1, deployed. The JL-1 has a range of 3073 km. JL-2, China's next generation SLBM will possibly have a range of 7200-8000 km. This version will most probably be equipped with MIRVs. The 2006 Pentagon Report says that the JL-2 will be deployed aboard the JIN-class (Type 094) ballistic missile submarine.

With a nuclear submarine equipped with SLBM with MIRV capability, it can be assumed China will be able to reach targets at will. This will also provide China will an additional survivable nuclear option. We also believe that China has under development a shorter DF-31 missile that will have a range of 14,000 km plus with a 700 kg (single warhead) payload. We think that this missile can be launched from land or from a submarine. The 2005 Pentagon Report expected that China's new generation nuclear submarine, (Type 093) will enter service that year. The 2006 Report confirmed that the SHANG-class (Type 093) SSN entered the fleet in 2006. [126]

Estimates of China's Missile Forces

There is no agreement on how many ballistic missiles China has. The numbers have varied over the years as depicted in Table 20 below.

Table 20
Estimates of China's Missile Forces

Missile	Nuclear Weapons Databook (1994)	Military Balance (1998-9)	Jane's Strategic Systems (1998)	US Pentagon Report (2006)
DF-3	50	38+	60-80	14-18
DF-4	20	10+	20-24	20-35
DF-5A	4	17	15-20	20
DF-21/21A	36	8	35-50	19-50
DF-15	N/A	4	400	275-315
DF-11	N/A	N/A	200	435-475
JL-1	24	12	12	10-14

Sources: James C. Mulvenon and Andrew N.D. Yang eds, The People's Liberation Army as Organization, Reference Volume 1, Santa Monica: RAND Corporation, 2002. p. 538. *Military Power of the People's Republic of China 2006*, Annual Report to the Congress. http://www.defenselink.mil/pubs/pdfs/China%20Report%202006.pdf

[126] http://www.defenselink.mil/pubs/pdfs/China%20Report%202006.pdf

We have independently estimated the number of missiles for DF-5 and DF-21 based on China's missile production capacity. According to our estimate, the total number of DF-5 would be 70 of which 24 may be deployed. The remainder may be in inventory. For the Jl-1/ DF-21 the estimate is 150. Of this 12 would be for the single submarine that carries 12 missiles. Another 12 may be back up in terms of inventory for the JL-1. This is our guess. The balance of 126 missiles would be the DF-21. It is not possible to make similar estimates about other Chinese missile because of lack of availability of information. The 2006 Pentagon Report estimates that by 2010, Chinese nuclear forces will likely include a combination of enhanced silo-based DF-5A ICBMs, DF-4 ICBMs; DF-21/21A MRBMs; solid-fueled, road-mobile mobile DF-31 and DF-31A ICBMs and sea-based JL-1 and JL-2s SLBMs.[127] It is believed that Chinese nuclear warheads are stored separately from the delivery vehicles and only mated during launch preparations.[128] Some scholars have argued that as China modernizes its missiles and makes them more mobile, it's ICBM and SLBM forces will increasingly be mated with warheads decreasing "the effectiveness of physical security methods in stopping unauthorized launches."[129] This is expected to "push operational launch authority to lower levels, require a more sophisticated command and control system, and likely to rely more heavily on technical means to prevent unauthorized launches." [130]

China's Missile Infrastructure

China has a widespread infrastructure including bases, test & launch sites and storage facilities to support its missile deployment. Chart XIV shows China's missile infrastructure.

China's Strategic Environment, Military Strategy and Its Ballistic Missile Programme

China's technological capability and economic development have had a direct link with the pace and direction of its strategic programme. Given China's political system with strong institutional overlaps between the political and the military organs, elite politics has also had its impact on the strategic programme. China has also seen a long-term debate on priorities between investments in its conventional military modernisation programme, vis-a-vis investments in its strategic programme. This debate has often caused major disruptions to the strategic programmess especially during periods of heightened political turmoil like the Great Leap Forward (GLF) and the Cultural Revolution. Leaders of China's strategic programmeme have tried to insulate it from vicissitudes of elite politics and the fight for resources by linking it to China's development needs in various scientific and industrial sectors.

127 http://www.defenselink.mil/pubs/pdfs/China%20Report%202006.pdf

128 http://www.nti.org/e_research/profiles/China/Nuclear/5569_5636.html

129 Ibid.

130 Ibid. Quoting Phillip C. Saunders and Jing-dong Yuan, "Strategic Force Modernisation," in *China's Nuclear Future*, eds. by Paul J. Bolt and Albert S. Willner, (Boulder, CO.: Lynne Rienner Publishers, 2006), p. 94-95.

Chart XIV


CHINA MAP
Chinese Missiles HQs & Related Facilities
Missile HQ
Warhead Storage facility
Launch facility
Test Facility
Proposed Launch Facility
SLBM Test Facility
Nuclear Test Site
Impact Zones
N
RUSSIA
KAZAKHSTAN
MONGOLIA
KYRGYZSTAN
DF-3
Harbin
Changchun
Shenyang
Shenyang
Lop Nur
Jrumqi
Shuangchengzi
Hohhot
BEIJING
Wuzhai
DF-3
Huludao
JL-1
NORTH KOREA
SOUTH KOREA
Shijiazhuang
Yinchuan
Taiyuan
Tianjin
Jinan
Yidu
INDIA
Xinning
Xining
Lanzhou
Xi'an
Baoji
DF-21
Zhengzhou
Yellow Sea
Nanjing
Hefei
Shanghai
Wuhan
Huangshan
East China Sea
NEPAL
Lhasa
Chengdu
Chengqing
Nanchang
SAM
Changsha
BHUTAN
Xichang
Huaihua
JL-1
Fuzhou
INDIA
INDIA
Guiyang
Kunming
Kunming
BANGLADESH
TAIWAN
Guangzhou
Hong Kong
Macau
1. TAJIKISTAN
2. AFGHANISTAN
MYANMAR
Nanning
Zhanjiang
Haikou
Wenchang
LAOS
Sanya
Hainan
South China Sea
VIETNAM
PHILIPPINES
International Boundary
Province-level Boundary
National Capital
Province-Level Capital
Bay of Bengal
THAILAND
Map not to Scale
Copyright © 2005 Compare Infobase Pvt Ltd.

China's Strategic & Military Doctrine and its Link with the Missile Programme

China's military doctrine reflects the periodic changes in China's threat perception, technological capability and economic development. There is no official Chinese declaration of its strategic doctrine, except a declared No First Use (NFU) policy. The current Chinese strategic doctrine as inferred from the size, nature and direction of its arsenal has the following features. China has a NFU, second strike, counter value strategy with a minimum credible deterrent. Given its second strike strategy, China assures deterrence through the survivability of its nuclear arsenal by ensuring launch unit mobility, hardened storage for its launchers, concealment and dispersal in mountains and caves.[131] China's threat perception and related developments in its missile development can be chronologically classified into the following periods.

The Era of the US Imperialist Threat: 1949 - 1960

The People's Republic of China (PRC) was set up amidst present and imminent threats around its periphery. The Korean War (1950) and the Taiwan Strait Crisis (1954) were military conflicts in which the China was pitted against the US aligned with China's neighbours and regional opponents. China fought both these conflicts under the shadow of a nuclear threat from the US. The backwardness of the Chinese forces underlined the importance of building modern weapons systems to combat the threats to China. These two crises convinced Mao Zedong of the need to acquire nuclear weapons. Mao saw them as necessary to ensure China's territorial integrity and its autonomy of action in international relations. These were the broad objectives with which China's nuclear (1955) and missile (1956) programs were started. The US, aligned with China's regional adversaries, was identified as the primary threat. The missile programme identified threats (the US) in a general sense. These threats were not linked specifically to identified targets in the initial years of the ballistic missile programme. In order to do this the capability to build missiles with the required ranges had to be first acquired.

During this period there was also no clear link between strategic weapons and military strategy. It can be argued that there was a dichotomy between the military doctrine and strategic R&D. While the doctrine of People's War placed "men over weapons", Mao simultaneously stressed the need to develop the strategic programme with Soviet assistance.

> In Mao's mind, it seems clear, his comrades had to distinguish between the unambiguous need for Soviet aid and the unwanted imitation of Soviet ideas and regulations that ran against China's cherished revolutionary traditions, especially the hallowed doctrine of People's War.[132]

[131] Nuclear Weapons Databook Volume 7, p. 370. Quoted in James A. Sands. *Evolution of China;s Nuclear Capability: Implications for US Policy*. Available at http://www.fas.org/nuke/guide/china/doctrine/sandsja.pdf

[132] John Wilson Lewis and Xue Litai, *China's Strategic Seapower: The Politics of Force Modernisation in the Nuclear Age* (Stanford: Stanford University Press, 1994), p. 3

The technological goals of the strategic programme were not held hostage to the concept of People's War and China continued to pursue its ballistic missile programme largely isolated from political wrangling over military doctrine.[133]

The concept of People's War was formulated on the expectation of a large scale, imminent nuclear war to be won by the superiority of men over weapons. Given the primitive technology base of the PLA, China followed a military strategy of deterrence through denial. This meant that China would absorb a nuclear first strike and then proceed to defeat the invading enemy forces through tactics of guerilla warfare by luring the enemy deep into Chinese territory.[134] This, strategy appears to be a case of turning necessity into a virtue. This two-faced strategy continued throughout the 1960s and 70s.

As we have recounted elsewhere in the report this was the period during which the Chinese set up their missile infrastructure. They also initiated work on the production of Soviet designed missiles. This was also the period of the Great Leap Forward, a time of great social upheaval. Though some limited work on solid propulsion was initiated the main focus of the missile programme was on liquid fuelled missiles with help from the Soviet Union.

A sea-based strategic posture using submarines to launch missiles was not considered relevant to China's policy of coastal defence. In fact, the solid rocket programme did not take off in any significant way till China decided to upgrade it naval capabilities.[135]

While the Chinese missile programme was in its early stages, relations between the Soviet Union and China started worsening over an ideological rift. In 1960 the Soviet Union abruptly stopped technical assistance to China's nuclear and missile programmes promised under the 1957 Defence Accord. In August 1960, the Soviet Union withdrew from the Accord. Under this Accord, the Soviet Union had also promised to give China a prototype atomic weapon, which was never delivered.[136]

The launching of the GLF by Mao saw the visible souring of relations between the USSR and China as it was highly critical of the Soviet revolutionary and economic model. The Great Leap Forward was Mao's attempt to re-infuse revolutionary fervour into achieving national goals of self-reliance and economic development through mass movements in record time. The Great Leap Forward was followed by the 'Three Hard Years' in the Chinese economy. China suffered a widespread famine and industrial production came plummeting down. The GLF had a deep impact on all aspects of Chinese society and the also interfered with the pace of R&D in China's strategic programme.

133 The Great Leap Forward, to a limited extent, and the Cultural Revolution to a larger extent did result in some setbacks for the strategic programme.

134 For a detailed statement of People's War see Nan Li, "The PLA's Evolving Warfighting Doctrine, Strategy and Tactics, 1985-95: A Chinese Perspective*", China Quarterly*, no. 146, June 1996. pp. 443-463.

135 John Wilson Lewis and Xue Litai, *China's Strategic Seapower: The Politics of Force Modernisation in the Nuclear Age* (Stanford: Stanford University Press, 1994.) p. 131

136 Immanuel C. Y. Hsu, *The Rise of Modern China*, (Oxford & NY, OUP, 1995) p. 679

Breakdown of Sino-Soviet Bonhomie an increasing Soviet threat accompanied by a continued US Threat: 1960 - 1972

China's external security environment was possibly at its worst during the period from 1960 to 1970. It had to contend with a continued threat from the US and a new fast-growing threat from the Soviet Union. During this period, while China's military doctrine continued to emphasise the concept of People's War, some concerns were being voiced within the Chinese Communist Party about the technological backwardness of the PLA and the need for a more updated military doctrine. China's erstwhile Defence Minister Peng Dehuai had earlier questioned the relevance of the doctrine of People's War in post-revolutionary China at a Party Plenum in Lushan in 1959. He was unceremoniously purged from the Party for voicing his views.[137]

As the Soviet threat in the North and the US presence in Vietnam grew, the concern of the military planners about China's outmoded military doctrine and backward technological levels heightened. These concerns were regarded as politically subversive by Mao Zedong. In principle the concept of People's War continued to dominate China's military doctrine. At the same time, Chinese leadership never abandoned its quest for strategic capability. China's detonation of its first atomic explosion in 1964 established this beyond any doubt.

However, even after the nuclear test of 1964, the PLA continued to follow the doctrine of People's War. There were two main reasons for this. First of all, China's deterrent was not credible and to deter the technologically and militarily superior Soviet Union, China was forced to stick with the strategy of deterrence by denial. Secondly, the mid 1960s were the years of the Cultural Revolution in China that saw an intense focus on Maoist principles in all spheres including military doctrine. To abandon the doctrine of People's War was not an option for military planners given this political climate in China. The harsh political climate of the times demanded the blind acceptance of Maoist principles. Though nuclear weapons and ballistic missile were seen as a currency of power necessary for preserving China's autonomy and protecting China's territorial integrity, the link between doctrine and strategy was not explicitly established. The strategic planners urged periodically for "longer ranges, better accuracy, improved reliability and operability, more rapid deployment capability" but without linking these to any particular strategic requirements.[138]

In spite of this ambiguity, China's ballistic missile programme continued to make progress. Consolidation and growth of the missile programme under the aegis of the newly created seventh Ministry of Machine Building, successful flights of the DF-3, development flights of the DF-4 and the DF-5, and the approval of the JL-1 SLBM project were some of the major developments during this period. The link between

[137] For a full discussion of the issue involved see David Charles, "The Dismissal of Marshal P'eng The-huai" *China Quarterly*, No. 8 Oct-December, 1961. pp. 63-76

[138] John Wilson and Hua Di, "China's Ballistic Missile Programme: Technologies, Strategies, Goals", *International Security,* Vo17. No. 2 Autumn 1992. p 20

development and deployment was also explicitly recognized with the creation of the Second Artillery Corps. As mentioned elsewhere in the report the targets specified to the missile engineers were all US allies – Japan, the Philippines, Guam and of course the continental US.

Meanwhile China's relations with the Soviet Union were going from bad to worse. Along with an ideological rift, the two nuclear-armed countries also had a running border dispute. The two sides started border negotiations in 1964, which broke down amidst growing hostility. Matters came to a head in 1969 when the Soviet and Chinese forces clashed over Damansky / Zhenbao Islands in the Ussuri River. During the conflict, the Soviet Union proposed a joint agreement with the US against any "provocative actions" by China or any other nuclear power.[139] This proposal was rejected by the US. While the crisis was contained, China and Soviet Russia maintained increasing force levels at their border through the next 15 years. Given the worsening situation with the Soviet Union, the planned range of the DF-4 was increased by 500 km to include Moscow within it range from Da Qaidam base in Qinghai province.[140]

Meanwhile China was undergoing massive domestic turmoil as the Great Proletarian Cultural Revolution was unleashed by Mao in 1966 to radicalize Chinese society. China cut-off almost all of its relations with the international community. The political vicissitudes of the Cultural Revolution continued well into the 1970s and ended only with the death of Mao in 1976.

The Cultural Revolution created major problems for the missile programme. Intellectuals were a major target and this included scientists and engineers working in China's nuclear and missile programmes. Many scientists and engineers associated with these programmes were denounced as "reactionary intellectuals". Both the DF-4 and DF-5 programmes suffered under the excesses of the Cultural Revolution. The major technical problems facing the JL-1 programme were further compounded by the political and organisational disarray created by the Cultural Revolution.

Power struggles between rival factions in the political arena spilled over into the strategic programmes. The entire Seventh Ministry of Machine–building was split into rival factions and a fight for survival ensued. Even Marshal Nie Rongzhen did not escape unscathed and was stripped of his responsibilities. The nuclear missile submarine project, which had been resurrected in 1965, under the Second Ministry, ran aground with the purging of Luo Ruiqing, China's erstwhile Chief of General staff and the head of the National Defence Industries Office. Luo Ruiqing was accused of raising concerns about China's military modernisation that challenged the concept of People's War.[141]

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[139] Immanuel C. Y. Hsu, *The Rise of Modern China*, (Oxford & NY, OUP, 1995) p. 684.

[140] John Wilson and Hua Di, China's Ballistic Missile Programme: Technologies, Strategies, Goals, *International Security* Vo17. No. 2 Autumn 1992. p.17.

[141] Robert S. Wang, "China's Evolving Strategic Doctrine" *Asian Survey*, Vol. 24, No. 10 October 1984. p. 1043. Also see John Wilson Lewis and Xue Litai, *China's Strategic Seapower: The Politics of Force Modernisation in the Nuclear Age* (Stanford: Stanford University Press, 1994.) p. 40.

Concerned with the unprecedented levels of political interference in the submarine programme, Nie Rongzhen recommended military take-over of all defence-research related facilities. Under this proposal, which was sanctioned by the Central Military Commission, PLA troops moved to take over the Second Ministry and the troops stayed there till 1973.[142]

In mid 1969, the *sanxian* or Third Line policy resulted in a major setback for all strategic programmes in China. The Third Line policy advocated shifting of China's entire strategic infrastructure deep into the mountainous interior and housed underground or in caves. This policy came into force from mid 1969 and resulted in a massive wasteful expenditure on the missile and nuclear submarine projects.

Despite these political hurdles, the work on the missile programme did proceed forward owing mainly to the looming Soviet threat.

