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An Assessment of Pakistan's Ballistic Missile Programme

Technical and Strategic Capability

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A Brief History of the Pakistan Missile Programme

In the early 1990s available evidence indicated that Pakistan had 3 missiles under development. These were the Hatf 1, the Hatf 2 and the Hatf 3 missiles.[1] There was also substantive evidence based on a number of images available in the public domain that these missiles were derived from and based on sounding rocket technology transferred by France.[2] The Dragon / Dauphin single stage 560 mm diameter sounding rocket was identified as the source of technology for the Hatf 1 missile and the two stage Eridan 560 mm diameter sounding rocket as the source for the Hatf 2 missile. The Hatf 3 was supposedly based on a larger 820 mm diameter rocket.[3] There is also a record of sounding rocket production technology being transferred by the French company Sud Aviation to SUPARCO the Pakistan organization that deals with Space and Upper Atmospheric Research. Images of the Hatf 1 and the Hatf 2 are available in the public domain.[4] The evidence confirms the French Connection.[5]

Though there was a lot of speculation about Pakistan's missile and space activities after these disclosures, there was little tangible evidence of missile launches or major programmes of flight testing. It was only after the launch of the Ghauri missile in April 1998 that the pace of missile launches has picked up. From April 1998 till December 2006 Pakistan has launched a total of 26 missiles. Table 1 provides details of these launches. 7 Ghauri missiles, 7 Shaheen 1 missiles, 3 Shaheen 2 two-stage missiles, 4 Ghaznavi and 5 Abdali missiles have been launched by Pakistan. Pakistan launched 5 missiles in 2002, 4 missiles in 2003, 6 missiles in 2004, 2 in 2005 and 5 in 2006. This change in the variety and tempo of launches seems to suggest that Pakistan wants to have in place a credible missile-based deterrence as soon as possible.

Table 1: Chronology of Pakistan Missile Launches

Date	Missile type	Fuel
April 6, 1998	Ghauri	Liquid
April 14, 1999	Ghauri	Liquid
April 15, 1999	Shaheen 1	Solid
February 7, 2000	Hatf 1	Solid
May 25, 2002	Ghauri	Liquid
May 26, 2002	Ghaznavi	Solid

1 Information on Hatf 1 and Hatf 2 was published in Jane's Strategic Weapons System – Issue 03 March 1990.

2 For details of French sounding rockets see David Baker "The Rocket – The history of the development of the rocket and Missile Technology", New Cavendish Books, London 1978.

3 See S.Chandrashekar "An Assessment of Pakistan's missile capability", Missile Monitor, Number 3, 1993.

4 The Hatf 1 and Hatf 2 images are available at http://www.fas.org/nuke/guide/pakistan/missile/hatf-1.htm and http://www.fas.org/nuke/guide/pakistan/missile/hatf-2.htm respectively.

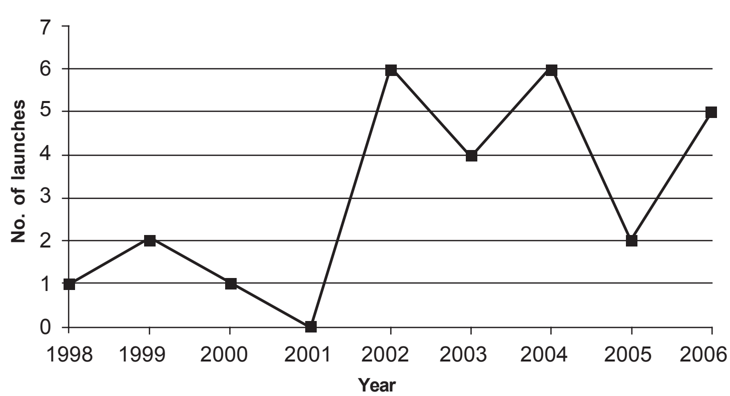
5 Details of French sounding rockets and developments related to missiles including transfer to India and Pakistan are available at http://www.univ-perp.fr/fuseurop/sudav_e.htm

Date	Missile type	Fuel
May 28, 2002	Abdali	Solid
October 4, 2002	Shaheen 1	Solid
October 8, 2002	Shaheen 1	Solid
March 26, 2003	Abdali	Solid
October 3, 2003	Ghaznavi	Solid
October 8, 2003	Shaheen 1	Solid
October 14, 2003	Shaheen 1	Solid
March 9, 2004	Shaheen 2	Solid
May 29, 2004	Ghauri	Liquid
June 4, 2004	Ghauri	Liquid
October 12, 2004	Ghauri	Liquid
November 29, 2004	Ghaznavi	Solid
December 8, 2004	Shaheen 1	Solid
March 19, 2005	Shaheen 2	Solid
March 31, 2005	Abdali	Solid
February 19, 2006	Abdali	Solid
April 29, 2006	Shaheen 2	Solid
November 16, 2006	Ghauri	liquid
November 29, 2006	Shaheen 1	Solid
December 9, 2006	Ghaznavi	Solid

Figure 1 below provides details of the year-wise launches of the Pakistani missiles. Figure 2 provides details of the different kind of missiles launched by Pakistan in the period 1998-2006.[6]

Figure 1

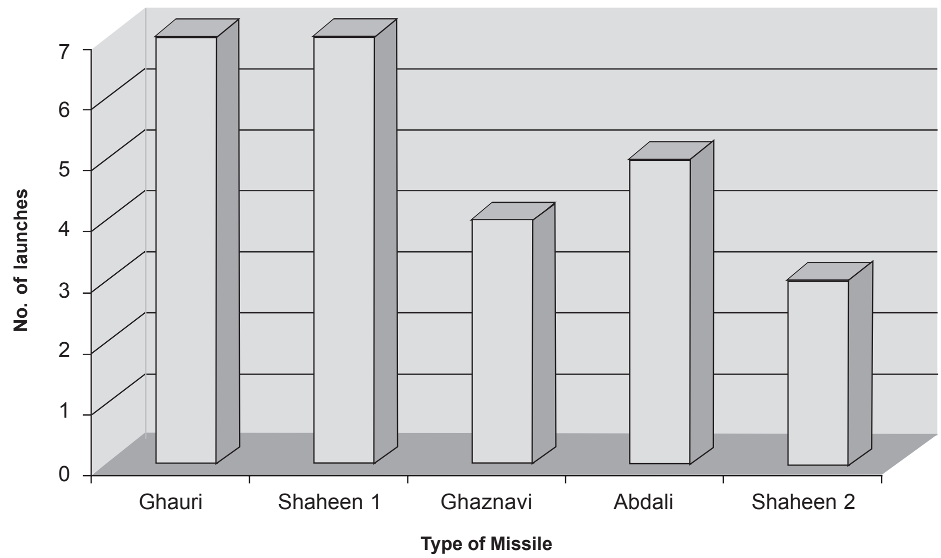
Pakistan Missile Launches- 1998-2006



[6] Pakistan launched its second Shaheen 2 missile on March 19th 2005. A Babur cruise missile was launched on August 11th 2005. Another Abdali launch took place on 19th February 2006. A 3rd Shaheen 2 launch took place on April 29th 2006. This was followed by Ghauri, Shaheen 1 and Ghaznavi launches on November 16, November 29 and December 9 2006 respectively.

Figure 2

Pakistan Missiles: *No. of Launches v/s Missile Type (1998 - 2004)*



Objectives of the Study

Though there is some material on the Pakistan missile programme in the public domain, it is still a very difficult task to separate out the wheat from the chaff and make a realistic assessment of the programme's true capabilities. Information in the public domain is often noisy, garbled and distorted. There are also vested interests and leaks that further muddy already muddy waters. This study on the Pakistan missile programme attempts to provide an independent assessment of Pakistani missile capabilities through a careful scrutiny and analysis of publicly available data. We believe that such an independent assessment will contribute towards a better understanding of the capabilities of one of India's most important neighbours.

Approach and Methodology

- Look at all the literature and published material on Pakistan's missiles.
- Specially look at images that are published or available on the Internet.
- In view of the reported connections between the Pakistan missile programme and Chinese and North Korean missiles, also look at images and information on Chinese and North Korean 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. Look at

connections between countries in terms of observed relationships in missile characteristics. Link these to published knowledge on technology transfer and exchanges.

- 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 Pakistan security system.
- Link these findings to the national security strategy of Pakistan.
- Critically evaluate alternative conflict scenarios between India and Pakistan.
- Draw some policy prescriptions.

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.

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.[7] In this study we have chosen a 1 second interval for these calculations.

Since most of the missiles analysed here are relatively short range missiles optimum angles of injection are close to 45 degrees. The simulated trajectories for the lift off portion of the trajectory can be modeled in such a way that injection values are close to this value of 45 degrees. Through

[7] 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.

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 liftoff and re-entry parts of the trajectory.

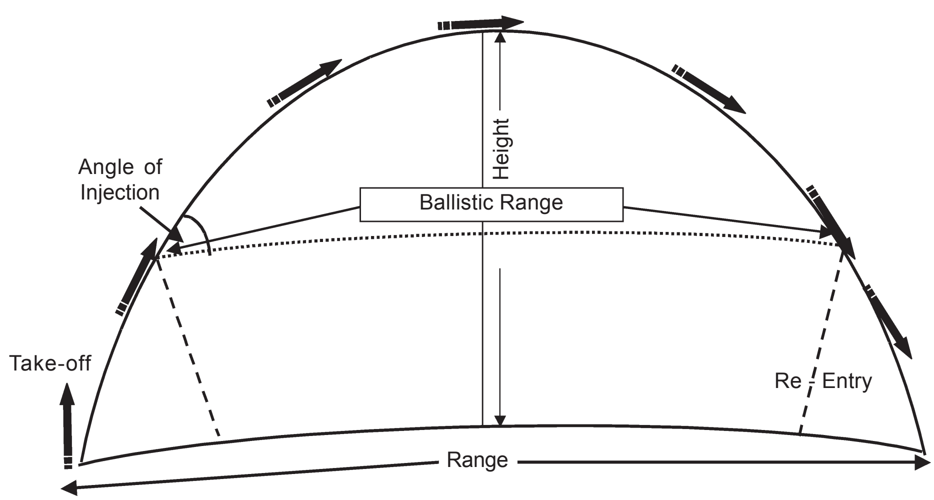
To get initial estimates of the thrust, if this information is not readily available, we use typical estimates of thrust to weight ratios available in the literature on rocket propulsion. Specific impulse[8] values are also taken from the literature if they are not explicitly stated.

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.[9] 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. **Figure 3** depicts a typical trajectory for a ballistic missile.

Figure 3

The Trajectory of a Missile



For each of the Pakistani missiles we have both a liftoff as well as a range model. In view of the fact that the origins of some of Pakistan's missiles are linked to technology transfer from China, we have also made such computations for some of the Chinese missiles for which images are available. These technical calculations along with measurements on the images of the missiles form the basis for much of our analysis.

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

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

Problems of Interpretation of Image Analysis Data

How can we reconcile all the variations that we see in the image data? It is possible that images especially digital ones undergo distortion of various kinds when they are transferred from one location to another. A plethora of formats and zooming and editing options available in the PC makes it difficult to separate out original images from various digital avatars. There are several obviously distorted images available on the Net. Images taken from TV origins are also likely to face some distortion. This is one kind of problem.

The second reason for the variation is that because of the surfeit of images, the image of one launch is used along with a story of a second launch. This could be because the image of the most recent launch is not readily available. This problem may surface if newspapers or news channels are sources. Agencies such as think tanks may also mistakenly put images into the wrong category simply because of the very large number of images that they may have to deal with.

Some variations we see may arise from doctoring. In the Ghauri set of images, image 6 seems to be one such image.

Some engineering logic may help reconcile some of the variations. It is likely that the first launch of any missile will only carry a dummy warhead.[10] This will mean a reduced overall length of the missile. In later flights the dummy warhead is replaced with a warhead that closely matches the real warhead to be used. This means that early flights may have a smaller warhead (a lower Length to Diameter ratio) and later flights a longer warhead (a higher Length to Diameter ratio).

It is quite likely that as a minimum all Pakistani missiles will carry 2 kinds of warheads – a conventional warhead and a longer nuclear warhead. This means that the Length to Diameter ratio (L/D) will vary over a certain range. In principle it is also possible that the missiles can also carry several different kinds of nuclear warheads.[11] One would therefore legitimately expect to see some variations in live tests of missiles over a period of time as a particular missile programme matures.

10 In development flights of launchers the first flight and maybe even later development flights may not carry a operational payload. They normally will carry extra instrumentation to monitor and measure performance both during liftoff and reentry. Such practices would be applicable to missiles also. The payload configuration and length may therefore be different and usually smaller.

11 One would expect this to happen as warhead developments especially in miniaturization and explosive power are progressively developed. Given the current status of the maturity of the warhead development in Pakistan one would not expect to see too many variations in the nuclear warhead part.

The Abdali Missile

Background

There is a lot of material and several pictures available of the Abdali missile. One of the publicly available sites also provides a live video recording of its launch and flight.[12] We picked a few of the available pictures for a more detailed analysis.

We know from earlier work that the Pakistan missiles known as the Hatf 1, Hatf 2 and the Hatf 3 were derived in large part from French sounding rocket technology.[13] The French company SUD Aviation transferred sounding rocket production know-how to SUPARCO. A rocket propellant and motor production plant was also set up.[14] The evidence seemed to indicate that the Hatf 1 missile was largely derived from the French Dauphin rocket with some stretching of the rocket motor to improve range and performance. These early assessments also seemed to suggest that Pakistan with some effort could produce Hatf 1 in reasonable numbers fairly quickly.

Even though these assessments were carried out in the early 1990s Pakistan did not appear to be having a major missile development programme that involved flight testing.[15] It has been only after the launch of Pakistan's Ghauri missile in April 1998 that evidence of Pakistan's growing mastery over solid propulsion technologies has emerged.

Abdali launches

There have been 5 reported launchings of the Hatf 1/Abdali missiles in the post Ghauri period. The first launching of what was reported as the Hatf 1A took place on February 7th 2000. Subsequent launchings of the Abdali missile are reported to have taken place on 28th May 2002, March 26th 2003, 31st March 2005 and 19th February 2006.[16]

Analysis of images

Details of an image by image analysis of the various Abdali Missiles are provided in the Appendix

12 Video recordings of different Pakistan missiles are available at http://www.pakistanidefence.com

13 S.Chandrashekar, "An Assessment of Pakistan's Missile Capability", Missile Monitor, Number 3, 1993.

14 Several sources talk about this. For a formal statement indicating transfer of technology and production know-how to SUPARCO please see the report on SUD Aviation Sounding Rockets "From Belier to Eridan" at http://www.univ-perp.fr/fuseurop/sudav_e.htm. The history of rocketry including the link between the civilian and military part of the French programme is well covered in the documents available in this site.

15 There were reports of flight tests conducted in 1989 and about a possible space launch. These are speculative and not substantiated by any hard publicly available evidence.

16 The sites of the images are in Appendix1. For details of the 19th February 2006 launch please see http://www.spacewar.com/news/missiles-05u.html and, http://www.paktribune.com/news/index.php?id=134741.

An analysis of the various pictures clearly indicates a trend of improving performance and capabilities. A comparison of the evolution of the Abdali warheads with the Chinese M11 warhead reveals many common features.

The more recent images show some stretching of the length of the missile. Both the rocket motor and the warhead seem to have been stretched. This would point to a gradual improvement in terms of capability. Measurements of the missile dimensions (based on a missile diameter of 0.56 m) carried out on these images are provided in the Table 2 below.

Table 2: Summary of Measurements on the Abdali Missile

Image		Length (m)	Warhead + interface (m)	Rocket motor + nozzle (m)
Image 1 [17]	Hatf 1 /1A	4.39 m	Not reliable	Not reliable
Image 2	Abdali	4.37 m	1.72 m	2.65 m
Image 3	Abdali	4.90 m	2.02 m	2.89 m
Image 4	Abdali	5.38 m	2.24 m	3.14 m
Image 5	Abdali	6.57 m	2.83 m	3.73 m
Image 6	Abdali	6.44 m	2.68 m	3.76 m

From Table 2 the two longer versions of the Abdali appear to have lengths of approximately 5.38 and approximately 6.50 metres. The rocket motors show an increase in length from 2.65 metres to approximately 3 m and then to approximately 3.75 metres. The warhead portions of the two longer missile configurations have lengths of 2.24 and 2.83 metres respectively. The rocket motor + nozzle part have lengths of 3.14 and 3.73 m. Taken together, they represent significant improvements over the original capability acquired from France through technology transfer.

Range and other parameters of the Abdali Missile

Data on various 560 millimetre diameter rocket motors are available in the public domain. Known lengths of these motors can be related to propellant loadings and stage masses.[18] Using this knowledge we can convert our measurements of rocket motor lengths into propellant and stage masses. Once stage masses and propellant weights[19] are known we can calculate ranges as well as other related parameters like time of flight, apogee height etc. for any payload.

[17] There could be some errors in measurement of the warhead, rocket motor and nozzle lengths.

[18] See "Early ONERA rockets" and "The Precious Stones" at http://www.univ-erp.fr/fuseurop/sudav_e.htm Details of various rocket motors are provided here that enables propellant mass stage mass and lengths to be related. Of course better propellants with better characteristics would have been used in the missile derivatives of the French sounding rockets. However, these would not alter the quantities of propellant and the stage masses of the missiles derived from them.

[19] The estimated propellant loading for the 2 longer versions of the Abdali are 863 kg and 1028 kg respectively. This translates into a booster weight of 1256 kg and 1530 kg. With a 500 kg payload this would mean a liftoff weight of 1756 and 2030 kg for these 2 versions of the Abdali.

The ranges estimated for the two versions of the Abdali missile with a 500 kg payload are 85 km and 95 km respectively. The time-of-flight and the apogee heights for the missiles are 163 seconds, 176 seconds, 28 km and 31 km respectively.

Assessment

Due to their limited range it is unlikely that the Abdali missiles carry nuclear warheads. Though these Abdali missiles do not pose a strategic threat because of their range limitations a study of their evolution over time provides us some insights into Pakistan's technological and organizational capabilities. We can see a progressive improvement that has built upon the original French sounding rocket technology, internalised it and is now able to substantially improve upon it. From the original Hatf 1 to the improved Abdali longer variants, Pakistan has demonstrated significant progress.

The refinements are seen in the stretching of the rocket motors, a reduction in the length of the nozzles, the improvements in the warhead section, and a possible ability to separate the warhead section and spin it up. The warheads also share some common features with Chinese M11 warheads. That this M11 knowledge has been transferred to the relatively indigenous Abdali programme provides additional evidence of Pakistan's improved understanding of solid propulsion technology. Production of these missiles in reasonable numbers should be expected.

The Transportable Erector Launcher (TEL) for the Abdali is based on the Russian / Chinese MAZ 543. The tyre diameter is however only 1.3 m, lower than the diameter of the tyres used for the Ghaznavi TEL which are 1.5 metres in diameter.