Sino-US Rapprochement, Defence Modernisation & Sino-Vietnam War: 1972 - 1982

After the 1969 Ussuri River clash, growing hostility with the Soviet Union over territorial and ideological issues prompted China to seek a counterweight to the USSR. The 1970s saw a major strategic reorientation in China with Sino-US rapprochement. The warming of relations between the US and China started with a secret visit by Henry Kissinger in 1971. China and the US signed an agreement, the Shanghai Communiqué in1972. Under this agreement the US agreed to recognize the PRC, abrogated its 1954 Mutual Defence Treaty with Taiwan and accepted the removal of all US military personnel from Taiwan. The normalization of relations between the two countries took almost a decade with the two sides finally exchanging ambassadors in 1979. This significantly downgraded the Chinese threat perception from the US.

On the other hand, the Soviet Union replaced the US as its primary security concern. Even as Deng downsized the Army, he increased the focus on scientific and technological research in defence under the Four Modernisations. The Four Modernisations provided the orientation for China's strategic, defence and economic policy for the next decade and a half and continue to be relevant even today as the four pillars guiding Chinese foreign and economic policies.

At the same time, the retreat of the radical elements in Chinese politics also led to a more pragmatic approach toward China's military and strategic planning. China launched its long overdue military modernisation programme in 1975. This was in response to (a) increasingly modern weaponry including nuclear capable missiles being targeted by the Soviet Union at China; and (b) China's own growing capability to develop nuclear-armed missiles. This spelled a change in China's military doctrine. The military doctrine changed from "People's War" to "People's War under Modern Conditions." Under

[142] John Wilson Lewis and Xue Litai, *China's Strategic Seapower: The Politics of Force Modernisation in the Nuclear Age* (Stanford: Stanford University Press, 1994.) pp. 33-39.

this, the assumptions about the type and nature of war that the PLA should prepare for were revised.[143] The PLA realized that in a war using modern weaponry with longer ranges and greater lethality, early victories in the war could be decisive. Hence the People's War concept of a protracted war would not be possible.[144]

A large part of China's nuclear and missile infrastructure was located in the North and the threat of a Soviet attack on these facilities had increased. The earlier strategy of "drawing the enemy deep" under the People's War doctrine actually made these facilities vulnerable to a Soviet invasion.[145] People's War also advocated abandoning of cities and retreating into the mountains and the countryside in case of an invasion. This was an approach that was no longer practical. China had developed major economic and technological centers in its urban areas, which could not be abandoned in the event of a Soviet invasion and needed to be defended with positional warfare.

The revised concept of People's War under modern conditions necessitated the development of a modern war-fighting capability with longer-range weapons both in the conventional and strategic arenas. The revised concept also incorporated into the Chinese strategy the possibility of deterrence through retaliation departing from the earlier strategy of deterrence through denial.[146] This reflected the rise in China's technological capability to develop long range missiles. While both the DF-4 and the DF-5 were not deployed till the early 1980s, both had been successfully tested by 1972. The DF-3/ 3A with a range of 2650/2800 km was deployed in 1971. This inspired confidence in the PLA about presenting a credible deterrent to a Soviet invasion by raising the costs of such an action. Though the Chinese arsenal was no match for the Soviet nuclear weapons, raising the cost of an invasion was considered to be a sufficient deterrent to a Soviet attack. Of course, it was obvious that this was the best strategy that China could adopt given its technologically and numerically inferior weapons.

The modernisation programme revived the focus on the strategic programme. There was once again a debate on priorities - the strategic programme or the modernisation of conventional weapons - given the relative cost benefits of the former.[147] In 1977, Deng Xiaoping decided to accord priority to conventional weapons. He also moved the weapons acquisition decisions away from the scientists, closer to PLA and other end-users.[148] It is arguable that at this stage, threat perception began to significantly impact strategic weapons decisions making. For example, there was a strong trend during this time in favor of developing tactical missiles (DF-61), which later petered off. In fact, the tussle for resources between different missile systems was very much in evidence during the 1970s.

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143 Nan Li, "The PLA's Evolving Warfighting Doctrine, Strategy and Tactics, 1985-95: A Chinese Perspective", *China Quarterly*, no. 146, June 1996. p.443.

144 Mark Burles and Abrams N. Shulsky, *Patterns in China's Use of Force: Evidence from History and Doctrinal Writings* (Santa Monica: RAND Corporation, 2000) p. 27

145 Robert S. Wang, "China's Evolving Strategic Doctrine" *Asian Survey*, Vol. 24, No. 10 October 1984. p. 1048.

146 Nan Li, "The PLA's Evolving Warfighting Doctrine, Strategy and Tactics, 1985-95: A Chinese Perspective", *China Quarterly*, no. 146, June 1996. p.443.

147 Robert S. Wang, "China's Evolving Strategic Doctrine" *Asian Survey*, Vol. 24, No. 10 October 1984. p. 1045.

148 Feignebaum, 1999. p. 98

During the 1970s, the missile programme suffered due to a combination of technological, economic and political factors. The DF-14 programme, designed to make a two-stage liquid propellant missile with a range of 8,000 km carrying a payload of 800 km was started in 1973. This programme was halted in 1975 because of a resource crunch that forced the allocation of scarce resources to the higher priority DF-4 and DF-5 programmes. However, upon Deng's insistence the DF-14 programme was revived in 1978 and renamed DF-22. Some difficulties were reported in the two-stage system and in the SLBM programme (JL-1, solid fuel) started in 1967.[149] R& D on the land variant of the SLBM, the DF-21 was started simultaneously and that too ran into some difficulties.

During the latter half of the 1970s, the missile programme also focused on improving the survivability of China's liquid fuelled missiles. This included making the missiles road-mobile and reducing the pre-launch preparation time to prevent the detection of a missile launch preparation and a pre-emptive enemy strike.

Meanwhile, China's relations with its erstwhile friend, Vietnam, were plummeting and the Sino-Vietnam war broke out in 1979. China invaded Vietnam in 1979, a week after Deng Xiaoping returned from his historic visit to the US to formalize relations with the US. The Chinese objectives in invading Vietnam were "to teach the Vietnamese a lesson" for cozying up to the Soviet Union and for invading Cambodia and Laos. The Chinese had defined limited objectives for themselves and wanted to replicate the quick invasion, victory and withdrawal experience of the 1962 India-China war. Though the Chinese won the war and withdrew voluntarily after a 17 days conflict, they could not dictate the terms of engagement as they had imagined. This brought home the imperative of modernising the military and increasing the pace of its strategic programme.

Success in the Solid Fuel Programme, Strategic Reorientation and the End of the Cold War: 1982 - 1990

After the death of Mao, China's military modernisation programme speeded up. In 1980 China finally tested the DF-5, its ICBM covering a distance of 6000 km from a test site in Gansu, western China to the Pacific Ocean.[150] In the next two years China tested both the DF-4 and the DF-5 trying to improve range and guidance systems on these missiles. In 1982, the Chinese successfully launched the JL-1, a solid fuelled SLBM. The SLBM programme had not been a top priority especially after the improvement of relations with the US. The Soviet threat to China was largely land-based along China's northern border and the military planners saw submarines playing only a marginal role in any possible Sino-Soviet conflict. It took nearly 15 years from the inception of the programme to its first successful launch. The JL-1 was deployed in 1988. The DF-21, the land mobile variant of the JL-1 was first successfully test

[149] Nuclear Threat Initiative's Missile Chronology. 1970-1979 Available at. http://www.nti.org/e_research/profiles/China/Missile/5657.html

[150] Nuclear Threat Initiative's Missile Chronology. 1980-1985 Available at. http://www.nti.org/e_research/profiles/China/Missile/5657.html

launched in 1985.[151] The solid rocket capability significantly improved the survivability and second strike capability of the Chinese arsenal.

In the mid-1980s, the reduction in tensions between China and its regional neighbours as well as improving relations between the superpowers prompted China's military planner to declare that it was no longer necessary to prepare for "early war, major war nuclear war with the Soviet Union."[152] By this time China had also built up a reasonable second strike capability to deter attacks from the Soviet Union. In 1983, China and the Soviet Union opened talks on normalising relations. Chinese concerns about Soviet missiles targeting China and Soviet forces deployed along China's borders figured in these talks. In the next few years China also urged the US and the Soviet Union to include Asia in their talks on missile reduction in Europe. China was concerned that reduction in European deployment might force the Soviet Union to shift those missiles to Asia. The coming to power of Gorbachev and the processes of Glasnost and Perestroika significantly reduced the threat of a Soviet attack. Given the strategic stalemate reached by the two Superpowers because of their huge stockpiles, nuclear war was ruled out. However, China still anticipated conflicts along its border of a limited nature. Therefore, the focus shifted to preparing for "local wars under high-tech conditions." These wars were categorized into the following five categories: [153]

- Small-scale border conflicts
- Confrontation over territorial seas and islands
- Surprise air attacks
- Resistance against partial hostile intrusions
- Punitive counterattacks.

The focus of defence preparation moved to building strategic capabilities in peacetime rather than responding to imminent threats. Technological advancement came to play an increasingly important role in the direction and pace of China's strategic programme.

The mid-1980s was also the time when Chinese leaders started identifying economic development as their primary focus. This acted as a restraint on adopting militarily aggressive policies. At the same time, China's Defence policy moved from defending China's territorial frontiers to securing China's "strategic frontiers." Strategic frontier was defined as "living space of a state and nation that contracts with the ebbs and flows of the comprehensive national strength of a nation".[154] A strategic frontier was deemed essential for China "to maintain the necessary security, survival space, scientific exploration

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[151] John Wilson and Hua Di, China's Ballistic Missile Programme: Technologies, Strategies, Goals, *International Security* Vo17. No. 2 Autumn 1992. pp.27-8.

[152] Mark Burles and Abrams N. Shulsky, *Patterns in China's Use of Force: Evidence from History and Doctrinal Writings* (Santa Monica: RAND Corporation, 2000), p. 29

[153] *Ibid*. p.31

[154] Nan Li, "The PLA's Evolving Warfighting Doctrine, Strategy and Tactics, 1985-95: A Chinese Perspective*", China Quarterly*, no. 146, June 1996. p.450

and technological development space and economic activities space, the necessary conditions for preserving the interests and security of the state."[155] This was indicative of the Chinese confidence to be able to defend its maritime claims and create a sphere of influence as a regional power.

In the mid 1980s China renewed focus on its tactical ballistic missiles and came out with two variants the M9 / DF -15 and the M11/DF-11. The M9 was a single stage, solid fuelled missile, with a range below 600 km. The M11 was a two-stage, solid propelled missile with a range below 500 km. The M9 was China's staple product for export and the Chinese exported these to many countries including Pakistan. Pakistan also received the M-11.

Gulf War & the Post Cold War Strategic Environment: 1991 - 2006

The collapse of the Soviet Union and the end of the Cold War reshaped China's strategic environment in the early 1990s. At this point in time, China's borders were the most secure since the establishment of the PRC. In the last decade China had concentrated on its missile programme with the aim of acquiring an all round capability that included cruise as well as ballistic missiles. Throughout the 1990s China sold its short range anti-ship missile to countries in the Middle East earning US displeasure. This caused major concern in the United States about advancing Chinese missile capabilities and periodically vitiated relations between the US and China. However, on balance, US-China relations were on an even keel and Russia-China relations were also improving. The 1991 Gulf War and the display of US military might during the conflict brought home to the Chinese the need to upgrade its missile capabilities especially its cruise missile programme.

China's ballistic programme has made steady progress with the JL-2 / DF-31 being readied for deployment soon. These advanced solid fuelled missiles whose capabilities have been discussed in detail elsewhere in this report would place China almost on par with the US.

China's current strategic environment comprises contending with the US military presence in the Asia-Pacific region that impact upon China's major security concerns, namely Taiwan and Japan. China's Defence White Paper in 2004 stated that the PLA must be prepared to fight: "local wars under conditions of informationalisation."[156] This addition seems to be prompted by Chinese observations of US use of precision guided munitions during the Iraq war and the increasing stress on use of satellites for military purposes. Taiwan continues to remain China's major security concern and a potential conflict in the Taiwan Strait continues to be the focus for its military modernisation. However, the 2005 Pentagon report on the Chinese military evaluates that China is looking at capabilities beyond a Taiwan scenario namely to protect its sea lines of communication and to expand its "maritime defensive perimeter

[155] *Ibid.*

[156] http://www.fas.org/nuke/guide/china/doctrine/natdef2004.html

further seaward".[157] This also dovetails with China's development of ICBMs in the absence of any threats from continental US.

However, at present, given the state of US-China relations and Taiwan's economic interdependence on the Mainland, the chances of a military conflict are remote. In the meanwhile China's considerable SRBM force continues to be deployed along the Chinese coast targeting Taiwan. It is estimated that as many as 650-730 M-9 and M-11 SRBM are deployed against Taiwan and that this number is increasing by a 100 each year.[158]

Relations between China and Japan have been plummeting since the past five years and there is growing concern about strategic stability in the region. Added to a protracted struggle over history, China and Japan also have a maritime territorial dispute over Diaoyutai / Senkaku Islands and a competition over energy resources in Northeast Asia. Chinese and the Japanese economies are interlinked through a web of economic interdependence that connects the US, Japan, China, Taiwan and ASEAN. This acts as a stabilizing factor in dealing with hostile political relations.

China's other major security concern lies in the South China Sea were it is in dispute with Vietnam, the Philippines, Malaysia and Brunei over the ownership of the Spratly Islands. These islands fall in a maritime region expected to yield rich hydrocarbon reserves. Chinese strategy of creeping occupation of marine features in the region since the beginning of the 1990s is prompting fears of an aggressive Chinese policy in the resolution of this dispute. The official Chinese policy in this region is of shelving of competing sovereignty claims and joint development of marine resource by the involved parties. However, growing Chinese military strength and its increasing economic clout is causing concern to other contenders in the dispute. US military presence in the region is acting as a stabilising influence in this region. On the other hand, continued US presence is urging the Chinese military, especially the navy, to modernise at a rapid pace, which in turn is increasing fears of China's neighbours. However, latest estimates argue that the potential and pace of China's strategic modernisation has been overestimated by US intelligence both in terms of nuclear warheads and missiles.[159]

China's major threats lie towards its eastern coastal periphery and India does not figure prominently in China's strategic calculations. While relations between India and China did take a downturn after India went nuclear, at present the relationship is stable with little chance of a military conflict between the two countries. The border dispute continues to be unresolved albeit negotiations to resolve the issue are on. India's perception of the threat from China continues to be high. In fact, India's indirect threat perception from China through help to Pakistan's strategic programme figures significantly higher than a direct military conflict with Beijing. Latest information available estimates the current Chinese nuclear arsenal to be around 130 nuclear warheads to be delivered by a triad of land, air and sea delivery

[157] *The Military Power of the People's Republic of China 2005*, Annual Report to the Congress, p. 12

[158] China Nuclear Forces 2006, *Bulletin of the Atomic Scientists* May/June 2006. p. 62

[159] Ibid., p.63

systems comprising missiles and bombers.[160] Its land based missiles are the DF-3 (liquid), the DF-4 (liquid), the DF-5 (liquid), and the DF-21 (solid). In our view, the DF-3, the DF-21 and the DF-4 are targeted at India.

During the 1970s the Chinese seemed to have looked at various technologies for countering ballistic missile defence. They had even experimented with the development of a Fractional Orbital Bombardment System (FOBS)[161]. Sometime in the late 1970s they thought that these various options did not make strategic sense and abandoned many of them.

While it is true that there are major technical problems to be overcome before even a simple BMD system can be deployed, the Chinese do seem to be concerned about such a possibility. The Chinese thrust in the Conference on Disarmament (CD) has been to counter US BMD developments by linking all international disarmament and security issues to the weaponisation of Space. With the US opting to push forward with the development of a multi-layered BMD system, China may decide that it also needs effective countermeasures to deal with these developments. The recent Chinese ASAT test, which is in direct contravention to its official position in fora like the CD, may be the first sign of a Chinese response to the US deployment of a BMD system. It would appear that the Chinese would want to protect themselves from any effort by the US to establish a preponderant and dominant position in the emerging strategic arena of Space. An increase in the number of missiles, improvements in the ability of these missiles to penetrate BMD systems, a larger and more sophisticated submarine based deterrent are all possible developments that one could expect.

Russia and China share many common concerns especially with respect to the US. They already have major collaborative ventures in many areas of military and aero-space technology. One would expect greater cooperation between them both on the political and technology fronts as they both strive to manage and deal with the United States.

[160] Ibid., p.60-63

[161] John Wilson and Hua Di, China's Ballistic Missile Programme: Technologies, Strategies, Goals, *International Security* Vo17. No. 2 Autumn 1992. p. 17

Conclusion and Major Findings of the Study

From the vast R&D, organisational and operational structure of Chinese missile forces, it is clear that China has tremendous indigenous capability to design, build and deploy increasingly sophisticated missiles. The evolution of the Chinese ballistic missile programme points to incremental but impressive progress in all missile domains including control and guidance, solid and liquid propulsion, warheads, re-entry vehicles, inertial platforms, onboard computers, launch platforms, materials and systems engineering.

China has successfully combined the organisational and technical aspects of missile development creating a massive missile infrastructure geared to respond to China's evolving strategic needs. This capability is set to enhance with the ongoing development of its SLBM JL-2 and its land based version the DF-31 and the DF-31A. The JL-2 when deployed on its new generation nuclear submarine (under development) will provide China with a survivable nuclear option. China is also in the process of increasing the survivability of its land based missile by phasing out the DF-3 and the DF-5 and replacing them with the DF-21 and the DF-31. With this missile arsenal, China is poised to enter a new level of strategic capability in the coming few years.