The Ghaznavi Missile

Background & Launches

Four flights of the Ghaznavi missile have taken place. The first of them took place on 26th May 2002, the second on October 3rd, the third on November 29th 2004[20] and the most recent of them on December 9th 2006.[21] There are also reports that the missiles have been declared operational.[22]

There has been much speculation about the origins of the Ghaznavi missiles. They have been linked to the Chinese M11 missiles as well as the Chinese M9 missiles. There are also lots of variations reported on its parameters - length, diameter, range, payload etc. in the published literature.[23] A Pakistani website carries a video clipping of the launch of the Ghaznavi missile.[24]

There were reports in the early 1990s that the Chinese were exporting M11 missiles and technology to Pakistan. The US government imposed sanctions on some Pakistani and Chinese entities in 1993-94 lending some credence to the claim of export of missiles and technology. According to various sources about 34 M11 missiles were supplied and Transporter Erector Launchers (TELs) for moving and launching the missiles were also a part of the deal.[25] Other reports suggest that Pakistan has in operation a facility for the production of M11 missiles[26].

It is only after the launch of the Ghauri missile in 1998 that Pakistan has launched a number of missiles including the Ghaznavi missile.

In our pursuit of the origins and current status of the Ghaznavi missile we have looked at available data and information on the Ghaznavi. In view of its possible Chinese origin we have also looked at data on the Chinese M11 missile. We have used available images to study these possible links in detail. We have also tried to estimate the range of the Ghaznavi using all this data and information.

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[20] The dates and the launchings have been compiled from various newspaper reports. Source details are available in the Appendix.

[21] See http://www.chinadaily.com.cn/world/2006-12/09/content_754829.htm and at http://mdn.mainichi-msn.co.jp/international/news/20061209p2g00m0in012000c.html for images of the December 9th 2006 launch.

[22] These handing over reports were widely reported in various Pakistan papers. See "Army gets Ghaznavi missile", Daily Times, February 22nd 2002, Online edition.

[23] There seems to be confusion both in terms of diameter as well as length. Diameter estimates vary from about 0.8 metres to about 1 metre. Length estimates vary from about 7.5 metres to 11.25 metres. Once a report based on some technical assessment even if it is wrong is put out it seems to have a life of its own even if it is corrected later.

[24] http://www.pakistanidefence.com

[25] Many sources talk of this. For one version of this see http://www.fas.org./nuke/guide/china/theater/df-11.html. Another source talks of the export. See http://www..aeronautics.ru/archive/wmd/ballistic/ballistic/css77-01.html It however confuses the Ghaznavi which is derived from the Chinese M11 and the Shaheen which is derived from the Chinese M9.

[26] Charles Smith "China's nuke missile plant in Pakistan - India developing land - based. Aerial, sub-launched nuclear capability" at http://www.worldnetdaily.com/new/printer-friendly.asp?ARTICLE, WorldNet Daily, Friday June 30, 2000.

According to many reports the Chinese M11 was supposed to be a solid propellant replacement for the liquid propelled SCUD B[27] 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 metres 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.[28]

As mentioned earlier there are also reports that production facilities for the production of these missiles have been set up with Chinese help. Pakistan has also had a long exposure to solid rocket motor production and technology in view of the French transfer of sounding rocket technology.

Analysis of images

Details of the analysis of the various Ghaznavi missiles are provided in the Appendix. To explore the China connection a bit further we also analysed 4 images of the M11 available in a semi-official Chinese website.[29] One of the pictures of the Ghaznavi available in a (official) Pakistani website shows the missile being erected from its TEL.[30] If the Ghaznavi is really an M11 variant, the TEL which is used to carry and erect the missile must be a Chinese copy of the Russian MAZ 543 TEL whose dimensions are well known.[31] Using this as a benchmark, the estimated diameter of the Ghaznavi is very close to the 0.88 metre diameter of the M11. This would tend to substantiate the Chinese origin for the Ghaznavi. The measurements for the Ghaznavi and the M11 from the images are summarized in Table 3.

[27] 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.

[28] 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

[29] A number of images and briefs on various facets of the Chinese military and defence programmes are available on the net. The images used are available at http://www.sinodefence.com/nuclear/df11.asp

[30] See http://www.pakistanidefence.com

[31] Reports on the dimensions of the TEL for the SCUD series of missiles including the Scud B are widely available. Our analysis uses this as a basis for many of the measurements made on the images. A Russian version of the MAZ 543 data is available http://legion.wplus.net/guide/army/tr/maz543.shtml#R0. Another version (German) can be found in http://www.reserve-info.de/aridat/scud.htm. Data can also be obtained from the Trembikta website in the Ukraine at http://www.trembikta.com.ua/eng/auto/maz-53.html. There is also information available on Iraq's version of the TEL.

Table 3: Measurement Summary Ghaznavi & M11 Missiles

Image	Warhead length	Rocket motor length	Total length
Image 1	3.76 m	5.05 m	8.81 m
Image 2	4.01 m	4.90 m	8.91 m
3rd launch (average)	4.31 m	5.17 m	9.48 m
4th launch[32]	4.11 m	4.80 m	8.90 m
M11 image 1	N.A	N.A	11.34
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 measurements on the Ghaznavi missiles indicate warhead lengths of 3.80 m., 4.14, 4.31 and 4.2m. 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. **The shorter Chinese warheads closely match the warhead dimensions of the Ghaznavi missile**.[33]

There are also 3 incremental versions of the Chinese M11 rocket motor with lengths of 5.76m, 6.17m and 6.54 m. The most reliable rocket motor lengths of the Ghaznavi missile as measured from the image set are 5.21 m, 4.91 m and 5.17 m.[34]. Assuming an average rocket motor length of approximately 5 to 5.1 metres, it is evident that the Ghaznavi rocket motor is shorter than the M11 rocket motor. **The average length of the Ghaznavi missile we are seeing is 9.1 m which is also substantially shorter than the shortest M11**.

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.

If we look at the shape and pattern of the Ghaznavi especially the warhead sections and the various dimensions there is evidence to indicate that the Chinese have indeed supplied Pakistan

[32] The image is such that the overall length measurement may be a little inaccurate.

[33] We can surmise alternatively that what we are seeing is the same warhead for the Ghaznavi and that the differences are due to measurement errors. We can also surmise that we are only seeing 2 warheads for the M11 and not 3. This argument is also consistent with our measurements.

[34] The 4th measurement may have some inaccuracies in length because of the nature of the image. This may also mean that the Ghaznavi does not have different rocket motors but only one rocket motor that is approximately 5 to 5.1 m long. This is about 0.7 to 1.5 m shorter than the M11 rocket motors we are seeing in our sample of M11 images.

with a shortened version of the shorter M11 variant. The warhead lengths of the Ghaznavi also closely match the length of the Chinese warheads.

We can conclude – the Ghaznavi is a shortened version of the shorter variant of the Chinese M11 missile. The Ghaznavi may carry two kinds of warheads - a longer nuclear warhead and a shorter conventional warhead. The warhead dimensions closely match warheads of the Chinese M11 missiles. The Chinese have however not transferred the longer version of their M11 missile nor the later more advanced longer (4.80 m) version of their warhead.[35]

The public evidence is consistent with the logic that the Chinese have transferred a shortened version of the shorter variant of the M 11 missile to Pakistan. This version, which the Pakistanis call as the Ghaznavi, has a length of about 9.1 metres (between 8.9 and about 9.5 metres depending on the warhead) and a diameter of 0.88 m. The Ghaznavi can carry two warheads - a warhead about 3.76 to 4 metres long or a longer warhead with a length of 4.31 metres. The warhead dimensions as well as the general shape of the warheads closely match the warheads of the M11. The observed evidence is consistent with the Chinese origins of the Ghaznavi missile.

Performance of the Ghaznavi

The M11 is supposed to be a substitute for the SCUD and is compatible with the Russian MAZ 543 TEL mobile launcher. Since there is a lot of information available on the SCUD[36] we can make some reasonable assessments of the lift off weights and propellant weights of a SCUD compatible solid propellant substitute missile.[37] Making such a calculation we estimate the stage mass of the Ghaznavi to be about 4903 kilograms and the propellant mass to be 3775 kilograms. With a payload of 1000 kilograms this gives a Lift off Weight (LOW) of 5903 kilograms.[38] The range of the Ghaznavi with a 1000 kg nuclear warhead works out to be 269 kms. The time of flight works

[35] Public accounts of the M11 talk of a conventional warhead, a nuclear warhead and an improved warhead with nozzle control. See http://www.fas.org./nuke/guide/china/theater/df-11.html. For another source with a similar view see http://www.sinodefence.com/nuclear/df11.asp

[36] 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

[37] 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. Using this value and typical mass fractions for solid rocket stages we get a stage mass for the Ghaznavi as 4903 kilograms. If we assume a payload mass of 1 tonne for a typical nuclear payload we can compute the range and other flight parameters of the Ghaznavi missile.

[38] This is an estimate for the typical nuclear warhead to be carried by a longer range missile.

out to be 267 seconds and the altitude of the missile works out to be 75 kms. The range with a 700 kg payload is 347 km with a time of flight of 301 seconds and a maximum altitude of 94 kms. **(See Figure 4).**

For comparison the range of the M11 with a 1000 kilogram payload is approximately 384 kilometres with a time of flight of 332 seconds and an altitude of 109 km.

Assessment

There is little doubt that the Ghaznavi is a shortened version of the Chinese M11 missile. It has a range of about 269 km with a 1000 kg payload (347 km with a

Figure 4
Ghaznavi Range

700 kg payload). 4 launches of this missile have taken place as compared to 7 launches of the Ghauri or the Shaheen 1 missile. This may be because these are well-tested operational missiles and therefore Pakistan does not need to test them. The more recent tests may also be to tell India that they have the missiles that can deliver required payloads.

The Ghaznavi Transporter Erector Launcher (TEL) is also a copy of the Russian MAZ 543 TEL supplied by China.

The Ghauri Missile

Background and Launches

Immediately after the first launch of the Ghauri missile they were a number of articles on its origins and capabilities.[39] Since the first launch on April 6th 1998 there have been 6 additional launches of the missile - April 14th 1999, May 25th 2002, May 29th 2004, June 4th 2004, October 12th 2004 [40] and 16th November 2006. 2004 saw 3 launches. The peak of 3 launches in 2004 would seem to indicate that the missile is operational.

We have studied some of the images that have been put out by Pakistan as well as other images that are available in the public domain.[41]

Analysis of Ghauri images

The Appendix provides details of the analysis on various Ghauri images in the public domain.

Since the warhead was difficult to separate from the other elements of the missile we used the red band [42] around the nosecone (found on all images of the Ghauri) as an identifying mark to separate out potential variants of the missile.[43]

Table 4 summarises the measurements we have made on the various Ghauri images.

Table 4: Summary measurements on Ghauri Images

Image	Date	L/D ratio	Length (m)	Red band (m)	Length less red band	Comments
Image 1	April 1998	**11.29**	**14.68 m**	**2.75 m**	**11.93 m**	**Same as Images 6, 7.**
Image 2	April 1998	**11.11**	**14.44 m**	**2.85 m**	**11.56 m**	**Similar to Image 1**
Image 3	April 1999	**11.23**	**14.59 m**	2.35 m	**12.24 m**	Not image 1

39 See David C. Wright "An Analysis of the Pakistani Ghauri Missile Test of April 6, 1998", Science and Global Security 1998, Volume 7, pp 227-236. Also see S.Chandrashekar "The Origins and antecedents of the Ghauri missile - An assessment", Current Science Vol.76 no.3 10th February 1999, pp 280-285.

40 Compiled from published information and Press reports.

41 The sources for the images are http://www.pakistanidefence.com, images available from newspaper and news agency sources such as the Tribune, Dawn, Al Jazeera. We have also used a couple of images taken from the FAS website which are in turn taken from official Pakistani government / semi government sources. We have tried to relate the images to the sources and specific dates of launching. Consistency checks between what we see in the image what we infer from published information and our own assessment is therefore crucial. All sources are referred to in the Appendix.

42 The warhead would be longer than the red band length and should include an interface with the booster stage.

43 The total length of the missile less the nosecone should approximately be equal to the stage length. This assumes that there is no interface between the nosecone and the stage. Obviously this is not correct. However since we are only trying to find out whether there has been a change in the stage length this may be a valid approach to follow.

Image	Date	L/D ratio	Length (m)	Red band (m)	Length less red band	Comments
Image 4	April 1999	*12.48*	*16.22 m*	*2.99 m*	*13.23 m*	**Same as Image 5**
Image 5	May 2002	*12.48*	*16.23 m*	*2.94 m*	*13.29 m*	**Same as Image 4**
Image 6	May 2004	**11.26**	**14.65 m**	**2.68 m**	**11.97 m**	Same as Image 1
Image 7	Oct. 2004	**11.31**	**14.70 m**	**2.84 m**	**11.86 m**	Same as Image 1
Image 8	Oct. 2004	*12.64*	*16.44 m*	*3.06 m*	*13.38 m*	**Same as Image 9**
Image 9	Oct. 2004	*12.51*	*16.27 m*	*2.90 m*	*13.37 m*	**Same as Image 8**
Image 10	Post 1st launch	10.83	14.08 m	2.10 m	11.98 m	Training missiles?
Image 11	Post 1st launch	10.89	14.16 m	2.38 m	11.78 m	Training Missiles?
Image 16	Nov. 2006	*12.33*	*16.03 m*	*2.74 m*	*13.29 m*	Different missile

We can infer from the analysis that Images 1, 6 and 7 though shown as images of different launches are possibly pictures of the same missile. In the same way Images 4 and 5 though shown to be different launches may also be the same missile. Image 6 appears to be a doctored image. A white strip across the diameter seems to have been pasted on to image 1 to get image 6. A close scrutiny of the images that are supposedly images of different launches taking place on different dates show that there are only 4 (maybe 5) distinct images. Many of the images we see are possibly the same missile.[44] The details of the logic that seems to suggest this are in the Appendix.

From Table 4 there seem to be 3 groupings – one group with a Length to Diameter ratio (L/D) of approximately 10.9, another with an L/D value of 11.10 to 11.3 and a 3rd with an L/D value of 12.3 to 12.6.

Image 10 and Image 11 have L/D ratios of 10.83 to 10.89 with corresponding length of 14.08 and 14.16 metres. They could be dummy missiles used to train the launch crews. It is quite possible from the measurements that the two images we see are pictures of the same dummy missile used for training.

From Table 4 a second Ghauri missile configuration has an L/D Ratio of 11.1 to 11.3 with corresponding lengths of 14.4 to 14.7 metres. A third configuration has an L/D ratio of 12.3 to 12.7 with corresponding lengths of 16 to 16.4 metres. This 3rd configuration length is close to the lengths of the Ghauri missile put out in the published literature.

In the absence of independent verification of the missile diameter we believe that the best estimate of the diameter is what is reported in the literature – between 1.3 and 1.33 metres. We will use a diameter of 1.3 metres in our analysis. Table 4 is based on a missile diameter of 1.3 metres.[45]

[44] Since there have been 7 launches of the Ghauri we should expect to see at least 7 different images. The evidence that we see in the images of doctoring would seem to indicate that there may have been 2 or 3 failures.

[45] If 4 Scud engines each with a diameter of about 0.4 metres are clustered with some minimum separation they would fit into a circle with a diameter of between 1.2 and 1.3 metres.

Publicly available data for the tests of May 2004 and June 2004 are sparse. The image purported to be that of the May 2004 launch (Image 6) appears to be doctored and not consistent with a successful launch. By contrast the evidence for the October 2004 launch is fairly convincing.

Based on Table 4 we can conclude that there are 3 configurations of the Ghauri missile. One configuration could be a configuration with a dummy warhead for training purposes. A second configuration which has a length of 14.6 to 14.7 metres may carry a conventional payload. The 3rd configuration which has a length of 16 to 16.4 metres may carry the nuclear payload.[46] All the configurations may use the same booster stage. The different lengths that we see are because of the differing lengths of the warheads. The basic booster stage for all the configurations would be the same. The analysis points to the Ghauri carrying at least 2 warheads with one warhead being about 1.3 metres longer than the other. The longer warhead may be the nuclear warhead and the shorter warhead could be the conventional warhead.[47]

Though Images 10 and 11 show the TEL, the dimensions of this TEL are not easily measured.

Performance of the Ghauri

Since it is difficult to accurately estimate the lengths of the propellant fuel tanks from the various images, we have used estimates of propellant mass, stage mass and lift off weight available in the published literature.[48]

There have also been some public statements from Pakistan sources that may help get a better fix on the capabilities of the Ghauri. Specifically in a public statement the head of Pakistan's solid propulsion missile programme Dr. Samar Mubarik Mand[49] has indicated that solid fuel based missiles are inherently superior to liquid rockets using kerosene and nitric acid. In view of the rivalry between the A.Q.Khan group (Khan Research Laboratories) responsible for liquid fuel based missiles and the solid fuel based missile programme under the Pakistan Atomic Energy Commission there is good reason to believe Dr. Samar Mubarik Mand's statement. If this were true one would expect that the fuel used by the Ghauri is RP 1 (kerosene) and Red Fuming Nitric

46 This assumes that as of now Pakistan has only one kind of nuclear warhead. As development proceeds one would expect to see other types of warheads.

47 We have also tried to measure the warhead lengths separately to establish that the rocket stage used is the same for all launches. Because of the nature of the images and their quality these measurements are not very accurate. Details are in the Appendix.

48 S.Chandrashekar "The Origins and antecedents of the Ghauri missile - An assessment", Current Science, Vol.76, no.3 10 February 1999, pp 280-285.

49 Dr. Samar Mubarik Mand is the head of a new organization called the National Engineering & Scientific Commission that deals exclusively with missiles.

Acid (RFNA) and not UDMH[50] and RFNA. This would in turn imply that the specific impulse[51] of the Ghauri would be lower than previous estimates.[52]

Based on the published data[53] on the propellant loading, stage mass and lift off weight, we also carried out a detailed assessment of the performance of the missile. We tried to reconcile the published data on flight time, altitude and approximate range with the results we get from our trajectory and range models. Fin area measurements from the first flight of the Ghauri were also used to refine our estimates of the range and other flight parameters of the Ghauri. The ranges and other flight parameters of the Ghauri with payload of 700 kg for specific impulses of 225, 230 and 235 seconds and for different injection angles were estimated.[54] Based on the reported launch and impact points we can estimate the range of the first launch to have been greater than 705 km but possibly less than 800 km assuming some margins for range and safety. The published reports also talks about a flight time of about 598 seconds and claims that the missile went up to height of 350 kms.

An injection angle of 58 degrees (a lofted trajectory) and a specific impulse close to 235 seconds gives a range of between 740 to 786 kms, a flight time of between 610 and 630 seconds and an altitude of 334 to 353 kms. These values are reasonably close to the values reported after the first launch. On this basis we would expect that the specific impulse of the Ghauri would be close to 235 seconds.

The range of the Ghauri with a 1000 kg and 700 kg payload is 818 km and 928 km respectively. The flight times and altitudes for the 1000 kg and 700 kg payload cases are 497 seconds, 528 seconds, 221 km and 247 km respectively.

Figure 5 shows the range for a 1000 kg and 700 kg payload.