The major technical findings of the study are as follows:

- The DF-5 widely believed to be a two stage missile is most likely a three stage missile with extra propulsion capability in the third stage.
- We find the range of the JL-1 to be higher than the reported range. The reported range is 1700-2500 km and we have independently assessed the range to be 3073 km.
- The DF-31, which has not been photographed except inside a canister, will probably have a MIRV capability with a range of approximately 8000 km and a payload of 1200 to 1350 kg. We have provided a schematic design of the possible configuration of the DF-31. In a single warhead configuration, the JL-2 / DF-31A will have a range of 12,000 to 14,000 km with a payload of 700 kg.
- We have independently estimated the number of DF-5 and DF-21 missiles that China can produce annually.

China also has impressive capabilities in place for operational testing of different kinds of missiles and missile subsystems

The missile programme has demonstrated clear capabilities of working closely with other ministries within the Chinese state for delivery of extremely complex national technology systems. Overlapping membership of top decision making bodies in the political, military, strategic and S&T arenas, buttressed by informal networks facilitates close coordination between these different areas.

Given current developments in Ballistic Missile Defence and the Weaponisation of Space, one would expect the Chinese to respond with some new initiatives. The recent ASAT test in January 2007 is a visible demonstration of Chinese intent, capability and determination to counter efforts by other countries to dominate the emerging strategic frontier in Space.

Appendix - I: Image Analysis

The analysis of the various images of Chinese missiles is provided in this Appendix. The Image numbers referred to here is based on a library of images that we have created for each missile type. A missile by missile analysis of the images is provided in the following sections.

Images of the DF-1, R-2 missiles

While there are many versions of the Russian R-2, there is only one image of the DF-1 that we could locate in the public domain. This is not a real rocket but the model of a rocket kept in an exhibition in Beijing.[1] There are some other pictures available of the R-2 – images 2, 3 and 4.[2] We could also locate some images of R-2 models at a third site.[3,4] Details of the analysis carried out on the various images are provided below.

Image 1 (image of the model of the DF-1 at the exhibition site at Beijing) measurements show that the model has an L / D (length to diameter ratio) of 10.09. Since there people in the image we can use estimates of their height to independently estimate the diameter and the length. The diameter appears to be between 1.05 and 1.12 m and the length works out to be between 10.63 and 11.25 m. The model is obviously a scaled down version of the DF-1. The L/D ratio of an early version of the Soviet R-2 (R-2A & R-2E) is 10.3 (Length17 m and diameter 1.65 m). This is close to the observed L/D value of 10.09.[5]

Image 2 enables us to make some measurements on various parts of the Soviet R-2 missile. The L/D ratio is 10.81. This is in close agreement with the L/D ratio of the original basic version of the R-2 missile. There are some people seen in the picture. Quality makes it difficult to measure their height precisely. However the crude measurements are consistent with a value of 1.65 m for the diameter. The span (fin to fin length) to the diameter ratio is also 2.15. This is again close to the value 2.16 we get from the literature. This makes it certain that we are seeing an early version of the basic R-2 missile.

Image 3 is another picture supposedly of the R2 missile. Measurements on this image give an L/D ratio of 8.99. This is well below the L/D ratio of the various versions of the R-2 missile. The image has people working near it. This enables us to get an independent verification of the diameter. The estimated diameter works out to be between 1.65 and 1.74 m. This is in reasonable agreement with the diameter of the R-2. However based on the L/D ratio we are doubtful whether this is the R-2 missile. Most

1 The model is available at http://www.astronautix.com/graphics/d/df1beiji.jpg. Another image is available at Robert S. Norris, Andrew Burrows, and Richard Fieldhouse ,"Nuclear Weapons Databook Series Volume V: British, French and Chinese Nuclear Weapons, figure 7.2 p.360, 1994. However we did not analyse this image.

2 See the http://www.russianspaceweb.com/r2.html

3 http://space.skyrocket.de/index_frame.htm?http://space.skyrocket.de/doc_lau/r-_2.htm

4 http://space.skyrocket.de/index_frame.htm?http://space.skyrocket.de/doc_lau/r-_2_sci.htm

5 The R-2 was produced in several versions including a production version. One of the early versions had a length of 17 m and a diameter of 1.65. A later version had a length of 17.65 m and a diameter of 1.65 m and a production version with maybe a longer thermo nuclear payload had a length of 21 m. For details see http://www.astronautix.com/lvs/r2.htm

probably this is the R-1 (Scunner), a Soviet copy of the German V2 rocket. According to the literature the length of various versions of the R-1 vary from about 14.02 to 14.14 m. The diameter of the R-1 is reported to have been the same as that of the R-2 – 1.65 m. This gives an L/D ratio of 8.57. This is close to the observed L/D ratio. We can therefore conclude that the missile that we are seeing is the R-1 missile and not the R-2 missile.

Image 4[6] shows another R-2 missile. The nozzle and the fin area are clearly seen. We did not make any measurements on this image. Image 5[7] is from a website which links the picture to the R-2 (Sibling) missile. Measurements made on this missile give it an L/D ratio of 10.52. Assuming a 1.65 m diameter this translates into a length of 17.36 m. This seems to be reasonably close to the R-2A scientific version or the R-2E prototype test vehicle of the R-2.

The last image[8] we have of the R-2 has an L/D ratio of 12.50. This is clearly a much longer missile with a length of 20.63 m based on a diameter of 1.65 m. This length makes this a possible production version of the R-2 (Sibling) missile that is reported to have had a length of 21 m. The warhead and its interface part of this missile is 6.61 m. This is a significant stretch from the earlier warhead lengths of ~ 3.71 m. This could possibly be an early version of a thermo-nuclear warhead. Table 21 below summarises the various measurements on the images.

Table 21
DF-1 / R-2 Measurements

Image	Length to Diameter Ratio	Length	Diameter	Comments
Image 1	10.08	Not checked	Not checked	Scale model
Image 2	10.81	17.84 m	1.65 m	Diameter 1.65 m . Soviet R-2
Image 3	8.99	14.84 m	1.65 m	This is R-1 not R-2.
Image 4	N.A	N.A	N.A	Tail and fin section seen
Image 5	10.52	17.36 m	1.65 m	R-2. Consistent with Image 2
Image 6	12.50	20.63 m	1.65 m	Production version – longer warhead
Average		17.60 or 20.63 m	1.65 m	Different versions of R-2 and R1 seen in images.

The DF-2 missile

Image 1[9] is an image of the DF-2 missile that is being exhibited to the public. There are cars parked in front of the missile that could be used to independently verify the dimensions of the missile. The

6 http://www.russianspaceweb.com/r2.htm
7 http://space.skyrocket.de/index_frame.htm?http://space.skyrocket.de/doc_lau/r-_2.htm
8 http://space.skyrocket.de/index_frame.htm?http://space.skyrocket.de/doc_lau/r-_2.htm
9 http://www.astronautix.com/lvs/df2.htm

L/D measured on this image works out to be 11.23. This is lower than the L/D value that the missile should have (L/D of 12.49 based on length of 20.61 m and diameter of 1.65 m) from data given in the published literature. The image makes it possible to estimate the tank lengths and also helps us to get some idea of the length of the engine. The image shows an increase in tank lengths from the R-2 tank length measurements. The image also shows that the engine and nozzle part of the missile is shorter. Since the R-2 / DF-1 and the DF-2 use the same engine this issue has to be resolved. The length of the warhead and the interface works out to be 4.47 m.

Image 2 is supposed to be another image of a missile that is part of a public exhibition in Beijing.[10] From the image the estimated diameter is consistent with the value 1.65 m quoted in the literature for the DF-2. The L/D ratio works out to be 10.68. From this the length of the missile works out to be 17.61 m. This is closer to the length of the DF-1 / R-2 missile. The warhead and its interface have a length of 4.64 m which is in reasonable agreement with the length of the warhead seen in image 1. The tankage length works out to be 8.02 m. This is more consistent with the tankage length we have seen in the DF-1. The length of the engine + nozzle + fin is 4.95 m. This is close to the value of the DF-1. According to the literature this should also be the value of length for the DF-2 since they use the same engine. On balance we would conclude that this is a DF-1 model and not the DF-2.

Image 3 is from the FAS site.[11] There are many problems in this being a real DF-2 image. The diameter of the top half of the missile is smaller. The interface between warhead and missile is also very different and seems to show some stretching. Additional tankage seems to have been added. The L/D ratio is 10.85.

The estimated diameter of lower tank based on height of man is consistent with 1.65 m diameter. The length based on 1.65 m diameter is 17.90 m. Total tankage length as measured is 11.30 m. However the engine + fin length is only 2.45 m. This is again much shorter than the measurements from other R-2 images. There are many inconsistencies that have to be resolved.

Originally we thought that this was a two stage missile – maybe the DF-4 which was flight tested much later. However the DF-4 is known to have a diameter of 2.25 m. There is no known record of the Chinese developing a two stage version of the DF-2.

We can clearly see wires leading to the warhead part of the missile. One explanation for the inconsistencies is that this is not a real operational missile but a dummy that is used to train personnel for operations. What we are seeing is therefore a training exercise not on the real missile but on a simulated dummy. This could account for the discrepancies in length especially on the engine side. Obviously they are using another dummy engine for the exercise. As we shall see later this appears to be a reverse engineering

10 http://geo.ya.com/travelimages/china55.jpg

11 http://www.fas.org/nuke/guide/china/theater/New-sm-1.jpg

effort of the Soviet R-12 missile. According to publicly available information Chinese engineers undergoing training in Moscow may have stolen some design drawings. This image provides concrete evidence that this allegation is indeed true. It also establishes the fact that the Chinese did invest time and effort in such a development in the early days of their programme.

Image 4 also from the FAS website shows the DF-2 in flight. From the image we can see a lot of condensation / vapour on the lower side of the missile. We believe that this is due to evaporation of water that had condensed on the cold liquid oxygen tank.

The measured value of L/D is 12.83. Based on diameter of 1.65 m the length is estimated as 21.16 m. This is reasonably close to the value 20.6 m reported in the literature. These measurements are consistent with published information. This could be an operational version of the DF-2 missile.

Image 5 is another image of the DF-2 available in the public domain.[12] The warhead part of the missile is missing making it difficult to make complete measurements. DF-2 markings on the missile can be seen with difficulty. The general shape and layout of this missile is consistent with the DF-2 – though the engine length seems to be shorter.

Image 6 is an image given in the book "China Builds the Bomb".[13] We can see that the L/D of 13.07 for this image is reasonably close to the L/D of 12.82 of image 4. According to Lewis & Litai this is a launch of the DF-2 missile with a live nuclear warhead that took place in October 27th 1966. The nuclear warhead exploded somewhere in the Lop Nor test area. This is the only known instance of an actual nuclear warhead being tested along with the missile.

The results of the measurements on the DF-2 missile are summarized below.

Table 22
Measurements on the DF-2 missile

Image	L/D Ratio	Length	Diameter	Comments
Image 1	11.22	18.53 m	1.65 m	Dummy engine
Image 2	10.67	17.61 m	1.65 m	Estimated diameter 1.65 m DF-1
Image 3	10.84	17.84 m	1.65 m	Variable diameter. Training?
Image 4	12.82	21.16 m	1.65 m	Flight version
Image 5	N.A	N.A	1.65 m	DF-2 markings seem
Image 6	13.07	21.57 m	1.65 m	Compatible with image 4

[12] http://www.sinodefence.com/missile/nuclear/df2.asp

[13] "China Build the Bomb", John Wilson Lewis & Xue Litai, Stanford University Press, 1988

The data is consistent with what is reported in the literature. The DF-2 uses the same engine as the DF-1. The DF-1 tankage length as inferred from images of the R-2 is on an average 8.90 m. The DF-2 tanks have been stretched to 11.38 m. This means that the DF-2 tanks are nearly 2.5 m longer.

We can also see that the R-2 / DF-1 and the DF-2 engines are very close in length. The average length of the engine + nozzle + fin for both the DF-1 and the DF-2 is 5.07 m. We can also see that the Chinese DF-2 warhead (average length 4.42 m) is longer than the 3.69 m average R-2 warhead. This is consistent with the reports in the public domain that the Soviets did not transfer any warhead know-how to the Chinese.

Based on this the length of the DF-2 would be $\sim 4.42 + 11.38 + 5.13$ m $= 20.93$ m.

The length of the DF-1 missile would be $\sim 4.42 + 8.02 + 5.13 = 17.57$ m.

This is consistent with what is reported in the public domain about the transfer of missile technology from the Soviet Union to the People's Republic of China.

The Soviet warheads are shorter ~ 3.70 m. One of the Soviet warheads is 6.61 m long. This could be an early thermo-nuclear weapon.

The DF-3 Missile

There are a number of images of the DF-3 available in several locations. Our study was able to locate at least 20 such images. The same image is of course available in several data bases. In our study we have tried to look at all the images and used the analysis of these images as a baseline for looking at the performance of the DF-3. We have also tried to use the analysis to speculate about the likely trajectory of development of the DF-3 missile.

Image 1[14] is an image available in several other websites. It shows the missile on its mobile launcher being readied for launch. A lot of technicians / army personnel milling around are preparing the missile for a launch. The 4 nozzles of the 4 liquid engines can be seen in the rear. We also see a ribbed construction on the skin of the missile leading from the inter-tank area to the engine section. The control actuators for the engines are probably located in the inter-tank area and this is possibly where all the control and electronics systems would be located. The DF-3 was the first Chinese rocket to use a strap-down control system. The tanks are probably separately constructed and then assembled together.[15] At this stage the Chinese may have found it difficult to build an integrated tank of the required size.

[14] http://www.lyshtw.com/chinaimg/imglib/china/missile/DandaoMissile/DF-3CSS-2/002.jpg

[15] If it were an integrated tank the wiring for controlling the rocket might go all the way from the top of the upper tank to the engine area. We do not see it in the various images of the DF-3.

Since the missile is tilted at an angle length measurements especially in the area of the nosecone section are not likely to be accurate. The tanks and the interfaces and the engine are all clearly separated. The presence of people close to the missile makes it possible to get a good estimate for the diameter of the missile. These estimates are in agreement with the diameter of 2.25 m quoted in the literature. Image 12 is the same as image 1 and has been used for making estimates

Image 2 is another image of the DF-3[16] also from the same site as Image 1. This is also a picture of the missile being readied for launch. But unlike image 1 the geometry is such that complete measurements on the missile are possible. Men working on the missile as well as the vehicles that are seen provide benchmarks that enable us to estimate missile dimensions in different ways and check for consistency in the various measurements. The image also enables us to get measurements on the various parts of the missile – the warhead, the upper and lower tanks, the engine & fin area as well as the various interfaces. The L/D ratio works out to be 9.73. Using the benchmarks the diameter is estimated as 2.33 m. This is reasonably close to the published value of 2.25m. The length of the missile based on a 2.25 m diameter works out to be 21.89 m. The image also is very useful since it enables us to get a good estimate of the true dimensions of various benchmarks like truck tyre diameters, tow truck tyre diameter, wheel bases and other dimensions of vehicles used in the operations to fuel and launch a missile. The ribbed structure from the interface between the tanks and the engine can easily be seen.

Image 3 is a truncated part of image 2 from a different source.[17] The estimated diameter based on a single benchmark in the picture works out to be 2.43 m. This is somewhat larger than the 2.25 m diameter mentioned in the literature. Though the length of the missile could not be estimated, the lengths of the warhead & interface, upper tank and the inter-tank interface could be estimated. These match well the dimensions obtained from the more complete image 2.

Image 4[18] is another image that is identical to images 2 & 3 but taken from a different source. No measurements were made on this image.

Image 5 shows a missile at some distance being readied for launch. A fleet of trucks are lined up side by side. A man is also standing near the first truck. The lower part of the missile is hidden by the fleet of trucks. Though the diameter can be measured, the distance makes it difficult to use available benchmarks to independently verify the diameter. Truck heights, truck tyre diameters, wheel bases can all be measured to be added to our data base of bench marks.

Image 6[19] shows a missile without its warhead part being lifted. The quality of the image is not very good, making an accurate measurement of the diameter difficult. A man standing near the missile

16 http://www.lyshtw.com/chinaimg/imglib/china/missile/DandaoMissile/DF-3CSS-2/001.jpg

17 http://www.cdi.org/issues/nukef&f/database/chnukes.html#df3

18 http://www.sinodefence.com/missile/nuclear/df3_gallery1.asp

19 http://www.sinodefence.com/missile/nuclear/df3_gallery3.asp

provides a benchmark to validate the diameter measurement. The diameter, based on the assumed height of the man to be 1.83 m (6ft.), works out to be 2.09 m. Measurements on tyre diameters and wheel bases were also carried out to add to our data base.

Image 7[20] is a launch pad image of a missile being readied for launch. It is similar to image 1 but is inclined at a different angle. Accurate measurements are difficult. The ribbed structures (there appear to be 2 of them) outside the skin of the rocket seem to link the tank interface to the engine section. No measurements were carried out on this image.

Image 8 is also from the same site as image 7[21]. The rocket is tilted forward making an accurate measurement of the length difficult. However we can make measurements on the diameter, the lower tank and the length of the engine.[22] We can also measure the fin area to feed into our trajectory model for improving results. The fin area works out to be 1.04 sq.m.

Image 9[23] is a very good image of the missile being towed by a tow truck at some parade. The warhead part is a little truncated. Measurements made on this missile (after adding 5 pixels for the missing part of the warhead) give an L/D ratio of 8.97. Based on a diameter of 2.25 m this works out to a length of 20.18 m. There are two men standing on the road. These men are quite some distance from the missile being paraded and using them as a benchmark cause big errors. The diameter of the missile based on the tow truck tyre diameter (estimated from Image 2) works out to be 2.25 m which is almost identical to the publicly available diameter of the DF-3 of 2.25 m.