The range values are lower than the values reported earlier.[55] We believe these values better reflect the capabilities of the Ghauri based on the available evidence.

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50 Unsymmetrical dimethyl hydrazine is a common liquid rocket fuel used widely.

51 Specific impulse can be defined as the thrust achieved for unit weight flow rate of the propellant. In layman's terms it is a measure of the efficiency of the propulsion system.

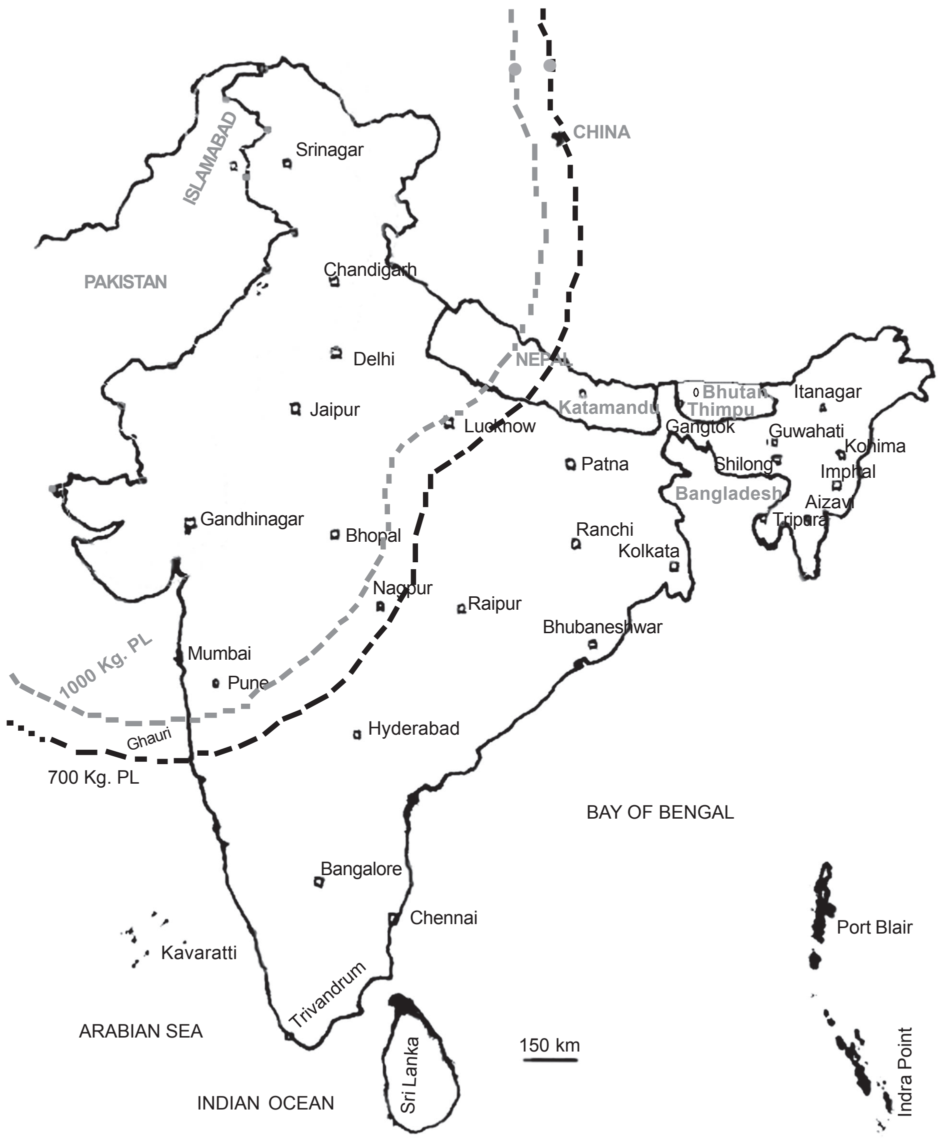
52 See Hanif Khalid "How Shaheen Was Developed" Rawalpindi, Jang 19 April 1999 page 10 available at http://www.kokaniz.com/shaheen.htm. In this article most probably based on an interview with Dr. Samar Mubarikmand the statement about nitric acid and kerosene making holes in the tank is mentioned. This article also advocates why Shaheen solid fuel missiles are inherently superior.

53 Lift off weight 16 tonnes, propellant mass 13 tonnes, payload 700 kg, place of launch near Malute, impact point near Quetta, flight time 9 minutes 58 seconds, altitude 350 km. See S.Chandrashekar "The Origins and antecedents of the Ghauri missile - An assessment", Current Science Vol.76 no.3 10th February 1999, pp 280-285.

54 An IRFNA and kerosene propellant combination would have an average specific impulse of around 235 seconds.

55 S.Chandrashekar, "The Origins and antecedents of the Ghauri missile - An assessment", Current Science Vol.76, no.3, 10th February 1999, pp. 280-285.

Figure 5
Ghauri Range



The Shaheen 1 Missile

Background and launches

There have been 7 launches of the Shaheen1 missile by Pakistan. These launches took place on 15th April 1999, October 4th 2002, October 8th 2002, October 8th 2003, October 14th 2003, December 8th 2004 and November 29th 2006. As in the case of the other Pakistan missiles there are a number of images of these missiles in the public domain. Some of them are officially put out by entities close to the government. There are also a number of reports and analyses on the Pakistan missile programme that we have consulted. There is also a site that provides a video of the launch.[56] Using the same methodology that we had adopted for the Ghaznavi and the Ghauri missiles we have analysed the Shaheen 1 missiles.

Analysis of images

As was the case with the Ghaznavi missile there is a lot of material in the public domain on the connections between the Shaheen missile and the Chinese M9 (DF 15) missile.[57] We have analysed a number of images of the Shaheen 1 and the M9 to critically examine this connection.[58] Details of the analysis of each image are in the Appendix.

The results of the analysis from the publicly available images of the Shaheen 1 missile along with some images of the M9 Chinese missiles are reflected in Table 5 below.

Table 5: Summary of Measurements Made on Shaheen 1 & M9

Image	L/D ratio	Warhead + if (m)	Motor incl nozzle (m)	Length (m)	Comment
Image 1	9.62	N.A	N.A	9.62 m	Diameter of 1 m validated via TEL
Image 2	9.89	3.71 m	6.18 m	9.89 m	Missile on launch pad
Image 3	9.92	3.56 m	6.36 m	9.92 m	Same as image 2 – launch pad image
Image 4	9.69	3.28 m	6.40 m	9.69 m	Launch image – resembles images 2 & 3. Tilt makes measurement inaccurate. Dummy payload?
Image 5	***11.43***	***4.27 m***	***7.15 m***	***11.43 m***	Launch image. Different from Image 4.
Image 6	**12.69**	**4.81 m**	**7.88 m**	**12.69 m**	Launch image – nuclear payload
Image 7	***11.64***	***4.45 m***	***7.18 m***	***11.64 m***	Launch image – shorter warhead – similar to Image 5.

56 A number of video recordings of different Pakistan missiles are available at http://www.pakistanidefence.com.

57 See for e.g. http://www.aeronautics .ru/archive/wmd/ballistic/ballistic/hatf4-01.htm There is a lot of confusion between the Ghaznavi and the Shaheen since their diameters are fairly close and the lengths not too different.

58 These are from various sources on the net. A list of the sources is available in the Appendix.

Image	L/D ratio	Warhead + if (m)	Motor incl nozzle (m)	Length (m)	Comment
Image 8	**12.83**	**4.83 m**	**8 m**	**12.83 m**	Launch image – nuclear payload – similar to image 6.
Image 23 Image 9 (M9)	*12.20* 8.86	*4.75* 4.41 m	*7.45 m* 4.45 m	*12.20 m* 8.86 m	New rocket motor + earlier warhead? 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.

The diameter of the Shaheen 1 and the M9 can be independently verified to be 1 metre. This common diameter validates Chinese help with the Shaheen 1 programme.

Images 1, 2 and 3 are images of the Shaheen 1 on its TEL or being readied for launch. Image 4 is the launch of a missile which closely resembles Image 2 and Image 3. From Table 5, Images 1, 2, 3 and maybe Image 4 are compatible with a approximately 9.9 metre long, 1 metre diameter Shaheen missile. It is also compatible with the logic of a dummy warhead being tested on early development flights of missiles. The rocket motor length for this early configuration is approximately 6.4 metres and the warhead along with its interface has a length of approximately 3.6 metres.

Image 5 and Image 7 seem to be very similar. This configuration of the Shaheen 1 has a length between 11.4 and 11.6 metres. It carries a shorter (approximately 4.35 m) warhead which may be a conventional warhead. The rocket motor length for this configuration is approximately 7.15 metres.

Image 6 and 8 are also very similar. This configuration of this Shaheen 1 has an overall length of 12.7 to 12.8 metres. It carries a longer approximately 4.8 m (nuclear) payload. The rocket motor length for this configuration is approximately 7.80 m.

From these images we can confirm that there have been at least 5 clear and separate launches of the Shaheen 1. The visual evidence confirms these launchings. Three different rocket motors with lengths of 6.4 m, 7.15 m and 7.8 m have been used in these launches.

Image 23 is a picture of the most recent Shaheen 1 launch of November 29th 2006. The warhead length (4.75 m) for this launch is very close to the warhead lengths we see in images 6 and 8. However its rocket motor length is 7.45 m which is somewhere between the 7.15 m and 7.8 m rocket motor lengths seen in earlier launches.

The sequence of rocket motor lengths approximately 6.4 m, 7.15 m, 7.45 m and 7.8 m, the sequence of warheads from dummy warheads via conventional warheads to nuclear warheads (lengths of approximately 3.60 m, 4.35 m and 4.8 m) and the clear evidence of at least 6 different and distinct flights indicates that Pakistan has a robust Shaheen 1 programme.

What is the contribution of China to the Shaheen 1 programme? Table 5 also provides data on Chinese M9 missiles. We can see very clearly that all the Shaheen 1 missiles have lengths that are much greater than the M9 missiles. This means that the Shaheen 1 is not a direct copy. Lengthening the rocket motor also implies that other parameters of the missile have to be modified or changed and should logically mean an increase in capability for system engineering and integration.

When we look at the warheads of the M9 and the Shaheen 1 there are a great many similarities. There are also differences such as the absence of fins in the warhead for the M9.

The incremental changes that we see in the sequence of Shaheen 1 missile tests would seem to suggest that though the Chinese have transferred the basic 1 metre diameter technology as well as some warhead related know-how, Pakistan has internalised this knowledge and is now able to build up on this and proceed independently on its own largely indigenous programme.

Performance of the Shaheen 1

The images, especially the ones of the Shaheen 1 in flight, also help us to get some idea of the sizes of the warheads, the rocket motor and the nozzles. This in turn enables us to get an idea of the amount of propellant that can be carried. We can use this information to estimate the mass of the missile. We can then run a trajectory and estimate the range and other flight parameters.[59] The stage mass and propellant mass for the Shaheen 1 is 7916 and 6333 kg respectively.[60] For the M9 the stage mass and the propellant mass work out to be 4426 and 3541 kg respectively. These values are used along with our lift off and range models to estimate various missile parameters like range, time of flight and altitude.

[59] Image 10 an M9 image indicates a maximum length of the rocket motor and nozzle of 5.27 m. Using values of 0.5 metres for the head end and tail end domes and a measured value of 1.15 metres for the visible nozzle part, the length of the propellant grain works out to be 3.12 m. This translates into a volume of 2.45 cubic metres. With a volume fraction of propellant of 85% and a mass ratio of 80% for the stage motor the propellant mass and the stage mass works out to be 3541 and 4426 kg respectively. A similar approach is used on the largest Shaheen motor to estimate the propellant and stage masses. For the Shaheen 1 the propellant mass and the stage mass are estimated as 6333 and 7916 kg respectively. These are the values used to estimate ranges and other flight parameters.

[60] One source reports the that the missile weighs 9 tons with a propellant weight of 7 tons, 1 ton motor and 1 ton warhead. The lift off weight we have got is close to the value reported. The same article also talks of many Indian targets within a 300 km to 400 km range. See Hanif Khalid "How Shaheen Was Developed" Rawalpindi, Jang 19 April 1999 page 10 available at http://www.kokaniz.com/shaheen.htm.

The maximum range of the Shaheen 1 with payloads of 1000 kg and 700 kg is 410 km and 495 km respectively. The time of flight and the apogee height of the Shaheen 1 for these 2 cases are 343 seconds, 375 seconds, 116 km and 136 km respectively.

By contrast 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.

Figure 6 provides the details of the Shaheen 1 range for payloads of 1000 and 700 kg.

We can see that though the diameters of the M9 and the Shaheen 1 are the same, the performance of the Shaheen 1 is much better with a range of 410 and 495 km with a 1000 kg and 700 kg payload respectively. As we have stated earlier, a comparison of the warhead part between the Shaheen 1 and the M9 reveal similarities that indicate a common origin. 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.[61] 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.[62] Since the Shaheen 1 missiles are longer than the M9 missiles the argument that it is Chinese technology that is manifest in the Shaheen 1 does have some logic.

On balance

- ❑ The warheads of the M9 and the Shaheen 1 are similar
- ❑ The original TEL carrying the Shaheen 1 on parade is similar to the MAZ 543 TEL. Images of the M9 are also similar or are the same as the MAZ 543 TEL.
- ❑ Pakistan does not appear to possess the Chinese developed TEL. The TEL carrying the Shaheen 1 is very similar to the M11 Ghaznzvi MAZ 543 TEL.[63] China has also used such a TEL for its launches though later versions of the M9 are carried on the new Chinese developed TEL.

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[61] 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.

[62] 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.

[63] Some modifications to the TEL may be needed to carry the larger diameter (1 m) Shaheen 1.

- The lengths of the Shaheen 1 missiles are longer. One early version of the Shaheen 1 has a length close to one of the M9 configurations. Later versions of the Shaheen 1 are all longer.

- The flight testing sequence seems to follow a logical - dummy warhead test followed by a conventional warhead test followed by a nuclear warhead test - sequence. Images we have looked at are consistent with this approach.

- No M9 with the length of the Shaheen 1 is seen in the publicly available images though it is possible that the Chinese have such stages.

- The different rocket motor lengths and different warheads that we see in the sequence of Shaheen 1 launches indicates an increasingly sophisticated capability to customize missiles for meeting different operational requirements.

The conclusion we can draw is that there is little doubt about Chinese transfer of technology for the Shaheen 1 missile development by Pakistan. However, this does not necessarily translate into an absence of technology, system design and integration capability in Pakistan. The evidence would seem to suggest that though the Chinese have helped, Pakistan is now quite capable of moving forward on is own.

(Map showing Shaheen Range overleaf)

Figure 6
Shaheen 1 Range

The Shaheen 2

The first launch of the two stage Shaheen missile took place on March 9th 2004. Subsequent launches took place on March 19th 2005 and April 29th 2006.[64]

Table 6 below summarises the measurements made on some of the images of these launchings. The details on each of the Images are available in the Appendix.

Table 6: Summary Measurements on Shaheen 2 Images

Image	Launch date	Warhead length[65]	2nd stage length [66]	1st stage length[67]	Length	Comments
Image 15	March 2004	3.18 m	3.53 m	5.19 m	11.88 m	Image of 1st launch
Image 16	March 2005	3 m	3.72 m	5.45 m	12.18 m	Measurements on images of the 2nd launch match well. They are reasonably close to the measurements from the 1st launch
Image 17	March 2005	3.2 m	3.45 m	5.40 m	12.05 m	
Image 18	March 2005	3.04 m	3.54 m	5.41 m	12 m	
Image 20	April 2006	3.38 m	3.65 m	5.65 m	12.68 m	Measurements of the 3rd launch match well. Increase in length compared to 1st and 2nd launches

We can see clearly from Table 8 that the length of the first 2 launches are clustered around approximately 12 m. Warhead lengths are approximately 3.10 m. 2nd stage lengths are approximately 3.56 m and 1st stage lengths are approximately 5.36 m.

The 3rd launch however seems to have an overall length of approximately 12.57 m which is higher than the values for the first two launches. The 2nd stage of this launch is quite close to the length of the 2nd stage of the other two launches. However, the warhead is longer and the 1st stage also seems to be marginally longer. The 3rd Shaheen 2 launch seems to be a stretched version.

These trends that we see in the Shaheen 2 substantiate what we had observed in our review of the Shaheen 1 programme – an increasingly sophisticated more customized approach towards the development of Pakistan's India-centric missile capability.

64 1 image of the 1st launch, 3 images of the 2nd launch and 4 images of the 3rd launch were available. 2 of the images of the 4th launch do not give measurements that are consistent with the other images. These 2 images have been taken out.

65 Length includes the interface with the rocket.

66 Includes the nozzle and the stage interface.

67 Includes the nozzle and the fin.

The 1st stage of the Shaheen 2 missiles though shorter than the stages of the Shaheen 1 are still longer than the stage lengths we measured for the M9 missiles. This substantiates the argument that Pakistan has internalized the transfer of technology and can system engineer the developments that it needs. Staging represents a substantial leap forward in terms of technology.

We can also see that the rocket motor length of the 2nd stage (2.08 to 2.25 m) is close to half the length of the rocket motor of the 1st stage (4.36 to 4.45m). These measurements can be used to estimate the quantities of propellants carried by the 1st and 2nd stages. From these the stage masses can also be estimated.[68] Using the stage masses, the lift off weight of the missile can be computed for various payloads. This works out to be 8134 kg for a payload mass of 1000 kg.

Using these values we estimated the cut off velocity of the 2-stage Shaheen 2. Range, time of flight and altitude reached were then estimated both for a 1000 kg and a 700 kg payload. The range is shown pictorially in **Figure 7.**

The range of the Shaheen 2 missile with payloads of 700 and 1000 kg is 851 km and 1136 km. The flight times and apogee altitudes for the 700 kg and 1000 kg cases are 506 seconds, 582 seconds, 245 km and 312 km respectively.

We can see that the much smaller 2 stage Shaheen 2 missile performs much better than the much larger single stage Ghauri missile.

As we know from our analysis of the Shaheen 1, Pakistan has a much bigger booster for the Shaheen 1. If this larger Shaheen 1 booster is coupled with the second stage of the flown Shaheen 2 we would expect a significant improvement in range. We have so far not seen any evidence of this new configuration. It could, however, be developed. Such a Shaheen 2 variant will have a range of at least 1142 km and 1489 km with a 1000 kg and 700 kg payload respectively.[69] **Figure 8** depicts the range for this improved Shaheen 2 variant.

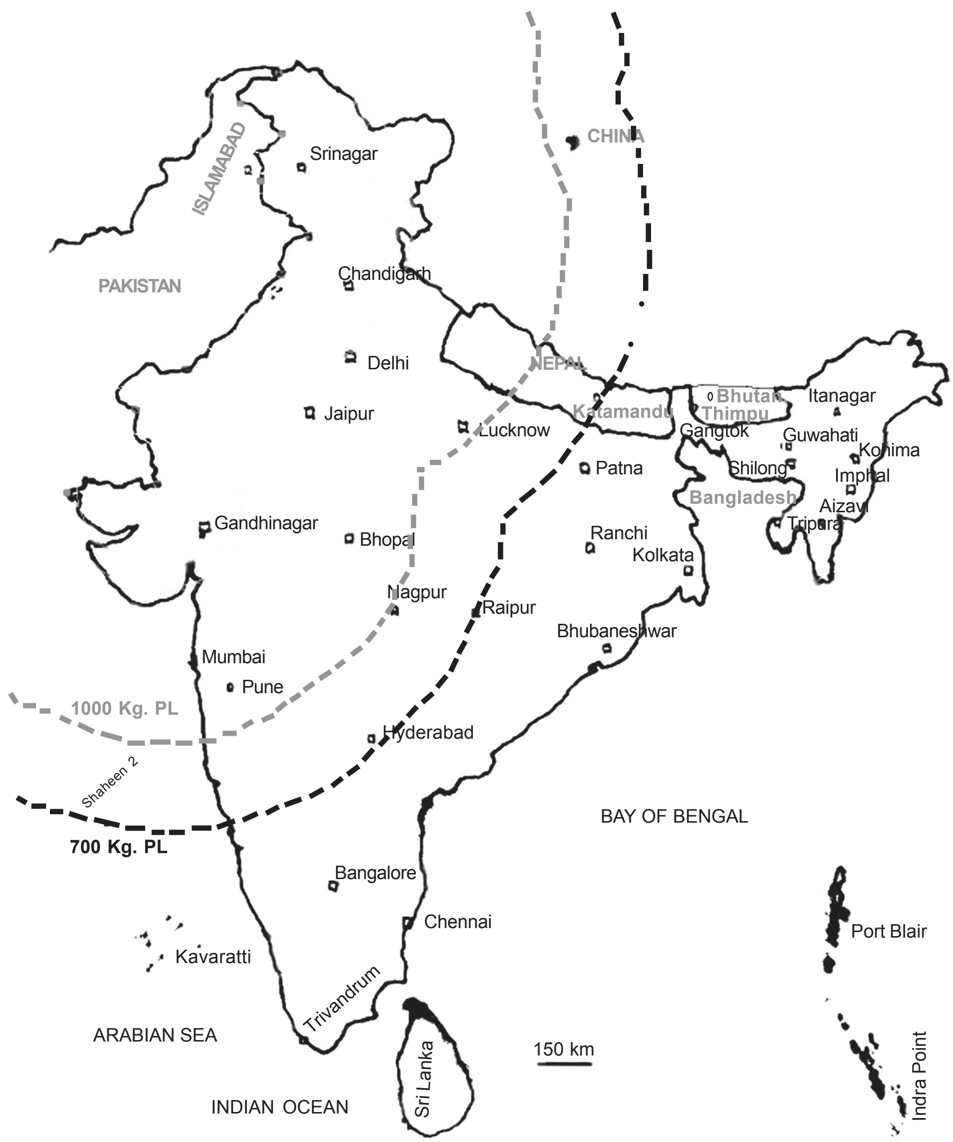
Though the variant we are talking about is not seen we can see that a combination of existing stages can provide Pakistan with a missile that can reach almost all parts of India. What has been seen in the 3 tests of the Shaheen 2 is only a limited version of the potential capability. Once stage separation has been mastered Pakistan can quickly build up the capability to deploy a larger

[68] From the image the length of the propellant grain of stage 1 works out to be 3.35 m which for a 1 metre diameter can accommodate 3802 kg of propellant with a first stage mass of 4752 kg. The 2nd stage propellant mass works out to be 1905 kg with a stage 2 mass of 2382 kg. For a 1000 kg payload the lift off mass works out to be 8134 kg.

[69] We have not carried out a detailed trajectory analysis for the variant but extrapolated from the Shaheen 2 data. One would expect to see a range greater than the one quoted here if a separate trajectory was run.

variant of the Shaheen 2.[70] It is our view that Pakistan can do this with or without Chinese help. **Deployment of the Shaheen 2 may start by the end of 2007 since 3 test flights have already taken place**. During this phase the limited capabilities of the Ghauri and the Shaheen 1 may be enough to take care of nuclear deterrence against an Indian pre-emptive strike.

Figure 7
Shaheen 2 Range



[70] If this logic (which we have seen in the testing phase of Shaheen 1) is to be considered valid, one would expect to see a longer first stage in the subsequent flights of the Shaheen 2.

Figure 8
Shaheen 2 Variant Range

An Overview of Pakistan's Missile Capability

We summarise below the conclusions we can make from this technical study of Pakistan's missile arsenal.[71]

Table 7: Pakistan Missile Overview

Missile	Range		Nuclear warhead	Status	Comments
	1000 kg warhead	700 kg warhead			
Ghaznavi	269 km	347 km	yes	Deployed	Shortened Chinese M11. Nuclear warheads may be transferred to longer range missiles
Shaheen 1	410 km	495 km	yes	Deployed	Based on the Chinese M9. Longer rocket motor. System engineering capability
Ghauri	818 km	928 km	yes	Deployed	North Korean technology. Liquid rocket. KRL management. Some failures
Shaheen 2	851 km	1136 km	yes	Service in 2008	2 stage missile. Significant capability. Deployment in 2008
Shaheen 2 variant	>1142 km	>1489 km	N.A	Not seen	This configuration possible but not seen so far.

It is well known that there are two groups within Pakistan looking at nuclear weapons and delivery vehicles. The Khan Research Laboratories (KRL) originally headed by A.Q. Khan is credited with Pakistan's acquisition of nuclear capability. They have been responsible for the Ghauri missile. The technology for this liquid fuelled missile was acquired from North Korea. The other group involved operates under the purview of the Pakistan Atomic Energy Commission (PAEC). They have been responsible for the development of solid rockets and missiles that include the Abdali, Ghaznavi, Shaheen 1 and the two-stage Shaheen 2 missiles. These groups had been working in parallel with independent control over both the development of missiles and warheads.

Based on our analysis the credibility and capability of the solid rocket group appears to be much better than their liquid rocket counterparts. As we have said earlier some of the claims on the Ghauri are not consistent with the available evidence. There are also problems with some of the images of the Ghauri that have been put out in the public domain. By contrast the solid group claims are more consistent. The rhetoric from them has been much more guarded and restrained. It is our view that major improvements in capability are more likely from this group.

As a part of our study we also carried out a technical evaluation of Pakistan capabilities in producing solid rocket motors in reasonable numbers. Both French and Chinese transfer of technology has happened. Our view is that much of this technology has been internalized and we

[71] We have not included the Abdali because it is a tactical missile.

think Pakistan would be in a position to build a new facility geared towards its operational strategic requirements. Whether it will do so or will it rely on its existing facilities is a moot point. An assessment of this is provided in a separate NIAS report which complements this report.[72]

However these perceived differences between two warring groups should not blind us to the capabilities of both the liquid fuelled and solid fuelled missiles in Pakistan's growing arsenal. Both the Ghauri and the Shaheen 1 have demonstrated capabilities and should be taken seriously by strategic planners and thinkers within India. The successful flights of the 2-stage Shaheen 2 will soon make most of India vulnerable to a Pakistani attack.

In view of its reliability the Ghaznavi will still be the most operational of the Pakistani missiles. A significant number of Ghaznavi missiles would have been equipped to carry nuclear warheads. As the Shaheen 1 and the Ghauri become operational some of the Ghaznavi warheads may be reconfigured to fit them. This is logical given that enriched uranium resources available to Pakistan may be limited. In such a situation one would expect a shift in priorities to missiles and warheads that can strike deeper into enemy territory.

After the departure of A.Q. Khan there is a possibility that some re-organisation and rationalization of the work being carried on by two independent groups will take place. Under President Musharraf's regime these may not create any major problems though it may create some bureaucratic turf battles.

The pace of launches and tests also indicates a major Pakistani commitment to create as quickly as possible a credible minimum deterrence that can target most of India. This focus and acceleration may be due to Pakistan's (President Musharraf) obsession on achieving strategic parity with India.

Information is now available from official sources or semi-official web sites about Pakistani capabilities and achievements. This is in sharp contrast to earlier practice. This may indicate a shift in thinking - from a tactical knee jerk kind of thinking - towards a more strategic rational view of India. Pakistan wants India and the rest of the world to know that it can protect itself against any pre-emptive attack that will deny it strategic parity. We believe based on our analysis that Pakistan will soon have within the next few years the capability to target most of India.

The maps provide additional information on current and projected capabilities of Pakistan's missiles.

[72] An analysis of Pakistan's Missile Production Capacity. NIAS report (forthcoming)

Implications of Pakistani Missile Capability for India

A self-contained nuclear warhead in the context of Pakistan is presumed to have a mass of between 700 and 1000 kg. As we can see from the attached maps the various Pakistani missiles have different ranges.

The Abdali missile (a variant of the Hatf 1 the first missile to be developed by Pakistan) has a range of 85 to 95 km with a 500 kg payload. With a heavier nuclear payload the range would be even less. In the context of India and Pakistan these missiles may not have a strategic role – though they would be used as tactical missiles during a conflict. Given their very short ranges it is unlikely that these missiles would carry nuclear warheads. This is particularly so in the context of limited supplies of enriched uranium. **Our assessment rules out the Abdali as a strategic nuclear threat to India**.

The first of the Pakistani missiles to pose a strategic threat to India is the Ghaznavi missile - a modified version of the Chinese M11 missile. Their range with a 700 to 1000 kg payload covers at least 3 major cities – Srinagar, Chandigarh, Ahmedabad and maybe the outer perimeters of the Delhi urban area. There is little doubt that significant numbers of these missiles have been transferred to Pakistan by China. Pakistan is also capable of producing them in some numbers. We would expect that there are at least a 100 of these missiles available to Pakistan. It is quite likely that Pakistan can produce them in reasonable numbers – maybe 15 to 20 a year.[73]

At the time Pakistan first acquired them (the early 1990s) many of them would have been capable of carrying a nuclear payload. It is also possibly the most reliable and most tested missile in the arsenal in view of its Chinese pedigree. As other longer range more capable missiles become available (the Shaheen 1, the Ghauri and the Shaheen 2) it is likely the nuclear warheads that were Ghaznavi compatible would be moved to fit into the other missiles. In spite of these moves one would still expect that a certain minimum number of Ghaznavi missiles would be nuclear capable because of reliability considerations. Keeping in mind potential targets (cities, big towns) we should expect at least 10 of these missiles to be carrying nuclear warheads. As other missiles become operational and if enriched uranium were in short supply the nuclear warheads could be moved out of the Ghaznavi into the more capable longer-range missiles.

There have been 7 launches of the Shaheen 1 missile including a possible nuclear version. The missile – a longer stretched version of the Chinese M9 missile – can be termed to have become

[73] These are our best estimates based on our study. Pakistan has in place a French supplied plant for the production of 560 mm propellant grains. This can be improved to produce larger grains.

operational. Put in a simpler way the nuclear tipped version of the missile can be used in the case of India Pakistan standoff today. In addition to the major cities of Srinagar, Chandigarh, and Ahmedabad, the Shaheen 1 can also definitely target parts of Delhi and its environs. Jaipur would also fall within its range. A large number of other mini cities and large towns would be covered. Based on the developments we have seen in the last 5 or 6 years deployment should have started in 2002. They may have about 20 missiles in the inventory and maybe about 10 of them could have a nuclear payload.[74]

The Ghauri missile has been tested 7 times since its first launch in 1998. It is a liquid fuelled rocket – carrying nitric acid and kerosene as oxidizer and fuel. It is clearly and unambiguously North Korean in origin. In spite of some anomalies in reports of its capabilities and testing, the evidence indicates that it has been successful in many of its 7 launches. In the event of a standoff and a nuclear confrontation it can be deployed. More recent estimates of range indicate that its actual performance may be slightly lower than earlier estimates. In addition to the cities of Srinagar, Chandigarh, Delhi, Jaipur and Ahmedabad, the cities of Mumbai, Pune, Nagpur, Bhopal and Lucknow could fall within the range of the Ghauri.

Since the Ghauri is liquid fuelled and uses corrosive and difficult to handle liquids – kerosene and nitric acid - the mobile launcher will have to be accompanied by separate tankers carrying the nitric acid and the kerosene fuel. The fuelling operation would also take some time maybe 1 to 2 hours during which the missile would be vulnerable. As easier-to-launch solid fuelled rockets become available these missiles may be phased out. We expect North Korea to have supplied Pakistan with at least 15 to 20 complete missiles as part of the technology deal. We also believe that Pakistan can produce about 5 to 8 missiles annually. Based on the schedule of observed launches an arsenal of about 30 missiles with about 15 of them being able to carry nuclear warheads would be a reasonable assessment of Pakistani capability.[75]

The Shaheen 2 is a two-stage solid fuelled rocket. It significantly enhances Pakistan's capabilities. 3 launches have taken place. The public evidence indicates that the launches seem to have been successful. Estimates of the range of the launched missile indicate all targets up to and including Hyderabad could fall within its range. The 3 launches of the Shaheen 2 used only a smaller Shaheen 1st stage. Pakistan has a bigger Shaheen 1 booster. If this was used as the 1st stage the range can increase further and even cities like Bangalore would be vulnerable. This Shaheen 2 variant is not visible yet.

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74 Based on a separate NIAS study that looks at production capabilities for the Shaheen 1 and 2. This study takes into account the cast cure cycle of propellant grains and the production of rocket casings. Pakistan has another production facility for the production of larger 1 m grains for the Shaheen 1 and 2 programmes.

75 Our estimate based on our production study.

The threat to India in the event of a nuclear stand off

- 10 Ghaznavi out of maybe about 100 missiles
- 10 Shaheen 1 missiles out of maybe 25 in inventory
- 15 Ghauri missiles out of maybe an inventory of 30 missiles
- A few Shaheen 2 missiles maybe 2 to 3 by 2008.

In spite of any possible counter-measures they could cause significant damage to India.

The National Security and Strategic Decision-Making System of Pakistan

The Organisation of the National Command Authority

There was an urgent need for Pakistan to establish an effective Command and Control Organisation over its nuclear weapons because of various international concerns in the immediate aftermath of the 1998 nuclear tests. Pakistan's nuclear command and control system formalises the roles to be played by the top military commanders in making decisions on the use of nuclear weapons. This system is very different from the system in India where the military has only a secondary role to play. Pakistan's defence authorities began organising a formal nuclear planning system and inter-service chain of command in early 1999. On February 7, 2000, Pakistan announced the establishment of a comprehensive command and control structure called the Strategic Command Organisation. This has three components - the National Command Authority (NCA), the Strategic Plans Division (SPD), and the Strategic Forces Commands (SFC). **Figure 9** provides an overview of the organisation of the Strategic Command Organisation of Pakistan. Based on this structure it is reasonable to assume that Pakistan has a well thought out operational strategic nuclear doctrine.

The NCA is responsible for the employment and deployment aspects of the nuclear force. It coordinates the development activities of strategic organisations, deals with arms control and disarmament matters, oversees the implementation of export controls and takes care of the safety and security of nuclear installations and materials. Each of the three services (the Army, the Air Force and the Navy) has its respective strategic force command. However, operational control over these strategic forces remains with the NCA. The Strategic Plans Division (SPD), which acts as the secretariat for the NCA, performs the overall coordination and control functions.

The final authority to launch a nuclear strike is dependent upon consensus within the NCA with the Chairman casting the final vote. At weapon launch sites the 2-3 man rule, codes, progressive alert status, etc., will be employed. Pakistan does not have a 'launch on warning' posture.[76]

The NCA responsibilities include policy formulation as well as the use and the development of strategic weapons systems. It is the chief decision-making body and operates under the chairmanship of the President. The Prime Minister is the Vice Chairman. The NCA has two committees operating under its ambit – the Employment Control Committee and the Development Control Committee.

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[76] Mahmud Ali Durrani, "Pakistan's Strategic Thinking and the Role of Nuclear Weapons", Occasional Paper No. 37 (Sandia National Laboratories: USA), p. 24

The Employment Control Committee (ECC) can be thought of as the external or international face of the NCA. Its function is largely related to justifying to the international community the rationale and purpose behind the use or potential use of nuclear weapons. One can assume that it would convene in a crisis to decide on suitable responses. The Chairman and Vice Chairman of the ECC are the President and the Prime Minister respectively. The Foreign Minister is designated as the Deputy Chairman of the ECC and may chair most meetings of the Committee. The ECC also includes cabinet ministers of defence, finance, interior, the Chairman of the Joint Chiefs of Staff Committee (CJCSC), the military chiefs, the head of the Strategic Plans Division (SPD)[77] and technical advisors.

The Development Control Committee (DCC) is the real power behind the formulation and implementation of the nuclear weapon use and deployment policy. It is responsible for the development and production of nuclear weapons, their related delivery systems and other support equipment. The Chairman and Vice Chairman of the DCC are the President and the Prime Minister respectively. The CJCSC is the Deputy Chairman of the DCC and may chair most sessions of the Committee. The other members are predominantly from the military and technical cadres and include the chiefs of all the 3 services. Representatives and heads of important technology organisations could also be members of the DCC.

It is clear from the broad responsibilities outlined that the SPD is a crucial and important part of the NCA. **Figure 10** provides some details about the responsibilities and the structure of the SPD. The SPD is headed by a Director General from the Army and comprises officers from the three services. The SPD has five Directorates:

- ❏ Operations and Strategic Plans Directorate
- ❏ Strategic Weapons Development Directorate
- ❏ The C^4I^2SR Directorate (Command, Control, Communication, Computer Information,
- ❏ Surveillance and Reconnaissance)
- ❏ Arms Control and Disarmament Directorate
- ❏ Consultancy Directorate

The SPD also has a cell called the Strategic Forces Command Planning (SFC) cell responsible for dealing with issues related to the use of nuclear weapons by the three services.

[77] The Strategic Plans Division (SPD) provides secretarial support to the NCA and handles all issues related to the nation's nuclear capability. The SPD functions directly under the President, the PM and the Chairman Joint Chiefs of Staff Committee. It is headed by a Director General from the Army and comprises officers from the three services.

We can therefore see that the SPD handles all aspects of the strategic programme on behalf of NCA.

The SPD

- formulates the country's nuclear policy, nuclear strategy and nuclear doctrine;
- formulates short and long-term development strategy and force goals for the strategic forces of the Army, Navy and the Air Force;
- formulates strategic and operational plans for the movement, and deployment of strategic forces of the three services;
- adopts measures for the safety and security of strategic assets;
- assists the President, Prime Minister, and the CJCSC in exercising control over strategic organisations and coordinating their financial, technical, developmental, and administrative aspects;
- provides military inputs to the Foreign Office and through them to the Conference on Disarmament (CD) in Geneva on international / regional arms control regimes, disarmament and related strategic issues; and
- coordinates and ensures the establishment of Strategic C^4I^2SR system (Command, Control, Communication, Computer Information, Surveillance and Reconnaissance) for the NCA for command and control of strategic assets with real-time linkages to the Services and Strategic Forces.