Image 10[24] is a liftoff image taken from a far distance. Individual parts or sections of the missile are not visible. The L/D ratio works out to be 8.51. On the basis of a diameter of 2.25 m, this translates into a length of 19.12 m. The L/D is compatible with the L/D of image 2.

Image 11[25] is the same as image 9 but taken from a different source. We did not make any measurements on this image.

Image 12[26] is the same picture as image 1 from a different source. Based on our measurements and using the height of various people in the image as a benchmark the estimated diameter works out to be 2.22 m which is in agreement with the 2.25 m quoted in the literature. Engine & fins, the lower tank and the upper tank as well as the various interfaces have been measured.

20 http://www.sinodefence.com/missile/nuclear/df3_gallery4.asp

21 http://www.sinodefence.com/missile/nuclear/df3_gallery5.asp

22 The measurement used includes lengths of the engine up to and including the fin as well as the interface between the lower tank and the engine.

23 http://www.aeronautics.ru/archive/wmd/ballistic/ballistic/css2_001.jpg

24 http://www.aeronautics.ru/archive/wmd/ballistic/ballistic/css2_003.jpg

25 http://www.nti.org/db/china/df3.htm

26 http://www.nti.org/db/china/df3.htm

Image 13[27] shows a number of DF-3 missiles in parade. Though the quality of the image is good, the orientation of the missile is such that it is difficult to make good measurements. Troops accompanying the missile can be seen in this image.

Image 14[28] is identical to image 2. Measurements made on Image 14 are in reasonable agreement with measurements on image 2. The internal consistency of each image as well as the consistency between images is good. It helps us to set up some bench marks. **However the values obtained from Image 2 seem to be more internally consistent and therefore maybe better**.

Image 15[29] is again the same image as image 2. We did not make any measurements on image 15.

Image 16[30] is the same image as image 13. Though the image is good we did not make any measurements on this image too because the image orientation makes measurements difficult.

Image 17[31] is a more recent image. It shows a missile being towed in a parade scene. The L/D of the missile works out to be 9.20. Based on a diameter of 2.25 m this translates into an overall length of 20.69 m. Using the tow truck diameter obtained from image 2 as a base we can estimate the diameter of the missile. This works out to be 2.21 m which is quite close to the publicly available value of 2.25 m. The dimensions of different parts of the missile have also been estimated and these are listed in Table 23

Image 18 is the same as image 1. No separate measurements were made on this image.

Image 19 and Image 20[32] are both taken from the same source. The image does not lend itself to accurate measurements.

The measurements we could derive from these images are summarized in Table 23

[27] http://www.nti.org/db/china/df3.htm

[28] http://www.nti.org/db/china/df3.htm

[29] http://www.globalsecurity.org/wmd/world/china/images/df-3ssm.jpg

[30] http://www.globalsecurity.org/wmd/world/china/images/df-3-4.jpg

[31] http://www.globalsecurity.org/wmd/world/china/images/df-3.jpg

[32] The images are taken from http://nuclearweaponarchive.org/China/Df3a.jpg and http://nuclearweaponarchive.org/China/ChinaArsenal.html

Table 23
Measurements on the DF-3 Missile

Image No.	L/D ratio	Length	Estimated Diameter	Comments
Image 1	N.A	N.A	2.24 m	Image orientation makes length measurement difficult.
Image 2	9.73	21.89 m	2.32 m	Image slightly tilted. Some source of errors especially rear end. Corrected for rotation
Image 3	N.A	N.A	2.43 m	Top portion of Image 1
Image 4				Same as images 2 & 3. No independent measurements
Image 5				Image is good. But measurements difficult. Fleet of trucks for operations.
Image 6	N.A	N.A	2.09 m	Missile warhead part absent. Quality of image makes measurement a problem
Image 7				Similar to image 1.Tilt angle appears to be different. No measurements
Image 8	5.71	No	2.23 m	Orientation makes length measurement problematic. Fin area 1.04 sq.m
Image 9	8.97	20.18 m	2.25 m	Some part of warhead missing. Good image for deriving measurements
Image 10	8.5	19.12 m		Lift off image. Distance makes independent verification difficult
Image 11				Same as image 9 but from a different source. Matches well with Image 9.
Image 12	N.A	N.A	2.07 m	Same as image 1. Better image. Measurements more accurate.
Image 13				Number of missiles in parade formation. No measurements possible.
Image 14	9.21	20.73 m	2.32 m	Same as Image 2. Image 2 more internally consistent.
Image 15				Same as Image 2. No measurements made on image
Image 16				Same as Image 13.
Image 17	10.68	24.02 m	2.21 m	Good image of missile on parade. Measurements may be okay
Image 18				Same as Image 1. No measurements made on this image.

Image No.	L/D ratio	Length (m)	Diameter (m)	Comments
Image 19	9.90			Orientation and quality problems. Measurements not accurate.
Image 20				Same as Image 19. No independent measurements made.

Further measurements on various parts of the missile are provided in Table 24 below.

The values that are in bold are measurements which we believe are accurate based on our assessment of the image and our measurement procedures.

Clearly only a few of the images provide quality measurements.

Table 24
Measurements on the Elements of the DF-3 Missile

Images	Warhead	Total tankage				Engine + nozzle + FIN + IF			Length
DF-3	warhead + IF	upper tank	tank IF	lower tank	*Total*	*Interface*	engine+FIN	Engine+ IF	
Image 1	N.A	2.1 m	1.12 m	3.09 m	6.31 m	**0.55 m**	**2.54 m**	**3.09 m**	Inaccurate
Image 2	**7.94 m**	**5.35 m**	**0.4 m**	**5.6 m**	**11.35 m**		2.61 m	2.61 m	21.9 m
Image 3	**6.03 m**	**6.67 m**	**0.47 m**						
Image 4	Same as Image 2 and Image 3 . No separate measurements made								
Image 5	Missile far away. Lower part of missile not visible. Trucks and people benchmarks								
Image 6	Missile being lifted without warhead. Measurements not very accurate.								
Image 7	Launch pad image. Similar to Image 1. No measurements made.								
Image 8	Distortions in upper part of image			5.08 m			3.26 m	**3.26 m**	
Image 9	**4.33 m**	**5.05 m**	**1.94 m**	**5.69 m**	**12.68 m**	**0.55 m**	**2.45 m**	**3 m**	**20.01 m**
Image 10									19.12 m
Image 11	Same as Image 9. Matches well with Image 9 measurements								
Image 12*	No measurements								
Image 13	Good image of missiles on parade. No measurements are possible								
Image 14	**7.52 m**	**5.08 m**	**0.52 m**	**5.28 m**	**10.88 m**		**2.51 m**	**2.51 m**	**20.91 m**
Image 15	Same as Image 2. No measurements made								
Image 16	Same as Image 2. No measurements made								
Image 17	**7.18 m**	**5.65 m**	**1.91 m**	**6.03 m**	**13.59 m**	**0.39 m**	**2.86 m**	3.25 m	24.02 m
Image 18	Same as Image 1. No measurements made								
Image 19	Image not conducive to good measurements								
Image 20	Same as Image 19. Not conducive to good measurements								
Note: *Same as image 1									

Image 9 appears to be one of the best images to give accurate measurements of the different elements of the DF-3 missile. The values that we get for the upper tank, the inter-tank interface, the lower tank, the engine-tank interface and the engine + fin are likely to be accurate. Image 11 taken from another source also matches well with these measurements. However the warhead length measured from Image 9 is only 4.33 m. This appears to be much lower than warhead lengths derived from the other images especially images 2 and 14. The warhead we are seeing in this public display parade image (Image 9) may be a conventional warhead and not the thermonuclear warhead. The Chinese exported a number of missiles to Saudi Arabia with conventional warheads and we may be seeing this version. Apart from the warhead Image 9 may be a very useful benchmark to look at the measurements we get from the other images.

Images 2 and 14 are images of the same missile from two different sources. Measurements on the engine side are likely to be less accurate than measurements on the upper part of the missile. When we look at these images and compare them with image 9 these appear to be earlier less advanced versions of the DF-3. Image 1 provides us with a more accurate measure of the engine and its interface with the lower tank. The inter tank length from these images (0.4 m and 0.52 m) are much lower than the 1.94 m inter tank length we get from the more advanced image 9.

Assuming that images 2 and 14 provide accurate measurements of the thermonuclear warhead we can get some idea of the earlier versions of the DF-3 missile using images 1, 2, 4 and image 9. The engine + fin + interface length should be around 3 m. Image 1 gives us a measure of the engine + interface of 3.09 m after correcting for rotation effects. This is in reasonable agreement with the engine + interface measurement of 3 m that we get from analyzing image 9.

The upper tank lengths from image 14 and image 9 match well (5.08 m and 5.05 m). In the same way the lower tank lengths from image 2 and image 9 match well (5.6 m and 5.69 m).As we had mentioned earlier the inter tank interface length from the earlier to the later versions of the DF-3 show an increase in length by about 1.4 to 1.5 m.[33] These 2 variants would have lengths of 23.41 (7.73 m warhead + 5.07 upper tank + 1.94 m inter tank length + 5.67 m lower tank and 3 m engine & interface) and 21.91 m (7.73 m warhead + 5.07 m upper tank + 0.46 m inter tank length + 5.67 m lower tank + 3 m engine & interface) respectively. In keeping with the nomenclature seen in the literature we would group all these missiles as the original DF-3.

When we compare Image 9 and Image 17 we see further differences. The inter tank length remains the same in both images but both the upper and lower tanks have been stretched by about 0.5 m in

[33] This is a rather large increase in the inter-tank length. Why did the Chinese do this for the DF-3 is not very clear. One possible reason could be that some inputs from the Soviet R-12 programme found its way into the design of the DF-3 and the DF-4 first stage. Literature on the R-12 says that the inter-tank interface was specially changed to accommodate control systems for the missile. For the DF-4 the inter-tank length is also close to the value of about 0.46 m that we observe in some images of the DF-3. Please also see our section on the DF-4 where the Soviet R-12 connection is discussed. There is also the possibility that these changes were connected in some way to MIRV tests that the Chinese were reported to have carried out with the DF-3.

Image 17. The upper tank length is 5.65 m and the lower tank length is 6.03 with the inter-tank interface remaining the same at about 1.94 m. The warhead + interface length has also come down in length to about 7.18 m. The length is 7.18 + 5.65 + 1.94 + 6.03 +3 or 3.25 m = about 23.7 to 24 .0 m. We could term this stretched version with a reduced warhead length as the DF-3A.

The DF-4 Missile

There are 17 images of the DF-4 that we have been identified from various locations on the Net. One of them is actually a DF-5 image another is a DF-2 or DF-1 image. There is yet another image which appears to be a two stage missile but whose diameter does not match the 2.25 m diameter of the DF- 4. There are also duplicates of the same missile available in different web sites. Taking all these facts into account there are not more than 6 images that are useful. Out of these 6 images some have other problems of scale and orientation. This leaves us with very few images that gave us useful measurements.

Image 3[34] shows a number of DF4 missiles on some kind of a parade. There are a number of people in front of the missile who are standing on some kind of ladder or steps. They seem to be taking some pictures. Close to the missile somewhere in the middle there is some kind of figure. It is difficult to make out what that figure is. If we assume that the picture we have is a X–Y orientation, the missile appears to be tilted in the X–Z plane by a certain angle. The missile also appears to be tilted to the X axis i.e. the O–X line due to the angle of the camera when the image was taken. Various parts of the missile are clearly seen. The tow truck wheels including the white circular markings are also clearly seen in this image. We can use this image to get some idea of the various dimensions of the missile.

Using the heights of the people in the picture standing in front of the missile we can get some idea of the diameter of the missile. The diameter can be estimated to be between 2.06 and 2.18 m. Since the men in the picture are well in front, using them as benchmark may under estimate the diameter.

We can use the circular white markings on the front and back tyres to estimate the rotation in the X–Z plane. The angle of rotation using the change in the diameter of the circular white markings on the front and back tyre work out to be 40.92 and 43.31 degrees respectively.[35]

We can also estimate the tilt along the O–X line in the X–Y plane. This works out to be 5.89 degrees.[36] We can now estimate the lengths of different parts of the missile using this data.

[34] http://www.sinodefence.com/missile/nuclear/df4_3.asp

[35] Corrections for this can be made by dividing the measured length by the cosine of the angle of rotation. We have used the average of the two angles measured in this particular case.

[36] The y coordinates of the front tyre and the back tyre differ appreciably. The camera x and y axes are tilted with respect to the image x and y axes.

After corrections the L/D ratio of this DF 4 image works out to be 12.05. This is reasonably consistent with the length and diameter given in the web site from which this image is taken – 28 m length 2.25 m diameter which works out to an L/D ratio of 12.44. Lengths of various elements have been estimated using the diameter of 2.25 as the basis. These are provided in Table 25

Image 1[37] is also from the same site as image 3. This photograph is taken from a camera fairly close to the missile. The missile is being towed in a vehicle that appears to be similar to what we see in image 3. About 24 soldiers can be seen in the van leading the missile. The angle of the photograph makes it difficult to see the warhead part of the missile. It is clear from the geometry of the image that we can make some corrections especially for the rotation in the X–Z plane – the axis going in into the picture. It is also clear from the geometry that scale effects are likely to become more serious as we move away from the engine side towards the warhead part that cannot even be seen in the image. We can use measurements of diameter along the length to correct to some extent for scale effects. However in spite of these corrections, the errors are likely to increase as we move away towards the far distance. The engine, fin area, and stage 1 measurements may be reasonably accurate. The image also helps us to get some idea of the wheel dimensions of the various vehicles accompanying the missile.

Image 2[38] shows a missile inside a silo. The diameter measurements of the upper and lower part of the silos enable us to get some idea of the height of the silo using the diameter measurement as a benchmark.[39] The image shows the stubby warhead tip suitable for withstanding the re-entry environment. This seems to be somewhat different from the warhead tip that we see in image 3.[40]

Image 4[41] shows a missile on parade. Only the upper part of the missile – the warhead and the upper stage are seen. The tow truck wheels have clear white markings that we can use to get an estimate of the rotation angle in the X–Z plane. The upper stage has certain striations. There is possibly a cable link between the inter-tank area of the upper stage and the warhead. Something like a nozzle can also be seen in the part that separates the warhead from the upper stage. We have used measurements made on the tow truck wheel diameter from earlier images (~1m) to get an independent estimate of the missile diameter which works out to be about 2.4 m. Using the published value of diameter (2.25 m) as a benchmark we have estimated the lengths of the various parts of the missile that are seen in this image.

Image 5 is the same picture as image 3. However it appears to be an image that shows a few more things than image 3. We can see a bridge that spans some kind of a ravine. In the background we can see a rocket that seems to be readied for some unknown purpose. We see regular structures spanning

37 http://www.sinodefence.com/missile/nuclear/df4_1.asp

38 http://www.sinodefence.com/missile/nuclear/df4_2.asp

39 We get an estimate of about 38 m for the silo height using some simple geometry.

40 The warhead is shaped somewhat differently from what we see in image 3. Carbon carbon or carbon phenolic could be the material.

41 http://www.aeronautics.ru/archive/wmd/ballistic/ballistic/css3_001.jpg

the bridge and maybe 3 tracks that seem to cross the bridge. We also see some kind of a rectangular structure maybe some kind of a crane.[42] We can also see some cars or vehicles parked in front of the entrance to the underground ravine area and a circular structure that could be the back end of a missile. The L/D ratio works out to be12.21. Based on the height of the people in front of the missile an estimate that we get for the diameter is 2.30 m. The length of the missile based on a diameter of 2.25 m works out to be 27.48 m.

Image 6 shows a picture of the missile on the launch pad.[43] It appears to be a single stage missile. The warhead and the upper tank area cannot be seen separately in this picture. The estimated diameter based on the height of people working close to the missile is 1.62 m. This is not compatible with the DF-4 or the DF-3. This is most probably a DF-1 or a DF-2 missile – most probably a DF-1 since the L/D ratio is 10.49.

Image 7[44] is another copy of images 3 and 5. We did not make separate measurements on this image.

Image 8 appears to be a mirror image of images 3, 5 and 7.[45] The L/D ratio based on an approach similar to that used for images 3 and 5 works out to be 10.90. The estimated diameter based on the average height of the personnel working in front of the missile is 2.41 m. The measurements on different parts of the missile are reflected in Table 25

Image 9 shows a missile on a launch pad. This is definitely a 2 stage rocket. It however has an L/D ratio of 9.64. Independent estimates of the diameter based on the height of personnel seen in the picture indicate a diameter of 2.74 m to 3 m which is on the higher side. In all probability this is a DF-5 image.

Image 10[46] shows a number of missiles on parade. Using methods very similar to those used for images 3 and 1 measurements of the different elements of the missile have been made on this image. We can see that the warhead part length seems to be very much on the higher side. Measurements were made on the first missile. The L/D ratio works out to be 11.31 and the length based on a diameter of 2.25 m is 25.45 m.

Image 11[47] is the same image as image 8 (mirror image of images 3, 5 and 7). No separate measurements were made on this image.

[42] Details seen could indicate that the missiles are being moved out of some kind of storage shelter on to the road.
[43] http://www.aeronautics.ru/archive/wmd/ballistic/ballistic/css3_003.jpg
[44] http://www.nti.org/db/china/df4.htm
[45] http://www.nti.org/db/china/df4.htm
[46] http://www.nti.org/db/china/df4.htm
[47] http://www.softwar.net/dongfeng.html

Image 12 is also the same image as image 8 and 11.[48] No separate measurements were made on this image.