The third constituent of the management structure of the Strategic Command Organisation is the Strategic Forces Command. These are being raised as an important unit in all three services. The services retain training, technical and administrative control over their Strategic Forces. However, operational planning and control rests with the NCA under the overall military direction of the CJCSC via the SPD. The SPD coordinates all related aspects with service headquarters. The SPD seems to be the new power centre in Pakistan especially after 2000.

This structure, after providing for adequate discussions amongst interested parties, gives ultimate responsibility for decisions on the use of nuclear weapons to the head of government. **Figures 11a and 11b** also shows that the Army exercises oversight and control over the various entities of the NCA. It is clear that the Army controls and dictates the formulation and implementation of policy related to the development, deployment and use of nuclear weapons. **Figure 11a** explicitly describes the organisation related issue during the pre–Musharaaf pre-Pokharan period. After Musharaaf became President, the scientific organisations associated with the strategic capabilities of Pakistan have seen significant changes. A.Q. Khan and Ishaq Ahmed, the heads of KRL and PAEC respectively have been ousted and replaced with other more pliable heads.[78] A new organisation called the National Engineering and Scientific Commission (NESCOM) vested with the responsibility for missile development has been set up.[79] There also seem to be a closer integration between KRL (liquid propellant) and National Development Council (solid propellant) programmes. The PAEC seems to have emerged as the more powerful technological entity after this re-organisation. The spate of missile tests after a lull in 2001 and 2002, seems to indicate that the re-organisation has been effective and is working out well.

Pakistan's Nuclear Doctrine – Ambiguity of Use the Key

Pakistan's nuclear strategy and operational planning are under the control of the military. The officials and key policy makers in Pakistan made general statements during 1998 – 99 describing Pakistan's strategy as "minimum nuclear deterrence". However, unlike India, they did not make a "no-first-use" pledge. Pakistan cites India as its sole nuclear threat. Given Pakistan's conventional military inferiority, lack of strategic depth and its relatively smaller stockpile of nuclear weapons, survivability of its forces must be a top priority.[80] As the weaker side in the highly asymmetrical conventional military balance, and the less asymmetrical nuclear balance, Pakistani planners are likely to conclude that only the threat of an ambiguous first-strike option will provide maximum nuclear deterrent credibility. Pakistan's weakness means a first-strike doctrine cannot annihilate India at this point in time. Instead it is intended to signal that escalation to crossing the threshold may not be gradual but sudden and extreme, with catastrophic consequences for India. Even if Pakistani planners operationally define the "red lines" that would set nuclear strike preparations in motion they would not publicly acknowledge these thresholds. Ambiguity, in their view, would contribute to deterrence and stability.[81]

This assessment seems to have been borne out. In January 2002, General Kidwai, Head of the SPD was interviewed by Italian non-proliferation researchers from the Landau Network – Centro Volta.[82] Kidwai said that Pakistan's nuclear weapons are stored in a disassembled state but can be assembled "very quickly." He added that Pakistan had no interest in developing battlefield nuclear weapons for artillery.

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78 More recently Karim Ahmed and Anwar Ali are reported to have become heads of KRL and the PAEC replacing J.A Mirza and Pervez Butt.

79 NESCOM is headed by Dr. Samar Mubarak Mand who appears to have become more powerful with responsibility for a closer and better knit missile development programme.

80 Rodney Jones, "Pakistan's Nuclear Posture: Quest For Assured Nuclear Deterrence - A Conjecture," Institute of Regional Studies, Islamabad, Pakistan, January 2000.

81 Hussain Haqqani, "Withdraw the Indian Threat of War," International Herald Tribune, 11 June 2002.

82 Maurizio Martellini, Paolo Cotta-Ramusino, "Nuclear Safety, Nuclear Stability and Nuclear Strategy in Pakistan," January 2002 (www.landaunetwork.org)

Moving on to the issue of deterrence Kidwai said, "In case deterrence fails, they (nuclear weapons) will be used if:

- ❑ India attacks Pakistan and conquers a large part of its territory
- ❑ India destroys a large part of either Pakistan's land or air forces
- ❑ India proceeds to the economic strangling of Pakistan
- ❑ India pushes Pakistan into political destabilization or creates a large-scale "internal subversion."

Questioned about the stability of this strategy, Kidwai stated that India and Pakistan would follow "rational decision making" and stay away from the nuclear threshold. He added that Pakistan does not currently plan to develop and publicize a nuclear doctrine like the draft one released by India in 1999.

Power Politics – the Dominant Role of the Army

Over all, the military in Pakistan is the most powerful institution and has been called the backbone of the nation.[83] The primary reason for the military's emergence as the most influential element in defence decision-making lies in the significant role it plays in the country's power politics. The military in Pakistan has always taken the responsibility of guarding Islamic ideological identity and safeguarding its frontiers and borders. The defence decision-making circle is characterised by the presence of a strong pro-military lobby. It is also very clear that the Pakistan Army has enjoyed more influence in policy matters than the other two services and the office of the Chief of the Army Staff has emerged as the focal point of power. He calls the shots not only in military matters but also in political and ideological matters. He is the piper who plays the tune that others march to. The reason for the military's emergence as the most influential element in defence decision-making lies in its significance in the country's power politics. It assumed the responsibility of guarding Islamic ideological identity and the frontiers of the country.[84]

The Army's influence has also prevented the other services (the Air Force and the Navy) from exercising influence during their tenure as JCSC. The institution of JCSC was founded primarily with the political aim of curbing and curtailing the Army's influence on Pakistan's power politics. The plan never succeeded because of the dependence of all ruling regimes on the Army for their political survival. In 1999 the Chairmanship of the JCSC was given to the Army bypassing the

[83] There is a general consensus on this fact among academics in Pakistan.

[84] Ayesha Siddiqa - Agha, "Pakistan's Arms Procurement and Military Buildup, 1979 - 1999: In Search of a Policy", (Sang-e-Meel Publication: Lahore, 2003), p. 56

Navy's turn to head this influential office. The position of Chairman JCSC was given to the Army Chief, General Pervez Musharaf, an action, which made the Army dominant once again in the decision making process. As we now know the rest is history.

The Pakistani Army's predominant position in power politics and policy-making can also be attributed to certain personalities such as General Zia-ul-Haq. During his rule the Army's power over political matters increased even though it also perpetuated the imbalance between the Army and the other services. Zia's regime was also instrumental in enhancing the image of the Army chief in Pakistan's decision-making process and politics.

The nuclear and missile organizations in Pakistan are not formally a part of the military establishment. However, the entire establishment works very closely with the Pakistani Army. As mentioned earlier, the Army in Pakistan is also the dominant factor in nuclear decision-making. The nuclear weapons programme codenamed 'Project 706' has always been under the command of the Army.[85]

The Power and Functions of the Civilian Bureaucracy in Pakistan

The civilian departments involved in defence decision-making are:

- The Ministry of Defence (MOD)
- The Ministry of Finance (MOF)
- The Ministry of Foreign Affairs (MOFA)

These ministries play a subordinate role to the military bureaucracy in matters related to strategic decision-making. This aspect is clearly seen in the allocation of roles and responsibilities between the Employment Committee of the NCA and the Development Committee of the NCA. The Employment Committee, which has a large number of civilians with the Foreign Minister as the Deputy Chairman, is directed by the Development Committee under Army control.

The Ministry of Defence (MOD) organisational structure has been designed to make sure the military role in matters related to defence and strategy remains firmly under the control of the military. Serving and retired military officials are posted and given important positions in the Ministry so that they can control and also help in fulfilling the demands of the defence establishment. The two additional secretaries in the defence production division, and the three in the defence

[85] Ibid; p. 67

division, are posted to the MOD from the three services of the armed forces. These important second in command positions enable the military to manipulate the largely subordinate civilian workforce involved in various defence related activities and industries. It was argued that such things would help in easing the problems that civilian bureaucrats might encounter in understanding the military's strategic requirements. This implicitly assumes that civilian officials of the Ministry were not capable of handling military affairs on their own. Pakistan has always had a culture where the political decision-making culture has been dominated by the military.

The other important Ministry is Foreign Affairs. However, the history in Pakistan shows no record of the military consulting this Ministry on defence and strategy related issues. The Foreign Office in Pakistan is rarely consulted in matters pertaining to military planning. The Kargil imbroglio is cited as an example of the communication gap between the Foreign Office and the military establishment.[86]

The third important Ministry in the civilian bureaucracy in Pakistan is the Ministry of Finance (MOF). The MOF controls the purse strings of the defence establishment. However, this Ministry cannot override decisions taken by the military. The decision taken by the Pak Army usually prevails. Administrative control of the armed forces and general military planning are areas where the armed forces do not allow any interference.

Other actors also play an indirect but very important role in building the influence of the military. These are - the military intelligence agencies, the religious fundamentalist groups and the media.

The Role of the Intelligence Agencies and the ISI

Pakistan's military intelligence agencies have played a significant role in its politics. They have also been involved with Pakistan's forays into Afghanistan and Central Asia. Though each of the three services has its own intelligence branch, the key role in the internal and external politics of Pakistan is played by the Inter-Services Intelligence (ISI). The power and influence of the ISI has increased substantially since the Soviet Union's invasion of Afghanistan. The ISI and the Army have often collaborated to further their mutual interests. In the 'Mehran' Bank scandal, money from the bank was given to the ISI to destabilise Z.A.Bhutto's government. The chief executive of the bank, Yunis Habib, admitted that he had provided General Mirza Aslam Baig, the then Army Chief and the ISI with fourteen million rupees to be used for manipulating the 1990 elections.[87]

86 Ibid; p. 72.

87 Ibid; p. 76

The Army controls the ISI. In spite of the ISI chief being appointed by the Prime Minister, the core of its personnel is drawn from the Army. This provides the Army chief with substantial leverage in using the institution to serve the greater organisational interest of the armed forces.

Robustness of Nuclear Command and Control Systems

It is true that the people involved in the nuclear establishment in Pakistan are formally not a part of the military bureaucracy. But at the same time, the nuclear establishment works in tandem with the Army, which plays a dominant and important role in nuclear decision-making. The linkages between the nuclear establishment and the Army can be understood from historical evidence. There was an upsurge in the number of Army officers posted at Kahuta especially after Zia's take over of the country.

As discussed earlier, the Strategic Command Organisation consists of three constituents – the NCA, the SPD and the SFC. This structure of the Nuclear Command Authority makes it highly unlikely that an unauthorised use of nuclear weapons will occur. The linkages between all the constituents and the norms and procedures that will be followed provide for a robust and stringent command and control system. However, this robust design per se does not rule out the possibility of accidental war in the Indo-Pak context.

As we can see from the above details, Pakistan has in place a reasonably rugged system to ensure that nuclear weapons will be used only after due authorisation of a central command authority. There are enough check and balances in terms of organisation design that preclude inadvertent and accidental use. Currently the military and more specifically the Army is in charge. The command to use nuclear weapons can only come after clearance by the highest authority and is implemented through the SPD bypassing the individual authority of the Army, Navy or the Air Force. This is, of course, a positive sign that makes accidental war less likely and the system more robust.

While this part of the security apparatus appears to be moving along the right lines other parts of the security system though not directly connected to the nuclear command authority could create conditions that could threaten the nuclear status quo. India has witnessed two major crisis points in its post-Pokhran relationship with Pakistan. One was the mini war over Pakistani incursion into Kargil and the other was the confrontation between the forces of the two sides along the border as the consequence of terrorists attack on India's Parliament. There is also the recurrent problem of terrorism in Kashmir which showed a very pronounced intensification just prior to the border confrontation between the two sides. The ISI and the Army which runs the ISI appear to be a parallel power centre whose actions could create a problem that could spiral into a potential conflict. These crises situations have raised questions about the stability of deterrence in the sub-continent. This is the issue that we would like to address in our next section.

Issues related to Deterrence and Stability

Ballistic missiles in Pakistan as in other countries serve as both potential war-fighting weapons as well as delivery systems for nuclear weapons. There is a clear linkage between nuclear deterrence and ballistic missile capability. The military capability of any nation is critical to deterrence, whether it is based on conventional or on nuclear weapons. For example, George Fernandes, India's former Defence Minister, made the following statement on April 23, 1999 "*The acquisition of a missile system capable of delivering conventional or nuclear warhead bridges a key gap in the nuclear deterrent profile of the country. The double distinction of being a nuclear-capable and possessor of the means of delivery means that India can hold its head high without fear of being bullied in a hostile security environment. China with its vast nuclear arsenal, Pakistan with its nuclear weapons and delivery system capability, America perching in Diego Garcia and 8 other Asian countries possessing missiles is quite a grim security scenario.*"[88]

In the formative stages of the US-Soviet nuclear competition, deterrence theorists identified a *stability-instability* paradox associated with the acquisition of offsetting nuclear weapon capabilities. The essence of this paradox was that nuclear weapons were supposed to stabilise relations between adversaries, and to foreclose a major war between them. At the same time, offsetting nuclear capabilities might well increase instability by encouraging provocations and conflict at lower levels – precisely because nuclear weapons would presumably provide protection against escalation.[89]

Many observers of South Asia have accepted Kenneth Waltz's position and have argued that the nuclear weapons force India and Pakistan to adopt a more cautious, less bellicose approach toward each other.[90] In their view, the possibility of large – scale, deliberate conventional conflict between the two States has lessened considerably, and nuclear deterrence ultimately will compel restraint, de-escalation, and disengagement on both sides.[91] Other scholars in India, Pakistan and the USA have argued that nuclear and ballistic missile proliferation will increase the likelihood of crises, accidents, and nuclear war.[92]

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[88] Press Information Bureau, Government of India, Internet: www.nic.in/india-image/pib/f230499.html and also quoted by Joseph Cirincione in his paper on "Indian Missile Deployments and the Reactions from China", Jane's Defence Review, May 1999, p. 3.

[89] Michael Krepon and Chris Gagne, eds., *The Stability -Instability Paradox: Nuclear Weapons and Brinkmanship in South Asia*, Report no. 38, June 2001 (The Henry L. Stimson Center, Washington, D.C.), Internet: www.stimson.org

[90] Kenneth Waltz, "More will be better", *The Spread of Nuclear Weapons*, (New York), 1995, pp. 47-91

[91] Maleeha Lodhi, 'Security Challenges in South Asia", *Nonproliferation Review*, v. 8, Summer 2001, p. 119.

[92] Kanti Bajpai, "The Fallacy of an Indian Deterrent", in Amitabh Mattoo, ed., *India's Nuclear Deterrent: Pokhran II and Beyond,* (Har Anand: New Delhi), 1999, pp. 150 – 188. Samina Ahmed, "Security Dilemmas of Nuclear-armed Pakistan", *Third World Quarterly*, v. 21, n. 5, September 2000, pp. 781-93. Scott Sagan, "More will be worse", in *The Spread of Nuclear Weapons*, (New York), 1995, pp. 47 – 91.

The recent crises in the Indian subcontinent have tested nuclear deterrence theory against the complex realities in South Asia. These crises have also renewed a debate on the viability and feasibility of nuclear deterrence and the role of ballistic missiles in Southern Asia. The South Asian context is quite different and in some ways more volatile than the historic U.S. – Soviet rivalry. The nuclear historian Scott Sagan notes that India and Pakistan have more in common than the Americans and the Soviets, who were on opposite sides of the globe and viewed each others as mysterious, often unpredictable adversaries. In contrast to the subcontinent, the U.S. and Soviet rivalry was ideological without disputed territory and a history of armed conflict.[93] Operationally the U.S. and Soviet Union maintained large nuclear-armed missile and bomber forces on hair-trigger alert status while both India and Pakistan separate delivery systems and nuclear weapons providing a stabilising delay.

The fear of retaliation is central to the concept of deterrence. One view could be that Pakistan seems to be losing this fear as exemplified by its 1999 Kargil incursion. Pakistan has never declared a no-first-use policy and there is a growing fear in India about the threshold at which Pakistan might like to use nuclear weapons. India must therefore avoid putting Pakistan into situations where it feels it has no alternative but to use its nuclear weapons. During the 2002 crisis (which lasted for more than ten months), India restrained herself from undertaking 'hot pursuits' in Pakistan–occupied Kashmir despite a number of provocative Pakistani actions.[94] Thus India's over-reliance on nuclear weapons for deterrence, combined with a no-first-use policy, actually seems to be adversely impacting its strategic choices.

Nuclearisation of South Asia has not yet brought about a period of détente and stability between India and Pakistan. India and Pakistan have had continuing skirmishes, a small war, and a near-war since they went overtly nuclear in May 1998. Although, there was a brief period of détente represented by the Lahore summit of February 1999, the "spirit of Lahore Declaration" was crushed by the Kargil conflict of June 1999 and disputes have grown more intense and more frequent since then. Hence, Kenneth Waltz's argument of stability does not appear to be applicable within the context of India and Pakistan.[95] However, deterrence has to be demonstrable to be effective. The current level of mistrust between India and Pakistan could be an obstacle to the creation of a stable deterrence. The ongoing peace moves and talks seem to be reducing the existing mistrust. This could lead towards a more stable scenario between the two countries.[96]

[93] Scott Sagan, 'The Perils of Proliferation in South Asia", *Asian Survey*, v. XLI, N. 6, 2001.

[94] Arvind Kumar, "Nuclear Deterrence: Waning Motif", *Deccan Herald*, August 22, 2002.

[95] Kenneth Waltz, n. 91.

[96] Whether current problems between India and Pakistan are transients towards a more stable position or are indicative of inherent instability is an open question for discussion.

Will the nuclearisation of the sub-continent stabilise the confrontation between both sides and reduce the threat of all kinds of wars? Or will it actually promote the testing of each other's will and resolve through a series of continuing skirmishes and conflicts on the assumption that neither side could afford to escalate the problem to war? Which of these perspectives is the right one?

Are There Any Alternatives to Deterrence ?

The information available (substantiated in this study) indicates that Pakistan may have currently about 35 to 40 nuclear tipped missiles in its arsenal. The ranges of these missiles vary from about 300 kms to about 1200 kms. Missiles with larger range could also be under development. Pakistan will add to this arsenal as nuclear material to make bombs becomes available. While some of the nuclear weapons may currently be carried on aircraft one would expect a larger fraction of them to move to a missile basing. The fact that the missiles of both India and Pakistan are designed for mobility makes it unlikely that a pre-emptive first strike by either side would completely eliminate the threat of retaliation. Even with the current arsenal of about 40, Pakistan would be in a position to inflict considerable damage on India even if some of these 40 missiles were taken out in a first strike by India. The same can be said of Pakistani attempts to take out the Indian arsenal. This is the classic two-person game where the payoffs for the two strategies of pre-emptive strike and deterrence can be represented as a 2 by 2 matrix. We can easily see that both [pre-empt, pre-empt] and [deterrence, deterrence] are Nash equilibria when the strategies of both parties are taken together. Thus in the early period after both countries went nuclear, possibilities of either country tilting towards pre-emption are as likely as the expected tilt towards deterrence. If we bring in fear, mistrust, lack of communication and complex national security systems with

The Deterrence Pre-emption Payoffs in the India Pakistan Game

	Strategy	**Pakistan**	
		Pre-emptive strike	***Deterrence***
India	***Pre-emptive strike***	Bad for India, bad for Pakistan **(Nash equilibrium)**	Bad but not so bad for India, very bad for Pakistan
	Deterrence	Very bad for India, bad but not so bad for Pakistan	Good for India, Good for Pakistan **(Nash equilibrium)**

organisational agendas different from the national agenda, there is a fairly strong case for a [pre-emption, pre-emption] strategy to influence strategic thinking on both sides. Such possibilities are more likely in the immediate period after two countries go nuclear as some parties on both sides may want to test the other side's resolve. This would be the period of greatest risk. Both Kargil and the standoff along the border triggered by a terrorist attack on India's Parliament can be seen as evidence of a move towards an unfavourable [pre-emption, pre-emption] Nash equilibrium. The possibility that threats and counter-threats that are a part of such moves - could either by default or accident - trigger something more serious is certainly a concern during this early period.

As time goes by and both countries and their leaders become aware of the real risks, it is likely that both countries will move away from the [pre-emption, pre-emption] strategy towards a [deterrence, deterrence] strategy. Though the choice of (deterrence by India, deterrence by Pakistan) would be the best for both parties one cannot automatically assume that this will be the immediate logical outcome of the game. Both countries will have to work hard to make sure that the desirable outcome of deterrence is reached.

How do these concepts translate into practice on issues of war and peace between India and Pakistan? If we assume that India has about a 100 missiles that can reach Pakistan and Pakistan has about 40 missiles that can reach India and if we assume that pre-emption on both sides is equally effective at about 50%[97], a nuclear war between the two sides would transform the conceptual matrix shown above into something like the one below. If India attacks first, 20 Pakistani missiles would hit Indian targets and all 100 Indian missiles would hit Pakistani targets. If Pakistan attacks first then 40 Pakistan missiles will hit Indian targets and 50 Indian missiles will hit Pakistani targets. If both countries fear pre-emption from the other side they could both launch missiles very quickly. In such a situation we could expect that the damage to both sides would be very high.[98]

The strategy of pre-emptive strike and deterrence adopted by either India or Pakistan can be understood by a two-by-two matrix[99] in a game theory model. As mentioned above if both India and Pakistan go in for pre-emptive strikes (attacking industrial centers and military installations) then there would be heavy casualties on both sides. The largest concentrations of industrial centers in India are in Maharashtra and Gujarat and in Pakistan they are around Karachi and Lahore. It is estimated that if both countries choose to use a 15 KT device (Hiroshima type of bomb), then the expected casualties in India would be around 13 millions and it would be 33 millions deaths in Pakistan. The studies[100] have shown that about one third of the population become casualties if a 15 KT device is used.

[97] A pre-emptive strike will destroy 50% of the enemy's arsenal.

[98] We can assume different probabilities and generate a variety of scenarios. Except in the very early stages of a weapons build up where there is a window of potential vulnerability retaliation may always be expected.

[99] The assumption made here is that each location will have a vulnerable population of 1 million people and casualties in the case of a nuclear strike will be one third of the population. These are reasonably consistent with the Hiroshima experience. India will target 100 locations in Pakistan and Pakistan will target 40 locations in India. All missiles will be effective in case of a pre-emptive strike.

[100] The calculations of the numbers (in terms of casualties) of deaths have been done on the basis of the following studies:

UN Study, "The Basic Framework of Disarmament", 1967; Michael E. Howard, "On Fighting a Nuclear War", International Security (USA), Vol. 10, n. 4., 1986; William Daugherty, Barbara Levi and Frank Von Hippel, "The Consequences of "Limited" Nuclear Attacks on the United States", International Security (USA), Vol. 10., n. 4., 1986; M.V. Ramanna, "Bombing Bombay? Effects of Nuclear Weapons and A Case Study of a Hypothetical Explosion", IPPNW Global Health Watch, (International Physicians for the Prevention of Nuclear War: 1999), Report no. 3.

The matrix also suggests that if India attempts pre-emptive strike and Pakistan retaliates by second strike then the casualties in India would be roughly 6.5 million and 33 million deaths would take place in Pakistan.

If Pakistan chooses pre-emptive strike then there would be around 13 million deaths in India. Under this case, India' survivable second-strike capability would inflict damage on Pakistan. It is estimated that around 16.5 million people would die in Pakistan.

Casualties in an India Pakistan Nuclear Exchange			
	Strategy	**Pakistan**	
		Pre-emptive strike	***Deterrence***
India	***Pre-emptive strike***	13 million deaths in India, 33 million deaths Pakistan **(Nash equilibrium)**	6.5 million deaths in India, 33million deaths in Pakistan
	Deterrence	13 million deaths in India16.5 million deaths for Pakistan	0 deaths in India, 0 deaths in Pakistan. **(Nash equilibrium)**

If both the countries decide not to cross the threshold then there will not be any casualties

From the above matrix if India chooses pre-emption, both deterrence and pre-emption are equally unattractive to Pakistan (33 million deaths in either case). A priori there is no specific reason why Pakistan should choose deterrence especially if it fears India. Should Pakistan expect India to follow deterrence its best response strategy is also deterrence.

By the same logic if India expects Pakistan to follow a strategy of pre-emption its best response can either be pre-emption or deterrence. They are both equally unattractive (13 million deaths in either case). If on the other hand India expects Pakistan to follow a strategy of deterrence its best response would also be deterrence.

We can easily make the inference that there are two Nash equilibria as the solution to the above payoff matrix. Both [pre-emption, pre-emption] and [deterrence, deterrence] are potential solutions to the game. If the game is played over a single period (which we can take to mean the early period after both countries went nuclear) there is no reason to assume a priori that the [deterrence, deterrence] joint strategy would win over the [pre-emption, pre-emption] strategy. In the real world the national security systems of both India and Pakistan are complex. There are multiple organizations and multiple powerful players all pursuing agendas that may not sum up to what is in the national interest. Their perceptions of risk of escalation may also be quite different. One could therefore expect different parts of this complex to respond differently to problems and crises as they emerge. Some may see deterrence while others may see pre-emption and act accordingly. The security complex may also be trying to co-ordinate actions and learning how to manage a nuclear arsenal. This period may be a particularly dangerous transition period during which the possibility of escalation of any small problem could be quite high. Kargil and the border standoff represent responses that typify this instability or vacillation between two Nash equilibrium points.

As the action reaction scenario unfolds and as altered perceptions, learning and understanding percolate through the national security complexes of both countries, one should expect a convergence towards the more rational strategy of [deterrence, deterrence]. This is what is hopefully happening between India and Pakistan currently. However, one should not forget that there are two equilibrium points and there could always be the inherent danger that the national security system on either side could easily tilt it away from a [deterrence–deterrence] strategy towards a [pre-emption–pre-emption] strategy. Both sides should therefore endeavour to make sure that the system stabilizes around a [deterrence, deterrence] strategy. This is the great challenge for both India and Pakistan.

Game playing and gamesmanship and sparring for temporary short-term gains should not blind the two countries to the fact that they are tied together by a common string that can be stretched only so far.

A number of reports suggest that India is interested in purchasing the U.S. – Israeli developed Arrow Missile Defence system from Israel. A number of recent reports have also suggested that U.S. might provide BMD systems to India.[101] The U.S may also provide the lower tier theatre missile defence (TMD) system to India. TMD systems are designed to intercept missiles within the atmosphere (using "endo-atmospheric interceptors") and are intended to protect relatively small areas against missiles with a range of 1000 kilometers or less.

Media reports suggest that the US would like to provide India with the Patriot PAC – 3 system. The PAC – 3 is an upgrade of the PAC-2 Patriot missile defence system, which was unable to cope with the inadvertent manoeuvres made by Iraqi Scud missiles during the first Gulf War. The original Patriot interceptor has been replaced by an entirely new missile called the ERINT. The ERINT seem to be much more manoeuvrable than the earlier Patriot interceptor and has a kinetic energy based hit-to-kill warhead instead of an explosive warhead with a proximity fuse.

Such sales could possibly trigger a regional offensive arms race. The Israeli Arrow 2 missile system is another option for a missile defence system. It is designed to provide terminal phase intercept

[101] Refer to the reports on Indo-US NSSP agreement and Secretary Condoleeza Rice's visit to India during March 2005.

against short and medium range ballistic missiles. It can detect and track up to 14 inbound missiles at distances of 500 km and then intercept them at distances of between 16 to 48 kilometers.[102]

During May 2003, India had discussed the sale of the U.S. Patriot Advanced Capabilities-3 or PAC-3 air and missile defence system with U.S. Deputy Secretary of State Richard Armitage.[103] This issue was raised again during Secretary Rice's visit to India in March 2005. Discussions on this possibility seem to have been underway with the Bush Administration since May 2002. However nothing concrete has happened on this so far. Raytheon is yet to provide India with pricing, availability and other related information that would be needed to begin the acquisition process. However, a media report suggests that the U.S. has cleared the sale of Patriot missile system to India.[104]

The implications of India acquiring ballistic missile defence systems have been debated among the members of strategic community in both countries. First of all, it might erode Pakistan's confidence in its missile capabilities. It could also break the current state of "mutual deterrence"[105] because of Pakistani fears of a pre-emptive Indian attack leading Pakistan to mate nuclear warheads with missiles to be ready to deal with an Indian attack. Pakistan might also like to pre-empt and employ its nuclear forces early in the conflict to penetrate defences. Even if these doomsday scenarios are not realised will a TMD system result in a superior position for India and will it win in a potential nuclear confrontation with Pakistan? The pay-off matrix provides an idea of the losses that both sides may incur in such a scenario.[106] We can see that there is no alteration in two Nash equilibria from the earlier case.

The damage to India even after the deployment of TMD is not substantially different from the earlier No TMD scenario. It is quite evident that in this scenario also the damage to both India and Pakistan would be high. The Patriot type TMD type systems have limited defence capabilities. They can be deployed only to protect strategic targets. Extending them to cover all vulnerable targets including major towns and industrial centres would require a very large-scale deployment and really major investments. There are also a number of simple fixes that Pakistan could develop to

[102] Andrew Feickert and K. Alan Kronstadt, "Missile Proliferation and the Strategic Balance in South Asia", CRS Report for Congress, October 17, 2003, CRS-16.

[103] Shishir Gupta, 'India Hopes for Patriot Nod", Indian Express (Mumbai), 23 May 2003.

[104] "U.S. Clears Sale of Patriot Missile System to India", Indian Express (Bangalore), June 15, 2005.

[105] Both India and Pakistan are believed to have their nuclear warheads and bombs separated from their missiles and delivery aircraft, thus providing a degree of security from undetected first use or accidental launch.

[106] The assumption made here is that India deploys TMD to protect 50 locations targeted by Pakistan. Since, Pakistan has the capability to target 40 of India's locations, it can suitably choose locations that do not have TMD. Hence, the argument made here is that even after deployment of TMD, the scenario would not be substantially different from the no TMD scenario.

counter them. There are a very large number of vulnerable targets in India and a TMD even if effective can only take care of a few of them.

We can see from the above analysis that the consequences of crossing the nuclear threshold for these scenarios are quite high for both countries. The bogey of a potential nuclear conflict on the sub-continent pre-supposes that India and Pakistan would behave irrationally. While there have been ongoing crises between the two countries in the early period after both countries went

Theatre Missile Defence & Nuclear War between India & Pakistan			
	Strategy	**Pakistan**	
		Pre-emptive strike Damage	***Deterrence Damage***
India	***Pre-emptive strike with TMD***	100 locations for India/ (13 million deaths in India. 33 million deaths in Pakistan)	PAK will not strike first India will strike first 6.5 million deaths for India, 33 million deaths for Pakistan
	TMD + Deterrence	13 million deaths in India 16.5 million deaths in Pakistan	0 India 0 Pakistan

nuclear, these have so far not led to any major nuclear confrontation - though there have been a lot of threats and counter-threats. As the countries engage with each other and learn to live with the nuclear reality deterrence may become the preferred approach to bilateral dealings. The post 9 / 11 environment has also had an impact with the US intervening to promote stability if needed. The possibility of accidental war also appears to be under control. Even introduction of things like the TMD may only raise the number of missiles and warheads but may not fundamentally alter the stability of deterrence.

Figure 9: National Command Authority of Pakistan–Organisation, Power, Authority

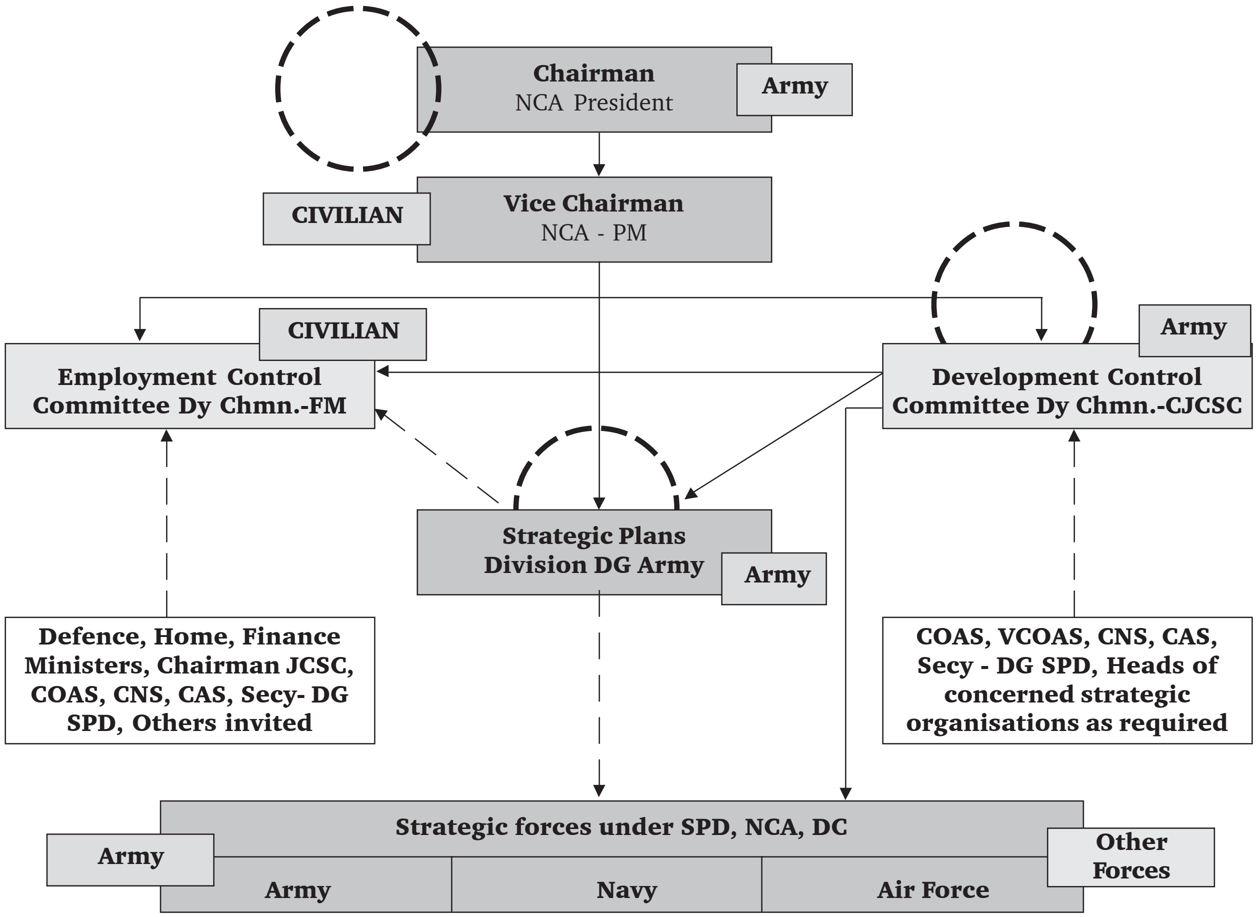
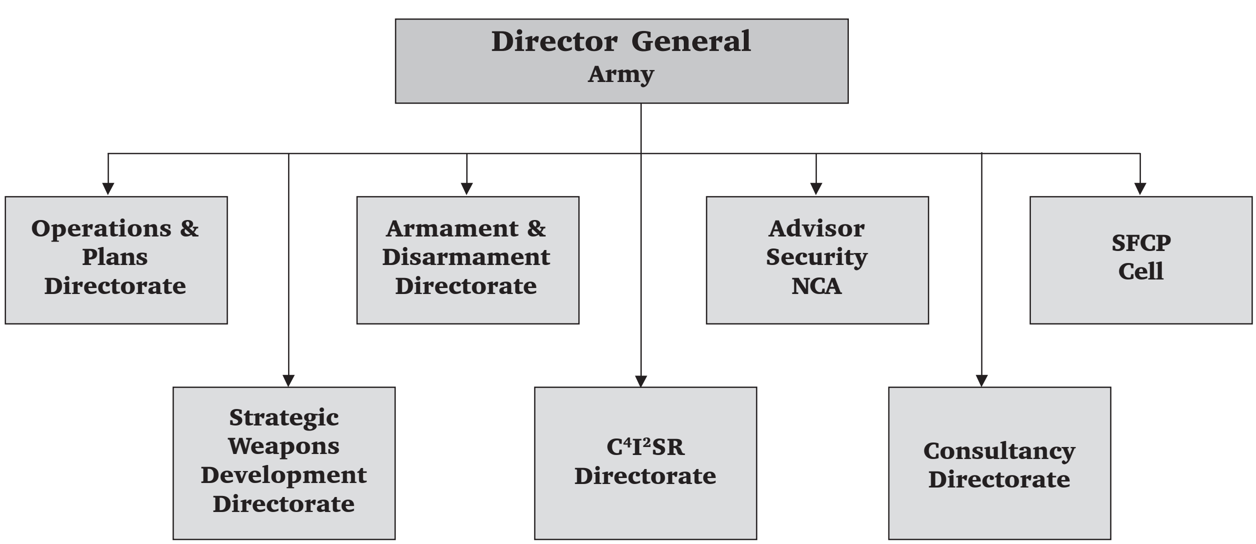


Figure 10: Organisation of the Strategic Plans Division



C^4I^2SR = Command, Control, Communications, Computer Information, Intelligence, Surveillance & Reconnaisance.
SFCP = Strategic Forces Command Planning