Image 13 was another picture of the missiles seen in Image 10. Measurements were made on the middle missile. These are tabulated in Table 25.

Image 14[49] is the same as images 3.5 and 7 and has not been analysed separately.

Image 15[50] is an image which we have seen before in our analysis of the DF-2 missile (image 3 of the DF-2) where we had identified this image as not fitting into a DF-2 category. Estimated diameter (based on heights of people working around the missile) is 1.60 m which is close to the diameter of the DF-2 missile. It appears from this image that the Chinese had tried to develop a 2-stage vehicle based on the DF-2 / DF-1 technology that they had acquired from the Soviet Union. The estimate of the L/D ratio of this image (12.63) as compared to the FAS image we saw in our analysis of the DF-2 (L/D = 10.85) is quite different. The length of the missile based on a diameter of 1.65 m is 21.33 m.

Images 16 and 17 are the same as image 4 and have not been analysed separately.

Table 25
Measurements on the DF-4 Missile

Image	L/D Ratio	Length	Diameter estimate	Comments
Image 1	7.37	Not possible due to image	No independent estimate	Blow up of the lower stage and the engine. Correction for rotation in X–Z plane. As we go towards warhead lot of distortions.
Image 2				Shows the missile especially the warhead part inside a silo. Crude estimate of silo height. Warhead looks pretty advanced
Image 3	12.04	27.11 m	2.06-2.18 m	These are obtained after corrections for rotation in X–Z plane and the tilt of the Y axis.
Image 4				Only upper part of the missile can be seen. The warhead and the upper stage are seen clearly.

48 http://www.globalsecurity.org/wmd/world/china/images/DF-4-1.jpg
49 http://www.globalsecurity.org/wmd/world/china/images/df-4.jpg
50 http://www.globalsecurity.org/wmd/world/china/images/df-4_p6-1.jpg

Image	L/D Ratio	Length	Diameter estimate	Comments
Image 5	12.21	27.48 m	2.30–2.4 m	This is the same image as image 3. More details. Missiles seem to be taken from some kind of storage place.
Image 6	10.48	17.30 m	1.62-1.72 m	This is not a 2 stage missile but a single stage missile – may be DF-2 or DF-1. Most probably DF-1
Image 7				This is the same image as Image3,5
Image 8	10.90	24.53 m	2.41 m	Mirror image of images 3,5,7
Image 9	9.64	21.65 m	2.25 m (assumed)	Scale effects may make independent verification of diameter difficult. Is it a DF-4?
Image 10	11.31	24.45 m	No independent estimate	Warhead length measurement seems inaccurate. Though overall seems okay. ~24 troops seen in truck accompanying missile.
Image 11				Same as image 8 – mirror image of images 3, 5, 7. Not analysed
Image12				Same as images 8 and 11.
Image 13 Image 14	8.09	18.19 m		Same as image 10 measurements made are of the middle missile. Same as image 3,5,7. No independent measurements.
Image 15	12.92	21.32 m	1.60-1.70 m	2 stage 1.65 m DF-2 derived vehicle. Early experiments in China.?
Image 16				Same as Image 4. No separate analysis
Image 17				Same as image 4 and 16.

Table 7 in the main report tabulates the separate measurements we have made on different parts of the DF-4 missile.

Of all the images the best measure of the upper portions of the DF-4 are obtained from Image 4 even though here also we have had to make some corrections for various rotation effects. Images 3 and 5 are the same image provided in two different websites. As we had mentioned Image 5 shows a number of missiles coming out of an underground or hidden storage area. On the margin it is also a bigger image and shows more detail than Image 3. Image 8 is a mirror image of Images 3 and 5 possibly obtained by using some commercial software. Images 10 and 13 show a number of DF-4 missiles on parade. The orientation of these images is such that measurements are likely to be inaccurate. Image 1 is also distorted but its orientation is such that the engine and the fin portion measurements may be more accurate than what we get from Images 3 and 5.

We will use all the data to get some idea of the dimensions of the DF-4. There is not much doubt that its diameter is 2.25 m.

The best measurements of the warhead length are from Images 3, 5 and 7. The average of the 3 measurements of the warhead portion that we get from these 3 images is 6.07 m. This is the value we will assume as the best estimate of the warhead dimension.

Image 4 gives us an upper stage measurement value of 4.73 m. The average upper stage measurement from Images 3 and 5 is 5.08 m. According to one authoritative source[51] the Chinese wanted to increase the range of the DF-4 in order to attack targets in the erstwhile Soviet Union including Moscow. They did this by increasing the thrust of the 1st stage (a DF-3) to 104 tonnes and by lengthening the upper stage by about 0.42 m. The upper tank measurements seem to validate this.

The length of the 1st stage upper tank, the inter-tank length and the length of the lower tank can be obtained as an average from Images 3 and 5. These lengths are 5.32 m, 0.45 m and 6.50 m respectively.

The best estimate of the length of the engine + the fin + the interface with the tank of the 1st stage is obtained from Image 1. This works out to be 2.75 m.

If the upper stage tanks are only 4.73 m in length one measure of the overall length of the DF-4 missile would be 6.07+ 4.73 +1.31 + 5.32 + 0.45 + 6.5 + 2.75 = 27.13 m.

If the upper stage tank length is 5.08 m the overall length of the missile from the data is = 6.07 + 5.08 + 1.31 + 5.32 + 0.45 + 6.50 + 2.75 = 27.48 m.[52]

Using these dimensions which have been validated we can then estimate the amounts of propellants and oxidizer carried by the DF-4 and estimate its performance.

The DF-5 Missile

There are 15 images that are available in the public domain. These have been analysed.

Image 1 shows a parade image of the DF-5.[53] The warhead and the upper stage alone are seen with the upper stage being towed by the truck that is carrying the warhead. The warhead part is separately

[51] John Wilson Lewis & Hua Di, "China's Ballistic Missile Programme: Technologies, Strategies, Goals", International Security Vol. 17 (Autumn 1992), p17.

[52] This is not too far away from the length of 28 m reported in the published literature.

[53] http://www.sinodefence.com/missile/nuclear/df5_gallery1.asp

seen and the interface between the upper stage and the warhead is prominent. The image is rotated in the X–Z plane. Using the white markings on the tyres, corrections for the rotation have been estimated and the lengths have been corrected for this. Independent estimation of the diameter is not possible because there are no clear benchmarks in the picture. The warhead, the warhead upper stage interface and the upper stage length without the engine have been estimated after correction for the rotation in the X–Z plane. The warhead length works out to be 7.65 m, the warhead upper stage interface is 2.55 m and the upper stage length is 6.30 m. The truck height estimated on the diameter of the DF-5 being 3.35 m also works out to be 3.35 m. The wheel base ratio of the truck carrying the warhead and towing the upper stage works out to be 1:1.8:1.

Image 2 is a lift off image from the same site as image 1.[54] Measurements have been made on this image. No benchmarks are present to estimate diameter independently. The L/D ratio is 9.38. Various lengths have been estimated.

Image 3[55] is also from the sinodefence.com site. It shows the missile on its launch pad ready for liftoff. This is the same image as Image 11 in our DF-5 data set. The same image is also there in our DF-4 data set as Image 9. The analysis carried out on this image is shown under Image 11.

Image 4 is another parade image maybe of the same parade as Image 1. But unlike Image 1 it shows a large part of the lower stage also. This is being carried on a separate truck. Troops are seen accompanying both the warhead train[56] as well as the lower stage. There are a number of people standing in front which gives us a way of independently measuring the diameter. The diameter so estimated is between 3.12 and 3.31 m. Since the people are well in front it is likely that the benchmark underestimates the true diameter. The warhead length is 6.62 m, the warhead upper stage interface measures 2.22 m and the upper stage has a length of 6.13 m. The wheel base ratio of the truck is 1:1.8:1 which is the same as for image 1 and the lengths of the 3 wheel bases are also quite close. The height of the truck however works out to be only 2.82 m which appears to be quite different from that estimated for image 1 (3.35 m).This is possibly because the diameter estimation is not accurate in image 1.

Image 5 is a lift off image.[57] The L/D ratio is 9.5. No independent verification of the diameter is possible. Based on a diameter of 3.35 m the length of the missile works out to be 31.83 m. The lengths of the different elements of the missile have been estimated based on a diameter of 3.35 m and are tabulated in Table.

[54] http://www.sinodefence.com/missile/nuclear/df5_gallery3.asp

[55] http://www.sinodefence.com/missile/nuclear/df5_gallery2.asp

[56] http://www.sinodefence.com/missile/nuclear/df5_gallery4.asp

[57] http://www.sinodefence.com/missile/nuclear/df5_gallery5.asp

Image 6[58] is another parade image similar to images 1 and 4. All parts of the missile are seen just as in image 4 being carried in different trucks. Troops are also seen accompanying the warhead truck as well as the lower stage truck as in image 4. Rotation corrections and scale corrections have been carried out on this image also. Based on the height of a man close to the lower stage truck the diameter of the missile has been independently estimated as being between 3.26 and 3.45 m. Lengths of different parts of the missile have been estimated from the measurements. The lower stage especially the lower tank lengths may be underestimated due to the rotation of the image in the X–Z plane. The height of the truck carrying the lower stage as estimated from diameter measurements nearby appear to be close to 3.15 m.

Image 7[59] is another liftoff image. This is identical to Image 10 and we shall look at it when we look at Image 10.

Image 8[60] is a black and white picture of the warhead and upper stage being taken in a parade against a background of pictures of leaders. We have measured the lengths of different parts of the missile.. The wheel base ratio of the first truck is 1:2:1 which seems to be slightly different from the earlier ratios.[61] The truck height has been estimated at about 2.80 m.

Image 9[62] is the same image as image 6. We have not made separate measurements on it.

Image 10[63] is identical to image 7. The L/D ratio works out to be 9.15. Based on a diameter of 3.35 m this translates into a length of 30.66 m. Measurements made on different parts of the missile have been converted to lengths based on a diameter of 3.35 m.

Image 11[64] is the same as image 3. We have also seen this as Image 9 in our DF-4 data set. It is clear based on the independent estimates of the diameter (3.22 to 3.41 m) that this is certainly not the DF-4 but is the DF-5. The L/D ratio works out to be 9.31 m and the length of the missile is estimated as 31.19 m. Estimates of lengths of different parts of the missile are in Table.

Image 12[65] is the same as Image 8 and has not been separately analysed.

[58] http://www.nti.org/db/china/df5.htm

[59] http://www.nti.org/db/china/df5.htm

[60] http://www.softwar.net/dongfeng.htm

[61] There seems to have been some lengthening of the upper stage also and this may have needed a larger separation between the two sets of wheels

[62] http://www.globalsecurity.org/wmd/world/china/images/df-5.jpg

[63] http://www.globalsecurity.org/wmd/world/china/images/df-5-2.jpg

[64] http://www.globalsecurity.org/wmd/world/china/images/df-5-3.jpg

[65] http://nuclearweaponarchive.org/China/ChinaArsenal.html

Image 13[66] is another liftoff image similar to Image 7. The L/D ratio has increased to 9.88. The estimated length based on a diameter of 3.35 m is 33.09 m. This seems to be a longer missile. Estimated lengths of different parts of the missile are in Table.26

Image 14[67] is the same as Image 8 and has not been analysed separately.

Image 15[68] appears to be the CZ-2 space launcher. The L/D ratio is 9.16 and the estimated length based on a diameter of 3.35 m is 30.69 m. The warhead / payload part is 3.76 m. This is significantly shorter than that of the missile. Measurements converted into estimates of lengths for different parts of the launcher are in Table 26.

The Table below provides an over view of the major measurements made.

Table 26
Measurements on the DF-5 Missile

Image No	L/D ratio	Diameter	Length	Comments
Image 1		3.35 m (assumed)	N.A	Only warhead + upper stage
Image 2	9.375	3.35 m (assumed)	31.41 m	Launch image
Image 3	See image 10	N.A		Launch pad image. Same as Image 11.
Image 4	N.A	3.12 – 3.31 m	N.A	Many missiles on parade. Only warhead + upper stage seen
Image 5	9.5		31.82 m	Lift off Image
Image 6	N.A	3.26 – 3.45 m	N.A	Missiles in parade – all parts
Image 7	See Image 10	See Image 10	See Image 10	Identical to image 10. See image 10
Image 8	N.A	N.A	N.A	Only warhead + upper stage. Same as Image 12. Larger wheel base as compared to trucks in Images 1 and 4.
Image 9	See Image 6	See Image 6	See Image 6	Same as Image 6
Image 10	9.15	3.35 m (assumed)	30.65 m	Image same as Image 7.
Image 11	9.31	3.22 -3.41 m	31.19 m	Same as Image 3. Shown wrongly as DF-4 in DF-4 data set (image 9 of DF-4)
Image 12	N.A	N.A	N.A	Same as Image 8
Image 13	9.88	3.35 m (assumed)	33.09 m	Longer stretched version?
Image 14	N.A	N.A	N.A	Same or similar to images 8 and 12.
Image 15	9.16	3.35 m (assumed)	30.69 m	Long March CZ-2 space launcher. Warhead part shorter. Consistent with space requirements.

66 http://nuclearweaponarchive.org/China/Df5a.jpg
67 http://nuclearweaponarchive.org/China/DF5.JPG
68 http://nuclearweaponarchive.org/China/LongMarch150.jpg

Image 6, Image 4 and Image 1 appear to be the same missile on parade. Image 8 is also an image on parade. Image 12 is identical to image 8.

Warhead measurements on Image 6, Image 4 and Image 1 are 6.13 m, 6.62 m and 7.65 m respectively. Image 6 in view of the scale may also be the best image for getting an accurate measurement of the warhead.

The other parade image, Image 8 is also a good image and the scale is such that accurate measurements are possible. The warhead length from Image 8 is 6.15 m.

The best estimate of the warhead length taking into account the nature of the images would be the average of Image 6 and image 8 = 6.14 m.

Images 10 and 13 are liftoff images of good quality even though the scale is small. Image 10 shows a warhead length of 5.28 m and Image 13 a warhead length of 6.7 m. We would have to assume that these represent reasonably accurate measurements of warheads.

Images 2 and 5 are also liftoff images though the scale may make measurements inaccurate. The estimates of warhead length that we get from these are 5.65 m and 5.44 m. This is not inconsistent with the measurements we get from Image 10.

Image 3 and Image 11 are two other images from which we can get good measurements. Image 3 provides a warhead measurement of 5.28 m. This is consistent with image 10.

Image 11 gives a warhead length of 5.79 m which we will have to assume is accurate in the absence of any other data. This is substantiated somewhat weakly by the warhead length of 5.65 m that we get from Image 2.

We therefore get warhead lengths based on our analysis:
1st warhead length: ~ 5.27 m (Images 3 and 10 substantiated by Image 5)
2nd warhead length: ~5.79 m (Image 11 weakly substantiated by Image 2)
3rd warhead length: ~ 6.14 m (Image 4, 6 and 8)
4th warhead length: ~ 6.7 m (Image 13)

These may represent different types of thermo-nuclear weapons.[69]

[69] Unfortunately we have not had the time to look into this aspect in some more detail. Though measurements indicate 4 types of warheads one issue to raise and ask is whether there are really 4 types of warheads and would all of them need to be deployed in the DF-5.

Images 10 and 13 are liftoff images that show upper stage lengths of 7.71 and 7.75 m respectively. Image 5 (not a very good image) also has an upper stage length of 7.54 m. This would mean that the DF-5 has at least one upper stage with a length of between 7.71 and 7.75 m.

Images 8, 4 and 1 have upper tank lengths (without the interface that may house the engine) of 7.26 m, 6.13 m and 6.3 m. If we add the interface length of ~ 0.91 m to these tank lengths we get an approximate stage length of 8.17 m, 7.04 m and 7.21 m. This would mean that there are at least two variants of the upper stage one with a length of ~ 8.17 m and the other with a length of 7.12 m.

Image 15 is a picture of the CZ-2 space Launcher. It has an upper stage length of 8.31 m reasonably close to the 8.17 m that we see in image 8.

Images 3 and 11 provide additional data points – upper stage lengths of 6.7 m and 7.25 respectively.

Image 6 gives a stage length of 6.55 + 0.91 = 7.44 not to far away from the values we get from Images 4 and 1. Image 2 also gives us an upper stage length of 7.12 m.

We therefore get 4 upper stage lengths:

1st upper stage length:	6.70 m
2nd upper stage length:	7.23 m
3rd upper stage length:	7.73 m
4th upper stage length:	8.20 m

1st stage tank lengths measured from Images 2 and 13 are 13.61 and 13.62 m. respectively.

Image 10 and Image 5 have 1st stage tank lengths of 12.56 and 12.08 m. The Image 10 measurement is likely to be more accurate.

Image 11 and Image 3 measurements of the 1st stage tankage are likely to be reasonably accurate – 14.79 m and 15.23 m respectively.

Measurements of the 1st stage tank length of Image 15 – the space launcher is 14.6 m is reasonably close to that from Image 11.

We therefore see 4 variants of the 1st stage tank lengths:

Variant 1:	12.1 m length
Variant 2	13.6 m length

Variant 3	14.8 m length
Variant 4	15.23 m length

The best estimate for the engine + nozzle length from the data is 5.11 m.

Data on tank lengths and interface lengths for both stages are also there in the data base and can be used for assessing performance.

JL-1 / DF-21 Images

There are 22 images of the JL-1 / DF-21 that we could access from the public domain. Details of our analysis are provided below.