Figure 11a: Pre -Musharraf and Pre - Pokhran Organisations in Pakistan

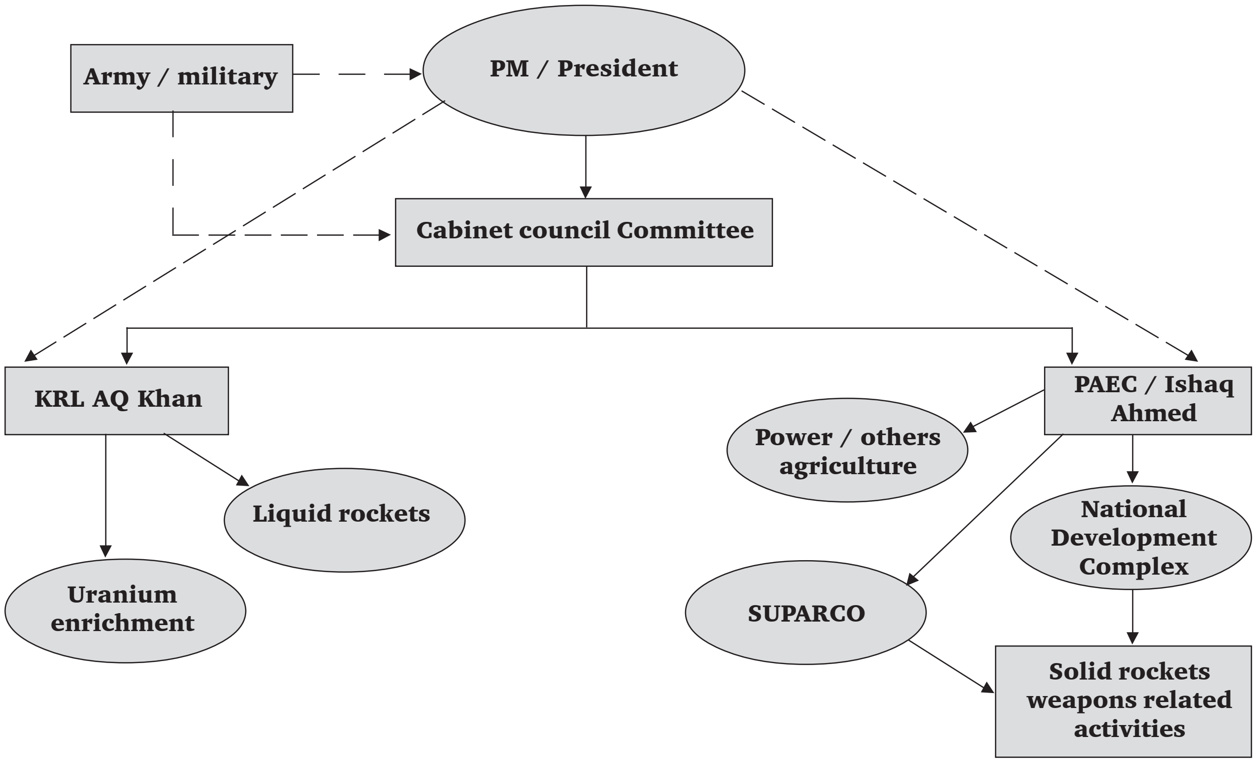
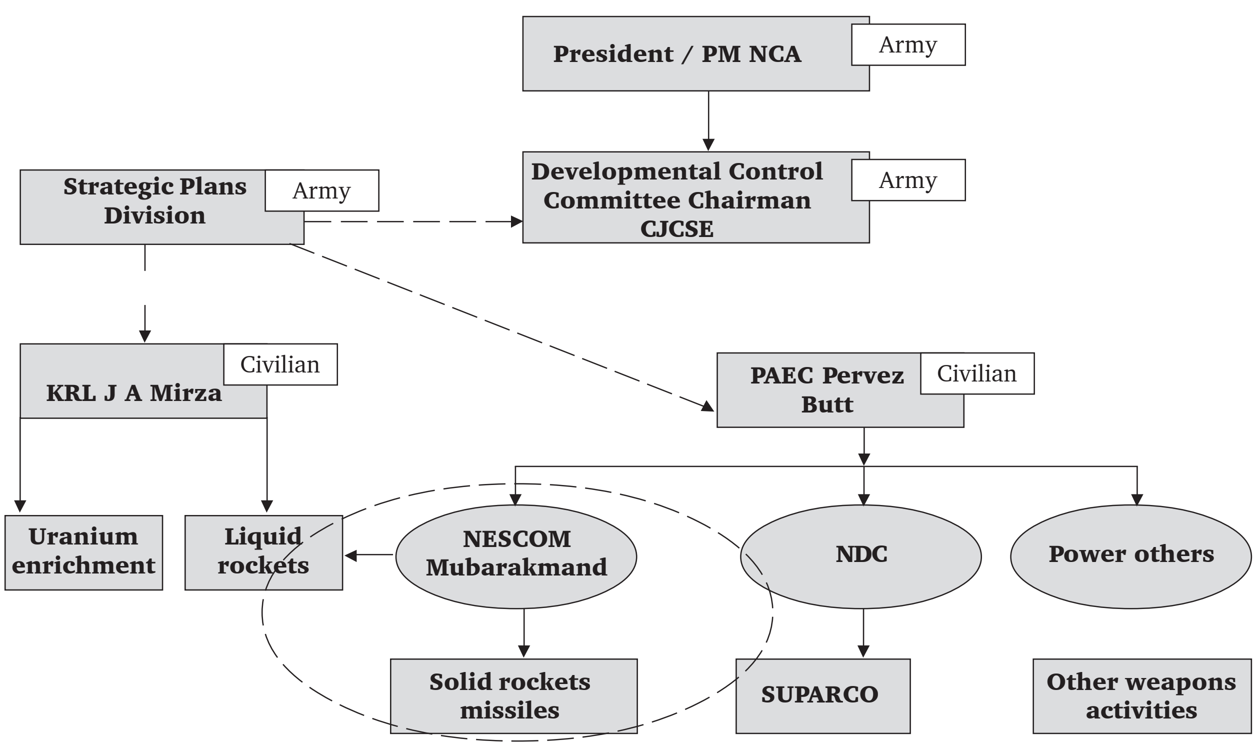


Figure 11b: Post Musharraf Organisation



Appendix - Image Analysis

The Abdali Missile

There are 6 images of the Abdali missile in the data base that we have created.

An analysis of the various pictures clearly indicates a trend of improving performance and capabilities. Early pictures of the Hatf 1 in flight (Image 1)[1] indicate that it is nothing more than a sounding rocket. The entire rocket is used for delivery of the payload. We can also see from the nosecone side of the Hatf 1 that it is not really very well designed to handle re-entry.

In contrast Image 2[2] which appears to be a later picture, shows a stream lined and superior shape. There is a clear separation between the nosecone and the main rocket motor. There is an interface between the rocket motor and the nosecone that smoothly tapers into the warhead section. Though not conclusive this change does indicate that the nosecone separates at some point before re-entry. The nosecone section that would carry the warhead may also be spun up before re-entry in order to improve the accuracy.

Images 3[3] and 4[4] are images of the Abdali taken from two different sources. As compared to images 1 and 2 they show some stretching of the length of the missile. The rocket motor and the warhead portion seem to have been stretched. They match the general shape of the improved missile seen in image 2 but are longer.

Image 5 is an image[5] of the missile ready for launch.

Image 6 shows the Abdali launching of February 19th 2006.[6] This launch appears to be very similar to Image 5 which is an image of the Abdali on the launch pad.

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1 This image is from the report in the Pakistani newspaper Dawn reporting the launch of the Hatf 1A missile in 2000 February. See http://www.dawn.com/2000/02/08.top1.htm

2 This is taken from the Tribune newspaper reporting the March 2003 launch of the Abdali. It may be a photo of an earlier launch. See http://www.tribuneindia.com/2003/20030327/world.htm#6

3 See http://www.bbc.co.uk/hindi/news/020529_missile for the image.

4 See http://www.pakistanpage.net/gallery/main/n/npak.html

5 See http://www.pakistanidefence.com/images/AbdaliPictures.htm

6 http://www.paktribune.com/news/index.php?id=134741

Measurements of some of the missile dimensions, based on a missile diameter of 0.56 m, are provided in the Table 8 below.

Table 8: Measurements on the Abdali Missile

Image	L/D ratio	Length (m)	Diameter (m)	Warhead + interface (m)	Rocket motor + nozzle (m)
Image 1 [7]	7.84	4.39 m	0.56 m	N.A	N.A
Image 2	7.81	4.37 m	0.56 m	1.72 m	2.65 m
Image 3	8.76	4.90 m	0.56 m	2.02 m	2.89 m
Image 4	9.61	5.38 m	0.56 m	2.24 m	3.14 m
Image 5	11.73	6.57 m	0.56 m	2.83 m	3.73 m
Image 6	11.50	6.44 m	0.56 m	2.68 m	3.76 m

We also compared the Abdali missiles nosecone and warhead section with a typical M11 Chinese missile. Though the Abdali missile is an indigenous programme with some French help, it is obvious that improvements seen in the Abdali missile warhead seem to have benefited from the Chinese connection.

The images clearly reveal an evolution in capability. Over a period of time there seems to have been both a stretching of the rocket as well as an improvement in the warhead part of the missile. From the early origins of a rocket motor of about 2.5 metres in length very similar to the length of the Dauphin / Dragon technology transferred in the early 1980s, the rocket motor has been extended to approximately 3 metres and then to less than 3.5 metres respectively for the 2 versions of the Abdali missile that we see in the images we have analysed.

From Table 8 above there are at least 2 larger versions having lengths of approximately 5.38 and 6.57 metres. The warhead portion seems to have a length 2.24 and 2.83 metres and the rocket motor lengths of 3.14 and 3.73 m. These are significant improvements over the original French capability. From some images the length of the propellant grain and the nozzle can also be separately estimated. (Table 9)

Table 9: Abdali Rocket Systems Measurements

Image	Warhead + IF length	Propellant grain	Nozzle length	Length (m)
Image 4	2.24 metres	2.52 metres	0.63 metres	5.38 metres
Image 5	2.83 metres	3.01 metres	0.72 metres	6.57 metres

7 There could be some errors in measurement of the rocket motor and nozzle lengths.

These pictures also suggest that there have been improvements in the Abdali missile over time. If the rocket motor is stretched by making it longer there is also a need to change the length of the nosecone section because the stretch would alter the centre of gravity of the missile. The interface would also become a bit longer.

Data available on the original French Dauphin[8] missile indicate a nozzle length of around 1 metre. Both the Abdali variants as well as the original Hatf 1 from which the Abdali missiles may have evolved have shorter nozzles.

These trends that we see in the images indicate that the agencies involved in the solid rocket programmes within Pakistan have acquired the capabilities to modify and improve upon the technologies they have gotten from other countries.

The Ghaznavi Missile

There are 7 images of the Ghaznavi missile that we were able to access. Of these images 3, 4 and 5 are reportedly images of the Ghaznavi launch of 29th November 2004. Images 6 and 7 are images of the December 9th 2006 launch of the Ghaznavi. 4 images of the M11 were also analysed to explore the technology links between them.

Image 1 of the Ghaznavi available in a semi-official Pakistani website shows the missile being erected from its Transporter Erector Launcher (TEL).[9] If the Ghaznavi is really an M11 variant, the TEL which is used to carry and erect the missile must be a Chinese copy of the Russian MAZ 543 TEL whose dimensions are well known[10]. The image makes it feasible to measure the width of the TEL. From the literature this width is known to be 3.02 metres. So if we can measure the width with some accuracy we can use this measurement as a basis for independently measuring the diameter of the missile and depending on the image we can extend this to getting reasonable measurements on other missile parameters.[11]

8 As per Sud Aviation sources the dimensions of the Dauphin sounding rocket are given as 6.21 metres in length and 0.56 metres in diameter. The 686 kg propellant Stromboli grain had a motor length of 2 metres. A variant of this with 740 kg of propellant used as the 2nd stage of the Bernice (a re-entry study rocket) had a stage length of around 3.2 metres. This would imply that for the 0.56 metres diameter rocket the nozzle length would be around 1 metre. Using the length of 6.21 metres this also implies that the Dauphin rocket has a nosecone length of 3.2 metres.

9 See http://www.pakistanidefence.com

10 Reports on the dimensions of the TEL for the SCUD series of missiles including the Scud B are widely available. Our analysis uses this as a basis for many of the measurements made on the images. A Russian version of the MAZ 543 data is available http://legion.wplus.net/guide/army/tr/maz543.shtml#R0. Another version (German) can be found in http://www.reserve-info.de/aridat/scud.htm. Data can also be obtained from the Trembikta website in the Ukraine at http://www.trembikta.com.ua/eng/auto/maz-53.html. There is also information available on Iraq's version of the TEL.

11 The dimensions we have used for calibration are the wheel base measures 2.2 metres : 3.3 metres: 2.2 metres (4 pairs of wheels which are independently driven giving rise to 3 wheel bases), the diameter of the tyre reported to be 1.5 metres, the width of the TEL reported to be 3.02 metres and the height of the TEL reported to be 3.03 metres. The length of the TEL varies depending on the missile being carried.

The diameter of the Ghaznavi using the TEL width as the calibration standard works out to be 0.9085 metres close to the publicly quoted value of 0.88m. The diameter value is in reasonable agreement with other assessments that relate the Ghaznavi to a Chinese solid rocket missile, the M11,[12] which in turn is based on the Soviet SCUD B missile whose diameter is known to be 0.88 metres.

If we use the publicly available value of 0.88 m for the diameter, the length works out to be 8.81 metres. The length of 8.81 seems to suggest that the 11.25 metre (SCUD B substitute) M11 length was reduced by about 2.5 metres before it was exported to Pakistan. These measurements on the first image are consistent with the Chinese origin of the Ghaznavi. The measurement on the warhead part indicates a warhead length of approximately 3.76 m. By subtraction the rocket motor stage length (propulsion + nozzle) works out to be approximately 5.05 metres.

The second image shows the Ghaznavi in flight[13]. Measurements indicate a Length to Diameter (L/D) ratio of 10.13 which is in reasonable agreement with the first image. If the publicly available value of the diameter is used (0.88 metres) the length works out to be 8.92 metres. The length of the warhead + interface part works out to be 4.01 metres. The length of the rocket motor + nozzle portion can be estimated as 4.91 metres.

Image 1 and image 2 are in reasonable agreement with each other. Evidence seems to suggest that the warhead part of image 2 is longer by about 25 cm.[14] Image 2 was also used to make an estimate of the surface area of the fin using the TEL dimensions as the standard. The fin area works out to be 0.471 sq. metres. Our liftoff calculations were refined using this value.

On November 29th 2004 Pakistan carried out a 3rd flight test of the Ghaznavi missile. 3 images of the missile available in the public domain were analysed.[15] Even though the quality of these images was not very good we were still able to make some measurements on them. The L/D ratio from these images of the November 29th 2004 launch ranged from 10.5 to about 11. Based on a diameter of 0.88 metres this translates into an average length of 9.48 metres. The average rocket motor length from the 3 images works out to be 5.17 metres and the average warhead length is 4.31 metres respectively.

[12] Reports seem to suggest that the original M11 was designed as a more reliable missile that could compete with the Soviet SCUD B in the export market. Once it became well known that the Chinese were exporting them to Pakistan, China apparently reduced the length of the missile to be in compliance with the MTCR guideline of a range of 300 km with a 500 kg payload. Our estimates suggest that the range of the Ghaznavi with a 500 kg payload exceeds the original MTCR limit.

[13] Images 1 and 2 are from http://www.pakistanidefence.com

[14] If a nuclear warhead replaces a conventional warhead since it is heavier some lengthening of the missile may be needed.

[15] "Pakistan successfully test-fires Hatf-III Ghaznavi missile" Pak Tribune: Monday November 29, 2004, online edition of 30th November 2004. http://www.paktribune.com/news index.php?PHPSESSID=8bed5ddbea402dd4c2177de36e4a09da&c=&m=11&d=30&y=2004&hId=0&nw=0. Also see http://www.tribuneindia.com/2004/20041130/main6.htm.

The 4th launch of the Ghaznavi took place on December 9th 2006. One of the 2 available images of this launch provided a reasonably accurate measurement opportunity.[16] The L/D ratio of this launch was 10.11 which translate into a missile length of 8.90 m. The length of the warhead was 4.1 m and the length of the rocket motor (including nozzle) was 4.80 m.

To explore the China connection a bit further we also used some publicly available images of the M11 available in a semi-official website.[17] 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 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 all Ghaznavi and M11 measurements are provided in Table 10.

Table 10: Ghaznavi & M11 Measurements

Image	**Length (m)**	**Diameter (m)**	**L /D ratio**	**Warhead length (m)**	**Remarks**
M 11 image 1	11.34 m	N.A	N.A	N.A No warhead fins	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.
Ghaznavi image 1	**8.81** m	**0.91 m estimate**	10.01	**3.80 m**	length and diameter based on TEL. Length 8.81 m based on 0.88 m diameter
Ghaznavi image 2	**8.92**	N.A	10.13	**4.01 m**	Lengths based on 0.88
Ghaznavi 3rd launch average	**9.48**	N.A	10.77	**4.31** m	Lengths based on 0.88
Ghaznavi 4th launch	**8.90 m**	N.A	10.11	**4.1 m**	Lengths based on 0.88 m diameter. Similar to Image 1, Image 2.

16 See http://www.chinadaily.com.cn/world/2006-12/09/content_754829.htm and http://mdn.mainichi-msn.co.jp/international/news/20061209p2g00m0in012000c.html for images of the December 9th 2006 launch.

17 A number of images and briefs on various facets of the Chinese military and defence programmes are available on the net. The images used are available at http://www.sinodefence.com/nuclear/df11.asp

For images 2 and 3 of the Ghaznavi an independent measure of the diameter is not possible.. Lengths are estimated on assumed diameters of 0.88 m.

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 suited for making an independent measurement of the diameter.

It would appear from these measurements that the 0.88 m assumption for the diameter of the M11 and the Ghaznavi 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. The measurements on the Ghaznavi missiles indicate warhead lengths of 3.76 m., 4 to 4.1 m and 4.31 m. The dimensions of the Chinese shorter warheads closely fit the warhead dimensions of the Ghaznavi missile.

There are also 3 incremental versions of the Chinese M 11 rocket motor with lengths of 5.76m, 6.17m and 6.54 m. The rocket motor lengths of the Ghaznavi missile as measured from the images are 5.05 m, 4.90 m, 5.17 m and 4.80 m indicating possibly two rocket motors with lengths of 4.80 to 4.90 m and 5 to 5.2 m respectively.

If we look at the shape and pattern of the Ghaznavi especially the warhead sections and the various dimensions and ratios there is compelling evidence to indicate that the Chinese have indeed supplied Pakistan with a shortened version of the shorter M11 variant. The warheads match closely with Chinese warheads. We can conclude that

- ❑ The Ghaznavi is a shortened version of the shorter variant of the Chinese M11 missile.
- ❑ The Ghaznavi can carry two kinds of warheads. These may be a conventional warhead and a nuclear warhead.[18]
- ❑ The warhead dimensions closely match warheads of the Chinese M11 missiles.
- ❑ The Chinese have however not transferred the longer version of their M11 missile nor the later more advanced longer (4.80 m) version of their warhead.[19]

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[18] The measured differences between the warheads for both the M11 and the Ghaznavi do not appear to be large enough for us to make the inference of a nuclear warhead. The Chinese M11 missiles do have nuclear warheads directed at Taiwan. This is clearly seen in the longest warhead they have tested. The Ghaznavi stretch of the warhead by about 25 to 30 cms may indicate a nuclear warhead. However, strategic considerations would suggest that Pakistan does indeed have capability to put a nuclear warhead on the Ghaznavi. It is also possibly the most reliable of their missiles.