Image 1[70] shows a JL-1 missile being readied in the clean room. The warhead shape is clearly seen. A number of clean room personnel in their typical clean room attire can be seen at the back. The image is tilted appreciably in the X–Z plane. We did not make any measurements on the image because of this.

Image 2[71] shows the JL-1 being readied. The personnel handling the missile look like sailors. It is therefore likely that this is a JL-1. The warhead is clearly seen. The warhead appears to be different from the warhead seen in image 1. Using the height of the personnel as a benchmark we can get an idea of the length of the warhead. The length of the warhead is 3.6 m.

Image 3[72] shows a JL-1 warhead along with its other stages being assembled in a clean room. A group of personnel are seated between the rocket stage and the warhead part. The missile appears to be the same missile that we see in image 1. However the warhead portion we see appears to be another view. We did not make any length measurements because of the rotation of the image in the X–Z plane.

Image 4[73] shows the JL-1 being lifted by cranes and being loaded on to what appears to be a submarine. We did not carry out any measurements on this image.

Image 5 shows a picture of the JL-1 being launched from under water.[74] The warhead nosecone and the water turbulence can be seen. Image 6[75] is a continuation of Image 5. It shows the missile coming out of water, the beginning of ignition followed by attitude acquisition and correction. The sequence of Images 5 and 6 show Chinese mastery of the technology related to the most difficult part of a missile launch from a submarine.

[70] http://www.sinodefence.com/missile/nuclear/jl11.asp

[71] http://www.sinodefence.com/missile/nuclear/jl12.asp

[72] http://www.sinodefence.com/missile/nuclear/jl14.asp

[73] http://www.sinodefence.com/missile/nuclear/jl13.asp

[74] http://www.sinodefence.com/missile/nuclear/jl15.asp

[75] http://www.sinodefence.com/missile/nuclear/jl16.asp

Image 7 shows another picture of the JL-1 or the DF-21[76] immediately after launch. It is difficult to find out whether the launch is from water or from land. We did not make any measurements on this image.

Image 8[77] shows a DF-21 on a trailer. The image is tilted in the X–Z plane. Though we could see some wheels they are only partially seen. We did try to make some measurements and also corrected for the tilt in the X–Z plane. However the data is likely to be inaccurate especially towards the tail-end of the missile. We have not used these measurements because of these reasons.

Image 9[78] is a very good image for analysis. Though there is no way of independently validating the diameter of the JL-1 / DF-21 from this image we can build up a good benchmark for using in other images based on the assumption that the diameter is 1.4 m. This image gives us good measurements for all parts of the JL-1 / DF-21 missile.

Image 10 is similar to Image 7. It shows the launch of a JL-1 / DF-21 missile. We did not make any measurements on this image.

Image 11 is the same image as Image 8 but from a different source.[79] We did not make any measurements on this image.

Image 12[80] is another larger variant of what we see in Image 1 and Image 3. The JL-1 warhead with its other stages is being assembled in a clean room. We did not make measurements on this image but have used it to validate some of our analysis on warheads.

Image 13 is an image of the DF-21 being carried on a trailer.[81] The image is tilted and the wheels are only partly visible. We did not make any measurements on this image.

Image 14 is a parade image.[82] There are 24 personnel in the vehicle in front of the missile. They look like sailors. So the missile that is shown in the parade is possibly the JL-1. This image gave us good measurements for all elements of the missile. Independent verification of the diameter gave a diameter value of 1.43 m. This is close to the public domain value of 1.4 m. The length of the missile is estimated as 11.9 m. It has a warhead length of 5.13 m which is longer than the other warheads we see for the JL-1 / DF-21.

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76 http://www.nti.org/db/china/jl1.htm
77 http://www.nti.org/db/china/jl1.htm
78 http://www.softwar.net/dongfeng.html
79 http://www.softwar.net/dongfeng.html
80 http://www.globalsecurity.org/wmd/world/china/images/jl-1-5.jpg
81 http://www.globalsecurity.org/wmd/world/china/images/jl-1-1.jpg
82 http://www.globalsecurity.org/wmd/world/china/images/84parade1.jpg

Image 15 shows a stage motor with 4 nozzles being lifted by a crane.[83] A man is standing in front not too far away from the missile. This enables us to independently verify the diameter. Our estimate of the diameter is 1.06 m. This is significantly different from the diameter quoted in the literature. This is neither the 1st nor the 2nd stage of the JL-1 both of which have diameters of 1.4 m. It could be a new upper stage for another SLBM the JL-2.

Image 16[84] and Image 17[85] are flight images of the JL-1 / DF-21 similar to images 7 and 10. We did not make any measurements on these images.

Image 18 shows the DF-21 being taken on its trailer.[86] It is a good image for measurements. Our estimate of the length of the missile is 9.17 m. The warhead is only 2.3 m long. We could also get reasonably accurate measurements of the other parts of the missile.

Image 19[87] is the same picture as Image 9. We did not make any measurements on this.

Image 20[88] is similar to images 7, 10, 16 and 17. We did not make any measurements on this image.

Image 21 is a parade image.[89] It is a good image for making measurements. Using benchmarks derived from other images we have validated the diameter as 1.4 to 1.44 m. Our estimate of the length of this missile is 10.29 m.

Image 22 shows another JL-1 / DF-21 on its trailer. A number of people are working on it. The missile orientation is such that measurements on the upper part of the missile are likely to more accurate. Wheel diameters and wheel bases can be used to get some measurements. Corrections for the tilt of the image in the X–Z plane can also be made. We get a length close to 10 m.

A summary of the best measurements for the various elements of the JL-1 / DF-21 have been provided in Table 13 of the main report. We believe that there are 4 versions of the missile with lengths of 12.1 m, 10.7 m, 10.2 m and 9.3 m respectively. The differences in length are due mainly to different warhead lengths.

83 http://www.globalsecurity.org/wmd/world/china/images/jl-1-7.jpg. This image is also reproduced in the Lewis and Litai book, “China’s Strategic Sea Power – The Politics of Force Modernization in the Nuclear Age”, Image 30. The caption claims that this is a 1.4 m diameter rocket motor.

84 http://www.globalsecurity.org/wmd/world/china/images/jl-1-3.jpg

85 http://www.globalsecurity.org/wmd/world/china/images/jl-1.jpg

86 http://www.globalsecurity.org/wmd/world/china/images/jl-1-b.jpg

87 http://nuclearweaponarchive.org/China/Jl1.jpg

88 http://nuclearweaponarchive.org/China/JL1p15.jpg

89 http://nuclearweaponarchive.org/China/DF21.JPG

Canister based DF-21 Images

15 canister based DF-21 images were collected and included in our data set. We analysed 5 of these images.

Image 1[90] is a good image for making measurements. There are 3 people standing in the image. We can use them as a basis to get an estimate of the vertical tyre diameter. Though the image is tilted in the X–Z plane measurements on the horizontal tyre diameter helps us to get an estimate of the rotation angle and correct for it. The Y axis is also slightly tilted and we can correct for this also. Our estimate of the canister diameter is 1.7 m. The total wheel base as well as the individual wheel bases (there are 5 of them) have also been estimated. The total wheel base is 10.34 m. The length of the canister is 12.1 m.

Image 2[91] shows the DF-21 being launched from its canister. Knowing the diameter of the DF-21 as 1.4 m the canister diameter is estimated as 1.7 m. This matches well with the value of the canister diameter obtained from Image 1.

Image 3[92] shows a DF-21 canister being erected for launch. While we did make measurements on this image scale effects is likely to introduce errors in our estimation.

Image 4[93] is a parade image which shows 3 DF-31 TELs moving together. The length of the canister using the wheel base as a benchmark gives an estimated length of the canister as 10.03 m. This is lower than the estimate for the canister length of 12.1 m that we got from Image 1.

Image 5[94] shows a number of DF-21 missiles being carried inside canisters. The canister length based on the total wheel base length is 10.11 m.

We can conclude from this analysis that the diameter of the canister is 1.7 m. There are two lengths of the canister, 12.1 m and 10.1 m respectively.

JL-2 / DF-31 Images

We looked at a few of the 24 images of the JL-2 / D-31 that we had collected. We tried to estimate independently the length and the diameter of the canister using benchmarks available in some images

[90] http://www.sinodefence.com/missile/nuclear/df214.asp
[91] http://www.globalsecurity.org/wmd/world/china/images/df-21_launcher.jpg
[92] http://www.globalsecurity.org/wmd/world/china/images/DF-21-1.jpg
[93] http://www.globalsecurity.org/wmd/world/china/images/DF-21-4.jpg
[94] http://www.globalsecurity.org/wmd/world/china/images/a199910114.jpg

and extending it to other images in which there were no benchmarks. We were independently able to get some idea of the length of the various wheel bases the diameter of the tyres.[95]

Image 1[96] is a parade image. 3 DF-31 missiles are in the parade. Two jeeps are there in front with personnel on them. Military personnel are also standing at some distance behind the parade. The first wheel base measurements for the 2nd and 3rd TEL have been independently estimated using the height of the personnel standing on the jeeps. We also estimated the diameter of the canister. The canister diameter is estimated as 2.19 m. The estimate of the first wheel base is estimated as 1.25 m. The diameter of the tyres has been estimated as between 0.86 and 0.92 m. The length of the canister cannot be estimated.

The second image[97] shows two DF-31 missiles (Y005 and Y004). A man is also standing on the pavement behind the rear of the missile. The length of the Y005 was measured. The various wheel bases were measured in turn from the left. Using the wheel base values obtained from Image 1 we estimated all the 7 wheel bases seen in the image. We also estimated the canister diameters using the tyre diameter obtained from Image 1 as a benchmark. The length of the canister is 13.43 m. The canister diameter is between 2.01 and 2.16 m. The diameter of the carrier is ~ 1 m. The total wheel base (centre of the first tyre to the centre of the last tyre) is estimated to be 13.14 m

Image 3[98] is another parade image. The first missile on its TEL has the number Y003. We measured the length of the canister. Using the various values of the wheel base measurements that we got from image 2 we got a length of the canister of 12.30 m. The total wheel base estimate that we got for this image was 13.22 m. This appears to be a different configuration of the DF-31 as compared to Image 2.

Image 4[99] is another image of the DF-31 mounted on its TEL. The image is rotated in the X–Z plane. The length of the canister using the total wheelbase as a benchmark was estimated to be 12.64 m. However the image is such that there may be some inaccuracies in the measurement of the length.

The total wheel base length was used as a yardstick to get some idea on the length of the canister. Of the 3 images on which this was possible one image had a canister length that was longer than the total wheel base length. In the other two images the length of the canister was shorter than the wheel base. This would seem to suggest that there are at least two versions of the DF-31.[100] One version has a canister length of about 13.4 m and the other a length of 12.3 m. Are these the DF-31A and the JL-2 / DF-31?

The canister diameter in all the 4 images we analysed was in the range of 2 to 2.2 m – closer to 2.2 m.

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95 The diameter of the tyre of the truck is smaller than that of the tow trailer. The wheel base lengths for the truck and the trailer are different. There are reports that the TELs have also been modified with some help from Belarus.

96 http://www.globalsecurity.org/wmd/world/china/images/a19991010.jpg

97 http://www.sinodefence.com/missile/nuclear/df311.asp

98 http://www.globalsecurity.org/wmd/world/china/images/DF-31-3.jpg

99 http://www.sinodefence.com/missile/nuclear/df312.asp

100 This would assume that the TEL wheel base dimensions would be the same.

DF-15 / M9 Images

There are 5 images of the DF-15 missile that we analysed.

Images 9, 10, 11 and 12 are of the Chinese M9 missile. Images 10 and 12 are images of the launch of the missile from a mobile MAZ 543 derived TEL. Images 9 and 11 are pictures of the M9 being carried on a Chinese built TEL.

Images 9, 10 and 12 have lengths ranging from 8.4 to 8.9 m. These differences are due to differing warheads (conventional warhead and a nuclear warhead) with some differences in rocket motor dimensions too. Image 11 has a length that is greater by nearly 1 m – 9.69 m. This could be a stretched version of the M9 with a more advanced nuclear payload.[101]

Images 10 and 12 are carried on a MAZ 543 derived TEL. The diameter measurements based on a tyre diameter of 1.5 m gives a missile diameter very close to 1 m.[102]

Images 9 and 11 do not use the MAZ TEL but another version of the TEL which seems to have a shorter wheel base and a smaller diameter tyre. A wheel base of about 1.35 m and a tyre diameter of about 1.05 m would be compatible with a 1 m diameter M9 missile.[103] Though there are references in the literature to the German origins of the TEL or to the TEL being based on a Mercedes Benz or Iveco technology[104], the Chinese TELs seem to be different. Their version resembles the MAZ 543 in outward shape with the dimensions being different. The TELs on which later M9 missiles are carried is also a Chinese made TEL.[105] Image 13 is a launch image that gave us good measurements. It matches the measurements we get from Image 9.

The summary of these measurements are already tabulated in Table 14 of the main report.

DF-11 / M11 Images

Four images of the M11 being carried on their TEL are available. This makes it easy to estimate the dimensions of the missile. Depending upon the image various parts of the MAZ 543 TEL have been used for calibration. While length measurements were possible for all the M11 images, an independent measure of the diameter could be made in only one of the images. Warhead lengths could be measured

[101] The D15 A is supposed to have a more advanced and more accurate nuclear warhead. See http://www.softwar.net/df15.html. Also see http://www.sinodefence.com/nuclear/df15.asp for the sources of the images.

[102] Values obtained using the tyre diameter for Image 10 and the width of the TEL for image 12 were 1.03 and 1.07 m. If wheel base measurements were used these values changed somewhat. These would change depending on where the standard is located and where on the image the measurement is made.

[103] If we assume a diameter of 1 m we can work out the other measurements.

[104] http://www.aeronautics.ru/archive/wmd/ballistic/ballistic/css6-01.htm

[105] The Taian 5380 heavy duty vehicle is the base for the M9 TELs. For some details see http://www.sinodefence.com/army/transport/tas5380.asp. There is also known transfer of MAZ 543 TEL technology from Ukraine to the Chinese.

in three of the images since the fins were visible. In one case there were no fins visible to separate out the warhead portion. Details of M11 measurements are provided in Table 27.

Table 27
DF-11 Measurements

Image	**Length**	**Diameter**	**L /D ratio**	**Warhead length**	**Remarks**
M 11 image 1	11.34 m	N.A	N.A	N.A	No warhead fins seen
M 11 image 2	**9.56 m**	N.A	N.A	**3.81 m**	Warhead fins seen. Can be measured.
M 11 image 3	10.64 m	N.A	N.A	4.09 m	Warhead fins seen
M 11 image 4	10.96 m	**0.89 m estimate**	12.31	4.80 m	Warhead fins can be seen.

The independent measurements of the diameter from the 4th image of the M11 indicate a diameter of 0.89 m. The other images were not suitable for making an independent measurement of the diameter. The diameter of the M11 quoted in the public domain is consistent with our analysis. The available evidence from the images of the M11 seems to indicate that there are 3 warheads – 3.81 m, 4.09m and 4.80m. There are also 3 incremental versions of the Chinese M 11 rocket motor with lengths of 5.76m, 6.17m and 6.54 m.

Appendix - II: An Assessment of the True Capabilities of the DF-31

The JL-2 / DF-31 Missile

China has been developing a long range missile called the JL-2 which has MIRV capability and can be launched from a large nuclear powered submarine under development by China. According to published reports this missile will have a range of about 8000 km and will carry 3 MIRV. Its land based version called the DF-31 will be road mobile and much more difficult to target. The reports also state that that a longer range missile variously termed the DF-41 or the DF-31A carrying a single warhead capable of reaching the continental United States is under development.

Since the publicly available images of the JL-2 / DF-31 missiles are stored inside canisters it is difficult to make measurements for assessing their performance. This exercise is an attempt to look inside the canister to find out what the Chinese may have done.

Measurements & Constraints

The measurements we made on the canisters housing the DF-31 missiles indicate that the diameter of the canisters is about 2.16 m. The diameter of the JL-2 / DF-31 missiles carried inside the canisters would therefore be about 2 m. This is consistent with other sources that indicate that the diameter of the JL-2 missile is about 2 to 2.25 m.

We get two different measurements for the canister length from the analysis of the images. One measurement we get is a canister length of 13.4 m. The other length we get for the canister is 12.3 m. One could speculate that these two lengths and the diameter are related to the lengths and diameter of the two advanced missile systems reported to be under development – the DF-31 / JL-2 and the DF-31A.

Since the JL-2 missile has to be accommodated inside a submarine the overall length of the missile has to be kept down. For the ranges reported - 8000 km for a MIRV system and over 10000 km for a single warhead system – it is quite evident that the missile will have 3 stages which are to be accommodated within the length. This would be the challenge facing the Chinese designers.

Possible Configurations

The question before us is given the constraints mentioned what configurations of the JL-2 provide the Chinese designers with the required performance? We believe that we can put together some logically consistent configurations that would give us a reasonable idea of the various technology choices and the likely performance of the JL-2 / DF-31 missile.

The Trident 2 missile[106] is an advanced SLBM developed by the US that entered service on a new advanced Trident submarine in 1990. Its dimensions -13.4 m length and 2.11 m diameter - are very similar to the dimensions of the JL-2 / DF-31. Though there is not much information available on the Trident there is some information that could give us a few leads on how the Chinese may have dealt with the design constraints that they faced.

We believe that a critical element that would affect the performance of the overall missile would be how the upper stage and the Post Boost Control Vehicle (PBCV) with MIRV can be accommodated within the length and diameter constraints. One approach would be a PBCV carried on top of the 3rd stage. The other approach would be to carry most of the requirements of the PBCV around the 3rd stage as is done in the case of the Trident.

If the JL-2 has to be an MIRV and the total diameter available is 2 m it is logical to mount the individual re-entry vehicles around the 3rd stage motor. To accommodate these within the 2 m diameter envelope, the diameter of the 3rd stage rocket motor has to be limited to 1 to 1.2 m. This would leave an annular ring of around 0.8 m to accommodate the 3 MIRV vehicles. This is similar to the design adopted in the Trident and probably, the Chinese have followed this design to accommodate their MIRV within the diameter envelope of 2 m. These 2 possible configurations of the upper stage and the Post Boost Vehicle are shown in Figure 1

From the configuration of the proven JL-1 booster, it is evident that the Chinese have successfully designed 4 nozzle configuration solid rocket motors. They have also adopted submerged nozzle designs in the solid rockets used in the launch vehicle upper stages. Submergence of the order of 20 to 39% is reported for the space motors.[107] The Chinese designers would have adopted either of these measures to obtain the required nozzle expansion ratio within the length constraints. Single nozzle configurations are relatively easy to realize from a technical point of view. However they have the disadvantage that they require increased nozzle length to get the desired expansion ratios and higher specific impulse. Our assessment indicates that for an upper stage diameter of 1 m and a length of around 1 m, a submerged/multi nozzle configuration could be evolved. Such a nozzle will have expansion ratio ranging from 36-50 and the nozzle divergent length could be contained in 0.5 m. If the length of the 3rd stage motor were to be increased beyond the assumed 1 m the reduction of the nozzle lengths becomes an even more important requirement. The easiest way to take care of this constraint may be the use of multiple (4) nozzle configurations for the 3rd stage.

The Post Boost Control Vehicle (PBCV) also requires some propulsion to provide the cut-off delta V and to make the necessary inclination corrections. The PBCV must carry enough propellant for providing an additional velocity from about 700 metres to 1000 metres per second.[108] It must also have an independent

[106] http://www.fas.org/nuke/guide/usa/slbm/d-5.htm

[107] The development of space solid rocket motors in China - Huang J; Ye D, Acta Astronautica, Volume 40 Number 2 January 1997

[108] Preliminary estimates are that this would be the additional velocity needed to provide an inclination change of about 5 degrees. Ideally to cover the continental USA maybe a much larger inclination change may be needed.

attitude control system. To reduce the propellant loading and increase its capabilities the 3rd stage motor may have to be jettisoned prior to the post boost phase. The design must be able to take care of all these requirements

The DF-31 upper stage sizing

Based on the Trident data, the available envelop for the third stage motor of the JL-2 is about 1 m diameter and a length (including the nozzle) of 3.28 m. The motor should be housed in the fairing and should allow the accommodation of the PBCV and the MIRV. Possible layouts are shown in figure 1.

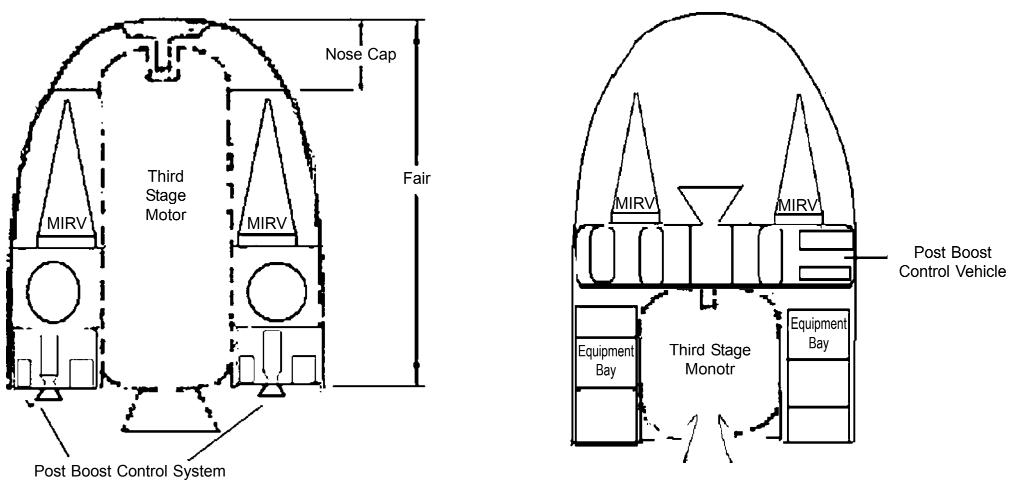

Figure 1

As pointed out the smaller the diameter of the 3rd stage the greater is the volume and space available for the MIRV carrying PBCV. From performance charts, a nozzle expansion ratio of 36 providing a thrust coefficient of 1.75 and a specific impulse of 287 seconds should be possible.

Sizing the 2nd and 1st stages

Assuming that the length and the diameter of the upper stage would be similar to that of the Trident we can then go on to size the 1st and second stages.

The canister length of 13.4 m should also accommodate the ejection system for cold ejection of the missile from the canister. Our assessment is that this would take away about 0.7 m from the available length of 13.4 m. In addition allowances for the inter-stages have to be provided. In the advanced version of the Trident (Trident D5), the inter-stage between the 2nd and 3rd stage is eliminated and equipment section is managed within the nose fairing. The Trident has an interstage between the 1st and 2nd stages to house the second stage control system, separation system and the ignition system. The Chinese could also follow such an approach. Based on our measurements of the JL-1 the best estimate of the inter-stage length would be about 0.25 m.

Taking away these lengths (0.7 m for the ejection system, 0.25 m for one inter-stage and about 3.28 m for the upper stage) we have a length of 9.17 m available for accommodating the 1st and 2nd stages of the JL-2. This of course assumes that the length of 3.28 m and ~ 1 m diameter of the 3rd stage provides enough volume to accommodate all the elements of the PBCV.

Building upon the above logic we tried to size the 2nd and 1st stages of the JL-2 / DF-31 missile. The ratio of the lengths of the two stages of the JL-1 missile from our image analysis is ~ 1:3. For the Trident it is 7:18. Using the Trident as a basis we went on to size the overall length of the first and second stages. Taking into account the nozzle lengths required (0.5 m for the second stage and 0.7 m for the first stage) we then estimated the required propellant and stage masses. For different payload weights we also looked at the range. Since the diameter of the upper stage is also important we looked at the performance of the missile for upper stage diameters ranging from 0.8 to 1.2 metres. The results of these configuration studies are presented in the table 28.

Table 28
JL2/DF31 Configuration Study Results

3rd stage diameter, Length for submerged[109] configuration	Range in kilometres			
	Payload 1800 kg	Payload 1500 kg	Payload 1350 kg	Payload 1200 kg
Configuration 3.28, 0.8	5280.00	6302.00	7000.00	8133
Configuration 3.28, 0.9	5461	6528	7257	8206
Configuration 3.28, 1	5622	6721	7470	8262
Configuration 3.28, 1.1	5763	6880	7640	8303
Configuration 3.28, 1.2	5883	7000	7768	8741

The Trident has a range of approximately 7800 km with a complement of 8 warheads with a total mass of 2800 kg. As we can see from the above table more than any changes in the diameter of the 3rd stage it is the reduction in payload weight that matters most. It is only with a payload of about 1200 to 1350 kg that the range of ~ 8000 km can be realized for the JL-2.

We can see from the above configuration studies that a multiple nozzle submerged upper stage of ~3.2 m in length with a diameter of 1 to 1.1 m along with a 2m diameter second stage of length ~ 2.58 m and a first stage of 2 m diameter and length of 6.6 m can match the range of the Trident if the 3 MIRV total payload is between 1200 and 1350 kg.

[109] The first number refers to the length of the upper stage and the second to the diameter. Configuration 3.28 , 1.2 would mean the configuration with an upper stage length of 3.28 m and a diameter of 1.2 m.

Is a tandem configuration possible?

We carried out another exercise for a configuration in which the post boost vehicle is carried on top of the 3rd stage. The results are in the Table 29.

Table 29
Alternate Configuration Study

3rd stage diameter, Length for tandem[110]Configuration	Range in kilometres		
	Payload 1500 kg	Payload 1350 kg	Payload 1200 kg
Configuration 3.28, 0.8	5443	6032	6780
Configuration 3.28, 0.9	5622	6231	7004
Configuration 3.28, 1	5777	6398	7184
Configuration 3.28, 1.1	5908	6534	7322
Configuration 3.28, 1.2	6016	6640	7423

The tandem configuration performance may not be adequate given the uncertainties in development. The submerged / multiple nozzles configuration, similar to the one shown in figure 1 is the more likely configuration. The Chinese may have no choice but to follow the Trident example.

Demands Imposed by the Post-Boost Control Vehicle

This 1200 to 1350 kg PBCV should accommodate the following*:*

- Three separate thermonuclear warheads packaged as re-entry vehicles with some limited maneouvring and terminal guidance capabilities. These will have to be ejected from the post-boost vehicle with suitable ejection mechanisms. The dimensions we can get from our analysis is that this package should not be more than 0.4 m diameter and about 2 metres in height.

- The propulsion unit for the Post Boost Control Vehicle must be contained in an annular portion between the 3rd stage motor and the diameter of 2 m. We think that this would best be provided by a bipropellant liquid rocket system. The thrust chamber and nozzle could be located above the 3rd stage with the nozzle facing downwards or upwards. A two engine configuration is also possible.

- The PBCV would have a pressure fed engine. Space for the fuel, oxidizer and gas bottles is needed. The configuration provides enough space to accommodate all of them.

[110] The first number refers to the length of the upper stage and the second to the diameter. Configuration 3.28 , 1.2 would mean the configuration with an upper stage length of 3.28 m and a diameter of 1.2 m.

- The operation of the post boost vehicle in this configuration would require the ejection of the 3rd stage rocket motor. This will also reduce the demands on the propulsion requirements from the Post Boost Control Vehicle.

- The nosecone should be opened up and maybe jettisoned after the burnout of the 3rd stage.

- The Post Boost Control Vehicle should be able to change the orbit in order to be able to eject the different re-entry vehicles at different points. Both in-plane and out –of plane corrections may be required.

- The fuel and the rocket motor to do this would take up some weight and volume. The annular space which accommodates the re-entry vehicles can accommodate some of these elements. The design of these elements and packaging within the available volume can be managed by suitable miniaturization and integration techniques.

- About 250 kg of fuel and oxidizer could be accommodated in two tanks of 1m length and 0.4 m diameter. Assuming another 50 kg weight for the gas bottles the total weight of the propulsion system would approach 350 kg. Assuming another 50 kg for the rest of the systems about 950 kg would be left for the 3 nuclear warheads.

While these may be easy to conceptualise, accommodating all these requirements within the space and weight constraints is a big challenge. The miniaturization of the warheads may still be the major issue.

The single warhead configuration

The table below provides the results of our analysis. In the case of a single warhead configuration the length is not such a big constraint. The missile may also carry bigger megaton warheads. There is no major post boost requirement and the technology challenges of integration into a limited space are much simpler.

A number of configuration options are available. An upper stage diameter of 1.1 m with a length of even 1.5 m is adequate to be able to give the missile the desired range.

A 700 kg warhead in a silo or TEL platform or a submarine can reach the continental United States quite comfortably. A heavier megatonne warhead may also be launched from a submarine suitably positioned at a considerable distance away from the continental United States.

The smaller canister length of 12.3 m may be the missile that provides inter-continental capability. This could be the DF-31A that is reported in the literature. As we can see from the table 30 there are many configurations that provide a range of 12000 to 14000 km.

Table 30

DF 31 A Configuration Studies

3rd Stage diameter, Length for single warhead Configuration[111]	Range in kilometres			
	Payload 700 kg	Payload 800 kg	Payload 900 kg	Payload 1000kg
Configuration 1.5, 0.8	10684	9216	8167	7367
Configuration, 1.5, 0.9	11402	9736	8572	7697
Configuration 1.5, 1	12091	10228	8957	8010
Configuration, 1.5, 1.1	12732	10681	9311	8303
Configuration 1.5, 1.2	13308	11086	9632	8570
Configuration 1.5, 1.3,	13804	11436	9912	8806
Configuration 1.5, 1.4	14209	11726	10150	9012

Both these versions can be launched from a submarine. Though the Chinese claim that the focus of the JL-2 / DF-31 has shifted towards mobile basing on land it is clear from a strategic angle that once the Chinese can put an MIRV and a single warhead on a nuclear powered submarine they would have closely matched the US capabilities. Clearly this should be the major focus of their efforts under the modernization plan.

Other Issues

- A four nozzle configuration is essential for containing the nozzle length and achieving a reasonable expansion ratio.
- Contouring of the nozzle and submergence will bring down the nozzle length.
- It is also necessary that the rocket motors for the three stages employ state-of-the-art motors. All of them including the upper stage may be 4 nozzle configurations.
- The propellant fractions in these rocket motors need to be of the order of 90 to 92%. This also would involve significant technology and development challenges. The Chinese by now have possibly solved most of these challenges.

It is our view that the Chinese are almost there. When the JL-2 / DF-31 become operational, the Chinese may be able to launch a MIRV from a submarine with a range of about 8000 km. While they may be able to launch only 3 MIRV compared to the 8 MIRV from a US Trident missile it is still a substantial capability. It would possibly put China almost on par with the US when this happens. We think this may happen soon.

With a one megatonne warhead launched from a submarine they would be able to reach any part of the world.

[111] The first number refers to the length of the upper stage and the second to the diameter of the upper stage

The missile configuration is schematically shown in figure 2.

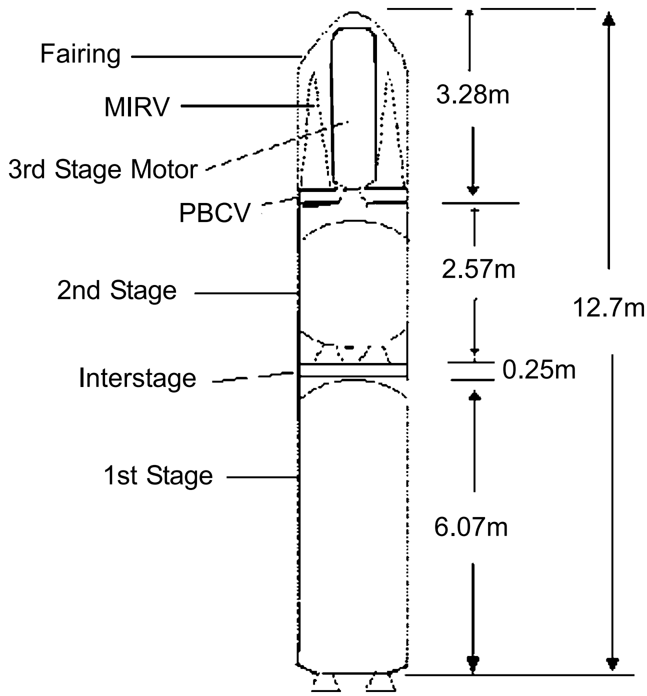

Figure 2

Appendix - III: Range Calculation for Cruise Missiles

Cruise missile operations are similar to an aircraft and as such the design and performance procedures can be applied to them. The aircraft operations include take-off, climb, cruise, loiter, descend and land. In addition fighter and bomber aircraft expend elements of their payload in flight. Cruise missile missions are simpler and one has to account only for the cruise part of the flight. The take-off and initial climb is usually provided for long range missiles by a solid rocket booster and the resulting performance can be separately calculated. The descent phase is there and some missiles like the advanced versions of Tomahawk also have a loiter capacity. The mission profile is indicated in figure 1.

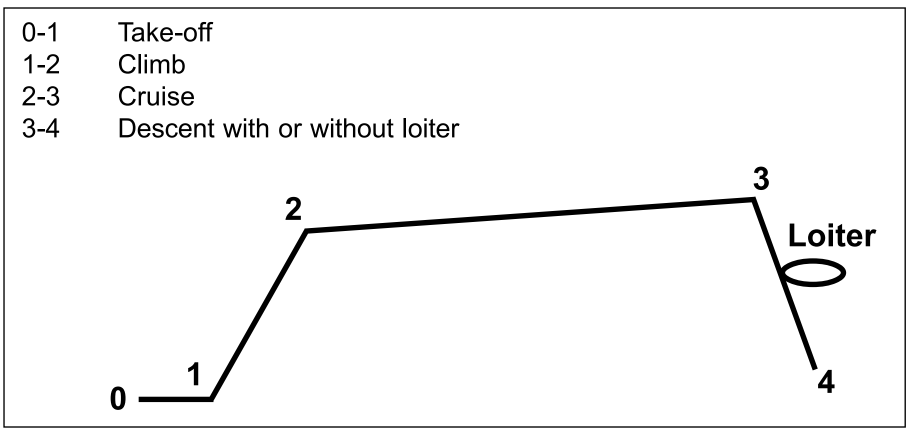

Figure 1: Typical Cruise Missile Mission

The major components of a cruise missile will consist of the structure, engine, fuel tanks, payload and avionics. The fuel may be distributed in more than one tank to manage the centre of gravity location of the aircraft. To obtain the performance of the aircraft, we need to have the projected outline of the aircraft, its wing area and planform, the overall area and the lift and drag characteristics. For jet engines, the specific fuel consumption—defined as fuel mass flow required per hour to produce unit thrust force –is required to determine the range of the aircraft. For a first cut estimation of aircraft sizing a simple procedure using historical data of similar operational aircraft can be used and the end results are within reasonable limits of detailed design exercises. For example, this methodology yielded a total weight of Tomahawk as 1360 kg against the reported weight of 1315 kg.

Figure 2 depicts the schematic as well as detailed view of the Tomahawk cruise missile. It is safe to assume that all the long range cruise missiles will have similar features.

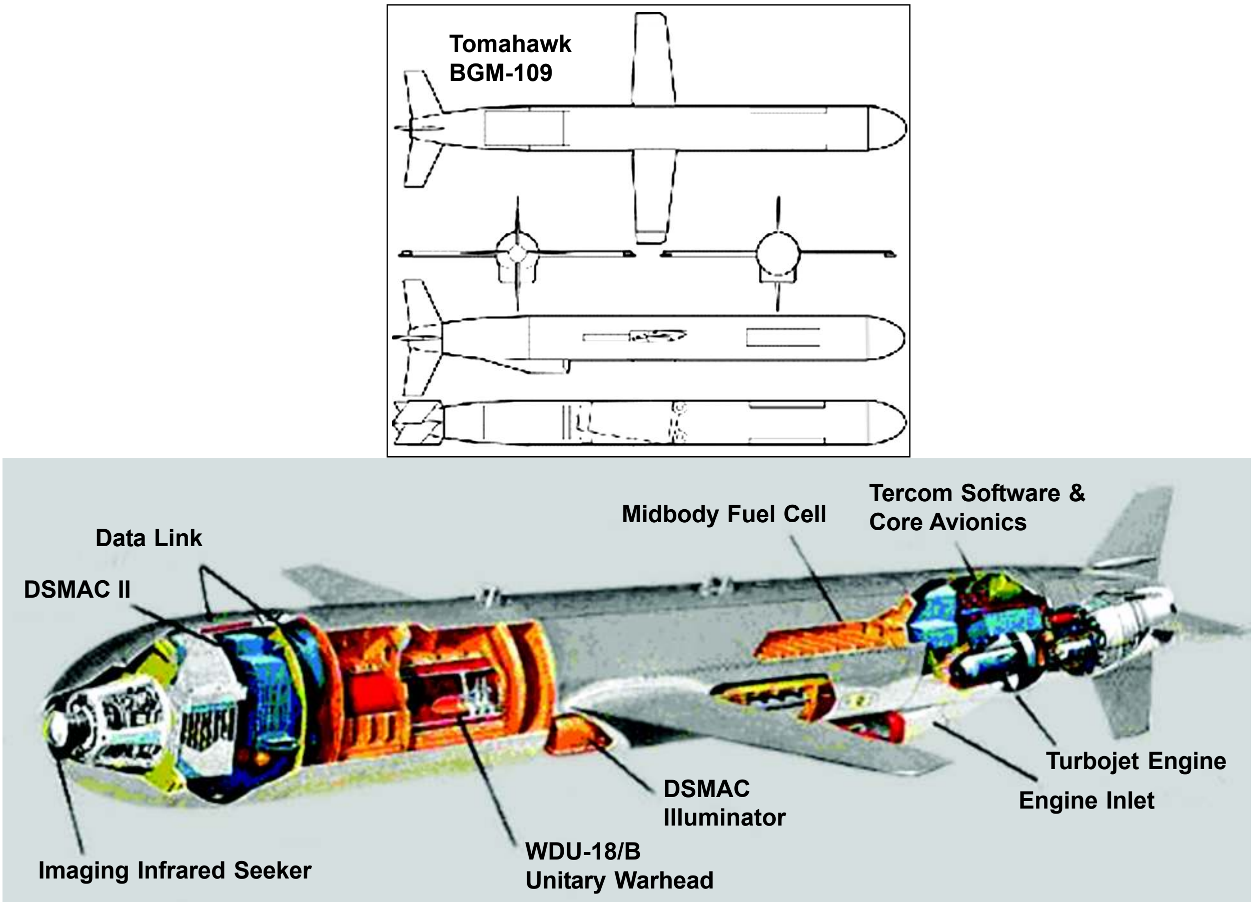

Figure 2: Tomahawk Cruise Missile[112]

The range and payload performance of the missile will depend largely upon the powerplant used, the amount of fuel carried, the structural weight and the aerodynamics of the missile.

Sizing Methodology[113]

The total weight W_0 of the missile is made up of the empty weight, W_e plus fuel weight, W_f and the payload weight, W_{pl}. ie.,

$$W_0 = W_e + W_f + W_{pl}$$

$$W_0 = Wpl / \{1 - (W_f / W_0) - (W_e / W_0)\}$$

The empty weight fraction can be estimated from known historical trends and varies between 0.3 – 0.7, reducing with total aircraft weight. The bulk of the fuel is used for the mission. In addition to this, one

[112] http://www.fas.org/man/dod-101/sys/smart/bgm-109.htm

[113] Daniel P. Raymer, "Aircraft Design: A Conceptual Approach" AIAA Education Series Publication

has to account for a small fraction of the fuel that may be trapped in the tanks and pipelines. The aircraft operation time or endurance and the specific fuel consumption dictate the fuel requirements. As the fuel is consumed, the aircraft weight reduces, which in turn affects the drag; consequently, the fuel used is a function of the aircraft weight. For various categories of aircraft, Raymer has worked out the trend if empty weight fraction can be represented by the equation:

$$\mathbf{W_e / W_0 = A\, W_0^{c}\, K_{vs}}$$

From examination of the various aircraft data provided by the author, the characteristics of a long range cruise missile are comparable to that of a military cargo/bomber aircraft and for this category, Raymer has indicated the value of

A = 0.88 (in metric units)
c = -0.07
K = 1.00 (for fixed sweep)

In addition, one needs to know the following terms for estimating the aircraft performance:

- Aspect Ratio (AR), which is defined as the aircraft reference area (S_{ref} equivalent to the wing area) divided by the square of the mean wing chord (b). For a rectangular wing, as is mostly seen on cruise missiles, this translates to the wing span 'a' divided by the chord 'b'.
- Wetted Area (S_{wer}) which is the toral area of the aircraft in the airflow and includes the wings, fuselage and tail plane.
- Specific Fuel Consumption, SFC of C, for jet engines is the fuel mass flow per hour per unit thrust force. The SFC is not a constant number, but varies with M No. and altitude.
- Mission Segment Weight Fraction is the ratio of the weight W_{i-1} at the end of a mission leg to the weight W_i at the beginning of the particular mission leg.

As in the case of ballistic missiles, Breguet range equation applies for cruise missiles also and the range is given by

$$R = (V / C)\ (L / D)\ \ln (W_{i-1} / W_i)$$

Or

$$W_i / W_{i-1} = e^{-\frac{RC}{V\,(L / D)}}$$

Where,

R *Range in m*
C *Specific Fuel Consumption mg/Ns*
V *Velocity in m/s*
L/D *Lift to Drag Ratio*

Raymer has plotted the trend line data corresponding to the wetted to reference area ratio, maximum L/D and the SFC vs M. No. for various categories of aircraft. These are shown in figures 3 – 5. From a study of the Tomahawk dimensions, weight apportionment and performance, it appears that the data relating to bomber/cargo aircraft can be applied to cruise missiles.

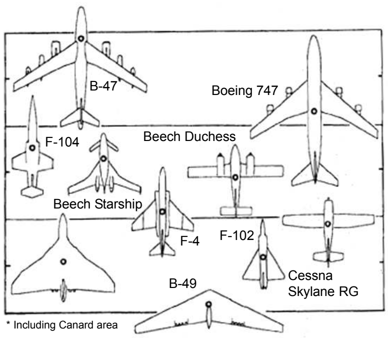

Figure 3:
Wetted Surface Area

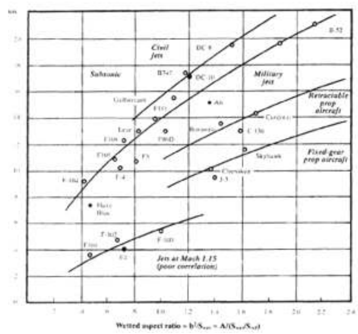

Figure 4:
Maximum L/D Trends

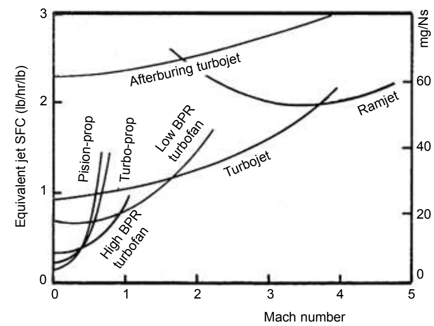

Figure 5:
Specific Fuel Consupmtion

Similar trend lines can be evolved for cruise missiles, if adequate dimensional details are available or derived from images. Cruise missile wings have generally low aspect ratios, but the wetted to the reference area ratio is in the range of bomber/cargo aircraft. The subsonic cruise missiles operate in the speed range of M 0.5 to 0.9 and can be assumed to be operating at sea level for getting a measure of their SFC. If we are able to get images providing us the dimensions of the wing and fuselage, it may be possible to arrive at a component weight apportionment and deduce the range of the missile.

Such an exercise was attempted for Tomahawk[113], for which the following details are available

Weight	1184 kg
Diameter	0.52 m
Length	0.55 m
Fuselage Wetted Area	9.12 m^2
Wingspan	2.59 m
Wing Aspect Ratio	6.0
Wing Reference Area	1.11 m^2
Fins Wetted Area	0.84 m^2
Fuel Weight	513 kg

The weight of the missile was worked out using the above data and using figures 3-5. For a given range of 1600 km , the weight of the missile (without the solid booster) was evaluated at 1361 kg against the indicated weight of 1184 kg. While for a first cut estimate, this procedure is simple and straightforward, it can be refined to produce a closer match.

[113] Lewis & Portal, "Long Range Nuclear Cruise Missiles and Stability.

Appendix - IV: Second Artillery Corps (SAC)

<table>
<tr><td colspan="5">Second Artillery Corps (SAC) Deployment Details</td></tr>
<tr><td></td><td></td><td>SAC HQ</td><td></td><td>Qinghe, 40°01'N 116°20'E</td></tr>
<tr><td>Name</td><td>Range</td><td>Bases HQ/ Locations</td><td>Brigade/ Suspected Numbers</td><td>Notes</td></tr>
<tr><td rowspan="9">DF-3 (road mobile- TEL launched)</td><td rowspan="9">3000- 4000 km</td><td>Dalong 26°39'N 114°02'E (www.fas.org) HQ Huaihua</td><td>403 Brigade</td><td rowspan="9">"The Air Force estimates the DF-3 [CSS-2] will remain active at Jianshui because its greater range is needed to target most of India, while the DF-21A [CSS-5 Mod 1] can cover Southeast Asia from the same launch facilities."

"In areas deeper inside China, where longer range is necessary for target coverage, DF-3 activities are relatively high, indicating the missile could remain in service in these regions until new missiles such as the DF-21 [CSS-5 Mod 2] are deployed. Once the DF-21 deployments are adequately under way, the CSS-2 will likely be removed completely from service, perhaps by 2002."

"DF-3 training also has been observed at Haiyan, indicating continued Chinese reliance on the older IRBM. Former Northwest Nuclear Weapons Research and Design Academy. Closure announced in 1987, closed in 1995."

"The location (Lianxiwang & Tonghua) makes DF-3's range largely redundant because the DF-21 can target all of Japan, North and South Korea, and parts of Taiwan from these deployment areas."

"DF- 3s at Lianxiwang could have been phased out in 2000. Replaced by DF-21"

"DF- 3s at Lianxiwang could have been phased out in 2000. Replaced by DF-21"</td></tr>
<tr><td>Datong, HQ Xinning 36°36'N 103°20'E</td><td>409 Brigade</td></tr>
<tr><td>Dengshahe, HQ Shenyang 39°13'N 122°04'E</td><td>410 Brigade</td></tr>
<tr><td>Haiyan, HQ Xinning? 36°57'N 100°55'E</td><td>Brigade N.A.</td></tr>
<tr><td>Jianshui, HQ Kunming 23°37'N 102°49'E</td><td>Brigade 4088 Launchers (1998)</td></tr>
<tr><td>Kunming, HQ Kunming 25°04'N 102°41'E</td><td>80303 Unit / 3 Division</td></tr>
<tr><td>Lianxiwang HQHuangshan 30°09'N 117°38'E</td><td>Brigade 407/ 10 Launchers in 1998.</td></tr>
<tr><td>Tonghua, HQ Shenyan 41°44'N 125°55'E</td><td>Brigade 406</td></tr>
<tr><td>Yidu,HQ ? 36°41'N 118°28'E</td><td>Missile Garrison/8 in 1998</td></tr>
<tr><td rowspan="4"></td><td rowspan="4"></td><td>Da Qaidam HQ Xinning 37°50'N 95°18'E</td><td>2</td><td rowspan="4">"10-20 total number (1998)" "The Delingha Unit is able to target sites in the former Soviet Union and India, and indications exist that the 80306 Unit may upgrade to the DF-21."</td></tr>
<tr><td>Delingha, HQ Xinning 37°19'N 97°13'E</td><td>Nuclear Missiles</td></tr>
<tr><td>Sundian Luoyang HQ 33°15'N 114°45'E</td><td></td></tr>
<tr><td>Tongdao Huaihua, HQ</td><td></td></tr>
</table>

Second Artillery Corps (SAC) Deployment Details				
		SAC HQ		Qinghe, 40°01'N 116°20'E
Name	Range	Bases HQ/ Locations	Brigade/ Suspected Numbers	Notes
		Xiao Qaidam, HQ Xinning. 37°31'N 95°25'E	Nuclear missiles	
DF - 5	12000-15000 km	Luoning, HQ Luoyang	8 (1997)	"At least one radar, near **Xuanhua** positioned on a mountain slope at 1,600 meter elevation near Xuanhua, is believed to be manned by Second Artillery forces. In 1994 it was reported that phased-array radar has been deployed to provide warning regarding possible Russian attack. A 1988 analysis of Chinese strategic force development noted that "A very large phased-array radar system, constructed in West China, is probably the first step in establishing a ballistic missile early warning system (BMEWS) - necessary for a launch-on-warning capability." As early as 1986 reports suggested the possible deployment of at least one LPAR in the vicinity of **Datong** or **Harbin**, though no locale was specified."
		Wuzhai	N.A	
		Xuanhua, HQ Beijing 40°38'N 115°06'E	N.A	
			LPAR Deployed	
		Tongdao, HQ Huaihua	N.A	
DF - 21	1800 km	Chuxiong, HQ Kunming		"The missiles located at **Chuxiong**, approximately 100 kilometers west of Kunming, are in range of several targets in India and Southeast Asia." "The DF-21 can hit targets throughout Northern India.A 1997 report by the Air Force National Air Intelligence Center stated that the CSS-5 was being deployed in Chinese border areas to provide coverage of Russia, Central Asian, India, Japan, Korea, and the Philippines." "Since no US bases remain in the Philippines, and the shorter-range DF-21 ballistic missiles which can strike Taiwan are deployed with the 52 Army [located in Eastern China], the need for the DF-3 has significantly diminished. The Air Force estimates the DF-3 force at **Lianxiwang** will decline to about eight launchers until the system is retired sometime after 2000." "The DF-21 can target all of Japan, North and South Korea, and parts of Taiwan from these deployment areas."
		Jianshui , HQ Kunming	8 Launchers	
		Lianxiwang HQ Huangshan		
		Tonghua HQ Shenyang	16 (1997)	
DF - 15		Leping 28°58'00"N 117°07'00"E HQ Huangshan	815 ballistic missile brigade.80302 Unit (also known as 52 Base)	"The DF-15 missiles are stored at the Jiangxi base, some 200 kilometers away from the Yungan and Nanping bases. Yongan and Nanping have direct railway links with the headquarters of the 815th ballistic missile brigade of the PLA in Jiangxi Province's **Leping**, and three to four hours would be required to transport missiles from Leping to Yongan via railway. The 80302 Unit is the Second Artillery's most important unit for conventional long-range precision strikes against Taiwan." "Yongan and Nanping in Fujian province are missile firing positions that were used when the People's Liberation Army (PLA) fired DF-15 / M-9 [CSS-6] missiles into the sea off Taiwan during the 1996 Taiwan Strait Crisis."
		Nanping 26°38'00"N 118°10'00"E		
		Yong'an 25°58'00"N 117°22'00"E		

Second Artillery Corps (SAC) Deployment Details				
		SAC HQ		Qinghe, 40°01'N 116°20'E
Name	Range	Bases HQ/ Locations	Brigade/ Suspected Numbers	Notes
DF - 31	3000-8000 km	Tai-Hang, HQ Beijing	N.A.	"An uncorroborated analysis by Yang Zheng, National University of Singapore claims that the Chinese media announced in early 1995 the completion of the "**Great Wall Project" for China's strategic missile force**. " "The Chinese reports asserted that for over a decade "tens of thousands" of workers had constructed tunnels in a mountain range in Northern China. Yang deduced that the locale of the project was probably the Tai-Hang Mountain Range which lies immediately to the east of the Taiyuan space launch center. **Located some 400 km southwest of Beijing between Hebei and Shanxi** provinces, the area is characterized by 1,000-2,000 meter-deep gorges and steep bluffs. Yang suggested that the Great Wall Project may have created a network of tunnels up to 5000 kms long in the mountain range. The Project would have included the construction of dozens of missile bases, perhaps including those used for the DF-15s launched against Taiwan. This complex, should it exist, might also be **a logical deployment area for the DF-31 and DF-31A / DF-41 ICBMs** as they enter operational service. "
		Wuzhai		
DF - 41	10,000-12,000 km	Developmental		– do -

Our estimates of the range of these missiles differs from some of the values given in this Appendix

The above table is compiled from the following sources.

http://www.globalsecurity.org/wmd/world/china/df-5.htm
http://www.nti.org/db/china/sac.htm
http://www.fas.org/nuke/guide/china/facility/qinghe.htm

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