[19] Public accounts of the M11 such as those found in the FAS website as well as other sources talk of a conventional warhead, a nuclear warhead and an improved warhead with nozzle control. See http://www.fas.org./nuke/guide/china/theater/df-11.html. These are also talked about by other sources http://www.sinodefence.com/nuclear/df11.asp

The public evidence is consistent with the Chinese transfer of a shortened version of the shorter variant of the M 11 missile to Pakistan. This version, which the Pakistanis call as the Ghaznavi, has a length of between 8.8 to 9.5 metres and a diameter of 0.88 m. The Ghaznavi can carry two warheads a warhead about 3.76 to 4 metres long or a longer warhead with a length of approximately 4.31 metres. The warhead dimensions as well as the general shape of the warheads closely match the warheads of the M11. The observed evidence is consistent with the Chinese origins of the Ghaznavi missile.

The Ghauri Missile

We looked at 16 images of the Ghauri for our study. Some of the images were not suitable for making accurate measurements. Table 4 in the main text summarises the measurements on the images that we used.

If we look at the images of the first launch[20] (images 1 and 2) the L/D ratios of 11.29 and 11.11 are reasonably close. We can make the inference that the first launch did have an L/D ratio of approximately 11.29.

There are two images of the April 1999 launch (image 3[21] and image 4[22]). Image 3 has an L/D ratio of 11.23 and image 4 has an L/D ratio of 12.48. Image 4 taken from a newspaper source on the day following the launch, is likely to be more authentic.

Image 3 which has a white band as a differentiator has an overall length and L/D ratio very close to that of Image 1. A closer look at the nosecone (red band) measurement would however seem to suggest that Image 1 and Image 3 are images of different launches.

Image 5[23] supposed to be the Ghauri launch of May 2002, has an L/D ratio of 12.48. As we can see from Table 4 its other measured parameters closely match that of Image 4. Its differentiating feature from Image 4 is a white band below the nosecone. Based on the measurements there is a fairly strong case for believing that Image 4 and Image 5 are the same image of the same launch.

Image 6[24] is presumed to be an image of the May 2004 launch of the Ghauri. It has an L/D ratio of 11.26. On blowing up the image it looks as though this is a doctored image. There seems to be

[20] Both images are from http://www.pakistanidefence.com

[21] Source: http://www.pakistanidefence.com

[22] See the newspaper Pak Tribune at http://www.tribuneindia.com/1999/99apr15/head4.htm

[23] Taken from http://www.pakistanpage.net/gallery/main/n/npak.html

[24] This image is taken from http://www.pakistanpage.net/gallery/main/n/npak.html

a white strip pasted on to the image. A plausible hypothesis is that an image of an earlier launch has been altered. We see from Table 4 that Image 1 has almost the same values as Image 6. It appears that a white strip has been pasted on to Image 1 in order to get Image 6. If a launch did take place successfully one would assume that an image would have been available. This does raise the issue as to whether the launch was successful.

Images 7[25], 8[26] and 9[27] are all related to the Ghauri launch of October 12th 2004. Image 7 from the Pakistanidefence.com site gives an L/D ratio of 11.31 which is close to the L/D ratio of the first Ghauri flight (Image 1). It has a white band below the red nosecone. Images 8 and 9 from the Tribune and Al Jazeera give L/D ratios of 12.64 and 12.51. These are consistent with each other. Both of them have white bands and though their measurements are close to images 4 and 5 on balance there are sufficient differences to infer that the October 12th 2004 flight did take place and the L/D ratio of the Ghauri launch on this date was between 12.51 and 12.64.

Images of the Ghauri in flight do not allow us to make independent measurements of various parameters of interest such as the length of the missile, the diameter of the missile or the length of the warhead. Images 10 and 11 are images of the Ghauri being readied for launch. People and parts of the TEL[28] used for launching can be seen in these pictures. These can be used in our study to see whether we could use them to get an independent measure of the diameter of the Ghauri missile.

Image 10[29] (L/D of 10.83) has people present reasonably close to the missile. Assuming some typical values of the height of a person we can estimate the length and diameter of the missile. Based on an average height of a person as 1.73 metres, the length of the missile works out to be 16 metres and the diameter 1.5 metres.[30] For all reasonable values of the height of the person the diameter measurements are much larger than what is reported in the published information. On technical considerations it is unlikely that the diameter will exceed 1.3 metres. The L/D value is also not in agreement with the flight images of the Ghauri.

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25 Taken from http://www.pakistanidefence.com

26 The Pak Tribune newspaper at http://www.paktribune.com/news/index.php?id=80137

27 http://www.aljazeera.com/cgi-bin/news_service/middle_east_full_story.asp?service_ID=5095

28 Unlike in the case of the M11 where there is sufficient public knowledge on the TEL there is not public material on the Ghauri / No Dong TEL. This makes possible only the use of TEL independent objects in the image to make independent measurements.

29 This image is available at http://www.bharat-rakshak.com/MONITOR/ISSUE5-4/arya.html. It is reported to have taken from the FAS website.

30 In a similar analysis David Wright in his article on the Ghauri reports a diameter value of 1.5 metres based on a reported length of 17 metres. He also questions the authenticity of the data source. See footnote 17, David C. Wright "An Analysis of the Pakistani Ghauri Missile Test of April 6, 1998", Science and Global Security 1998, Volume 7, pp 227-236.

For Image 11[31] the L/D ratio of 10.89 is consistent with the L/D ratio of Image 10. Independent estimates of the diameter made from the image give values of the diameter that are much larger than the 1.3 m diameter that one should expect.

One possible explanation for the differences we see in these 2 images may be that they are dummy missiles used to train the troops. There is a practice of the Chinese doing training exercises with dummy missiles during the early days of their programme. Possibly what we are seeing here is also something similar.

On November 16th 2006 Pakistan launched another Ghauri missile.[32] With an L/D ratio of 12.33 (Image 16) the length of this missile can be estimated as 16.03 m. Though slightly shorter this matches reasonably well with images 4, 5, 8 and 9.

Based on the measurements we can conclude that the 2 configurations of the Ghauri missile have lengths of 14.6 to 14.7 m and 16 to 16.4 m. These 2 configurations use the same booster but have different warheads. The shorter configuration could carry a conventional warhead and the longer configuration could carry a nuclear warhead.

The Shaheen 1 Missile

12 images of the Shaheen 1 and 6 images of the M9 missiles were analysed. The measurements are summarized in Table 5 of the main text. Some important details on the images are provided in Table 11 below.

Table 11: Details of the various Shaheen 1 and M9 Images

Image	Comment
Shaheen Image 1	This is a missile shown in a parade. The TEL is a MAZ 543 Soviet TEL derivative. The diameter based on the TEL wheel base is close to 1 metre. Consistent with public information
Shaheen Image 2	This is also an image of a missile shown on a launch pad. Possibly an early version with a dummy warhead
Shaheen Image 3	Another image of the Shaheen on the launch pad. Same image as image 2 different source
Shaheen Image 4	This is reported to be an image of the flight in October 2003 as per the Daily Times a Pakistani paper. It is possibly one of the earliest Shaheen flights with a dummy warhead. Compatible with images 1, 2 and 3.

31 http://www.bharat-rakshak.com/MONITOR/ISSUE5-4/arya.html

32 See http://www.presidentofpakistan.gov.pk/NewsEventImagePopUp.aspx?ImageID=224 and http://www.spacewar.com/reports/Pakistan_Fires_Nuclear_Capable_Missile_999.html for images of this launch.

Image	Comment
Shaheen Image 5	Image from CNN reporting the launch of the Shaheen 2 stage missile on 9th March 2004. The image is of course an earlier Shaheen 1 flight.
Shaheen Image 6	October 8th 2003 launch of the Shaheen 1. This is the 4th launch. Longer warhead, longer rocket motor compatible with a nuclear warhead. Fits testing sequence.
Shaheen Image 7	Shaheen 1 October 8th 2002 launch. Compatible with image 5. Conventional warhead launch.
Shaheen Image 8	October 8th 2003 launch . Compatible with image 6. Nuclear warhead longer rocket motor?
Shaheen Image 23	November 29th 2006 launch
Image 9 M9	A TEL wheel base of 1.35 m is compatible with a 1 m diameter rocket. Warhead compatible with conventional warhead of the Shaheen. Shaheen 1 bigger rocket than M9
Image 10 M9	This is a image of an M9 being readied for launch. The TEL is looks like a Soviet /Ukrainian MAZ 543 TEL. Wheel base or tyre diameter gives missile diameter as 1.02 –1.12 m. On balance diameter of 1 m validated
Image 11 M9	Looks like a stretched version of the original M9. The warhead part bigger than the rocket motor. A new advanced warhead? The TEL is not the MAZ but a new TEL.
Image 12 M9	Image of a take off from a TEL. Diameter based on the MAZ width works out to be 1.07 m
Image 13 M9	Launch image

The first 3 images (Image 1, Image 2 and Image 3) are images of the Shaheen on parade (Image 1) and images of the Shaheen being readied for launch (Images 2 & 3) from two different sources.[33] Image 1[34] (a 1999 image showing the Shaheen mounted on a TEL during a parade) can be used to independently assess the diameter of the missile since the TEL on which the Shaheen is carried is a modified version of the Soviet MAZ 543 TEL. While there are some problems with a clear measurement,[35] the diameter estimates are close to the publicly known value of 1 metre.[36]

Images 2[37] and 3[38] which are images of the missile (the same image from different sources) being readied for launch helps us to get some idea of the warhead and rocket motor lengths. Assuming the diameter of the missile as 1 metre we can convert measured values of these parameters into lengths. These measurements on images 2 and 3 are compatible with each other and quite close to the length determined from image 1.

33 These are the same image being taken from 2 different sources.

34 Source:http://news.bbc.co.uk/2/hi/south_asia/2534731.stm

35 Though the quality of the image is very good a precise measurement of the diameter is difficult because there is no clear separation of the missile from the TEL.

36 The derived value based on the TEL wheel base of 2.2 m works out to be 0.99 m. which is very close to 1 metre the publicly expected value.

37 Source:http://www.skyrocket.de/space/space.html

38 Source:http://www.geocities.com/Pentagon/Barracks/9722/Missiles/

The 4th image is also very similar to images 2 and 3 but shows the missile in flight.[39] Though the source from which the image is taken seems to suggest that it is an image of one of the Shaheen flights of October 2003, it is most probably an image of one of the early flights of the Shaheen 1. The tilt of the image is such that we would expect some underestimate of the length. This seems to be an early flight of the Shaheen 1 with a dummy payload. It very closely resembles Images 2 and 3 – though visual inspection clearly shows it is a different missile.

Images 1, 2, 3 and 4 are compatible with a 9.9 metre long, 1 metre diameter Shaheen missile. It is also compatible with the logic of a dummy warhead being tested on initial launches of missiles.

Image 5[40] is taken from a report on the Shaheen 2 two-stage missile test of 9th March 2004. It is obviously an image of an earlier Shaheen 1 flight. The various parameters derived from this image (L/D ratio, length based on a diameter of 1 metre, warhead length, rocket motor length) are quite close to that of Image 7.

Image 7[41] is reported to be a picture of the 3rd launch of the Shaheen that took place on October 8th 2002. It appears to be a Shaheen 1 with a shorter conventional payload.

Images 6[42] and 8[43] have L/D ratios of 12.69 and 12.83 respectively. Both of them are supposedly images of the same launch – the 4th Shaheen launch of October 8th 2003. Since it is the 4th launch it is quite likely that the launch would carry a nuclear warhead. The evidence and the timing are also consistent with the desired sequence of testing.[44]

This means that there are 2 variants of the Shaheen missile. Variant 1 is a missile that carries a conventional warhead (length 11.4 to 11.6 m, diameter 1 metre, warhead length 4.25 to 4.45 metres, rocket motor length of 7.1 to 7.2 metres[45]). Variant 2 has a longer (heavier) nuclear payload. It has a length of between 12.7 to 12.8 metres, a diameter of 1 metre, a warhead of 4.8 metres and a rocket motor length of 7.9 to 8 metres.

39 Source:http://www.dailytimes.com.pk/default.asp?page=story_9-

40 Source:http://edition.cnn.com/2004/WORLD/asiapcf/03/09/pakistan.missile/

41 Source: http://www.commondreams_org-headlines02-images-1008-02_jpg.htm

42 Source: www.globeandmail.com/.../ BNStory/International/

43 Source:http://msnbc.msn.com/id/4483834/

44 The sequence typically followed would be a dummy payload followed by a conventional payload followed by a simulated nuclear payload.

45 The rocket motor length measurement includes the nozzle and any other interface.

The Shaheen 1 was again tested on November 29th, 2006. There are three different images of the same launch – one from the Hindu newspaper[46] and two images from a Chinese newspaper, the China Daily.[47] We made measurements on all the 3 images.

Based on the measurements we came to the conclusion that the Hindu image represents one configuration of the Shaheen we have already seen being tested.

The China Daily has two separate images purporting to be the Shaheen 1 missile launched of 29th November 2006. One has a warhead length of 4.69 m and a rocket motor + nozzle + fin length of 6.55 m. It represents a combination of an earlier rocket motor with an existing warhead.

The other China Daily picture shows a warhead length of 4.75 m and a rocket motor + nozzle + fin length of 7.45 m. The length of this version would be 12.2 m. This seems to be a new configuration of an existing warhead with a new rocket motor. **Our view is that this is the most likely configuration that was flown.**

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 metres. 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 metres. This could be a stretched version of the M9 with a more advanced nuclear payload.[48]

Images 10 and 12 are carried on a MAZ 543 derived TEL. The diameter measurements based on a tyre diameter of 1.5 metres gives a missile diameter very close to 1 metre.[49]

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 metres and a tyre diameter of about 1.05 metres would be compatible with a 1 metre diameter M9 missile.[50]

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[46] http://www.hindu.com/2006/11/30/stories/2006113001891400.htm

[47] http://www.chinadaily.com.cn/world/2006-11/29/content_746307_2.htm and http://www.chinadaily.com.cn/world/2006-11/29/content_746307.htm

[48] 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.

[49] 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.

[50] If we assume a diameter of 1 metre we can work out the other measurements.

Though there are references in the literature to the German origins of the Chinese TEL or to the TEL being based on a Mercedes Benz or Iveco technology.[51] 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.[52]

When we compare the Shaheen 1 and the M9 missiles it is clear that one of the most important parameters the diameter is the same for both. However, the lengths of the missiles are very different. The Pakistani Shaheens are longer missiles with a longer range. There are also similarities in terms of warhead dimensions. One can argue that in theory that if designs were based on similar principles and assumptions one would end up with similar designs. If however one looks at the pictures of the warhead portion of the missiles we see very great similarities. If this similarity is linked with the known connection between Pakistan and China regarding the Ghaznavi and the M11 link, the case for Chinese help and technology in the case of the Shaheen is quite strong.

This connection should however not blind us to certain facts. The Pakistanis have a fairly long history of working on solid rocket propulsion technologies. They have benefited from early help for sounding rocket production from the French. The recent spate of launches of the Shaheen 1 and the launch of the 2-stage Shaheen 2 is evidence of good capabilities for the development and production of solid rockets and missiles.

The sequence of testing visible from the images of the Shaheen 1 seems to show the transition from a dummy warhead to a conventional warhead to a nuclear warhead. This sequence for the Shaheen1 is quite different from the sequence we see in the Ghaznavi.[53] The Shaheen programme is obviously much more than just technology transfer or licensed production. There are 4 rocket motors for 3 warheads visible in the 6 proven flights out of 7 launches reported. They are also longer rockets than the M9.[54] While one can argue that this is not conclusive to make clear inferences on indigenous capability it does appear very plausible that the Pakistanis have indeed internalized much of the technology. The programme may have gained from the Chinese especially in the warhead parts of the technology and maybe even in some areas like control and guidance

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

52 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.

53 Of course the Ghaznavi launches are only 4 in number and we have only a few images of flights.

54 We can see from the parameters that the M9 missiles openly displayed by the Chinese are shorter than the Shaheen 1. Their range with a 1000 kg to 700 kg payload is between 224 and 308 km. This is lower than the range of the smaller diameter (0.88 m) M11 missile. This is a strange development leading to the logical conclusion that the M9 was originally designed to be a bigger missile and that it has been cut short intentionally. This could also account for the longer length of the Shaheen missile as being close to the original M9 length. There are reports that the M9 we are seeing is the 1st stage of a larger 2-stage M18 missile. There is some logic for this. Reports indicate that it is deployed with a 500 kg tactical nuclear payload directed at Taiwan.

technologies.[55] However, the programme today appears to be robust and strong with the capability to produce Shaheen missiles in reasonable numbers. It also appears to be a much more open and transparent capability than the capabilities in liquid propulsion as seen in the Ghauri missile.[56] This openness could be intentional and part of a new doctrine of letting the world know that Pakistan is certainly capable of protecting itself.

The Shaheen 2

There are 8 images of the Shaheen 2 that were available. All 8 images were analysed.

The first launch of the two stage Shaheen missile took place on March 9th 2004. Subsequent launches took place on March 19th 2005 and April 29th 2006.

Images of the 1st launch were put out after the launch by the Pakistani press. An image available in the public domain (Image 15) was used for our analysis.[57]A TEL that helped launch the missile is clearly visible in the image. This image is such that no independent verification of its diameter or length is feasible even though a TEL is visible.[58]

The second launch of the Shaheen 2 took place on March 19th 2005. Three images of the Shaheen flights were available for analysis. Two images[59] (images 16, 18) showed the rocket on the launch pad before liftoff with President Musharaff being present. The other image[60] (image 17) shows the Shaheen in flight. Visual observations coupled with measurements confirm that the 3 images (Image 16, 17 18) are of the same rocket. The measurements confirm that this launch is similar to the Shaheen 2 flown on March 10th 2004.

The 3rd launch of the Shaheen 2 took place on April 29th 2006. 4 images of this launch were available.[61] Two of these images provided us useful measurements.

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55 One source suggests that the impact point of the warhead and the reentry point of the rocket are separated by 40 to 50 km. This suggests separation and may be spin up of the warhead at some point prior to reentry. See http://www.kokaniz.com/shaheen.htm for a report on the Shaheen development by Hanif Khalid. This is apparently taken from the Rawalpindi paper Jang 19 April 1999 page 10.

56 Maybe Pakistan wants the world as well as India to know what it has. There seems to be a proactive planned strategy of disseminating information. See the part on the Ghauri missile.

57 See http://www.dailytimes.com.pk/default.asp?page=story_10-3-2004_pg1_1

58 The TEL resembles an MAZ 543 though it is not very clear

59 http://story.news.yahoo.com/news?tmpl=story&u=/050319/481/kar10303191403 and http://www.paktribune.com/news/index.php?id=98371

60 http://story.news.yahoo.com/news?tmpl=story2&u=/050319/photos_wl/mdf900669&e=12&ncid=708

61 See http://news.monstersandcritics.com/southasia/news/article_1159371.php, http://www.app.com.pk, http://www.cbsnews.com/stories/2006/04/29/world/main1561478.shtml?source=RSS&attr=World_1561478

Table 11 below provides details of the various usable measurements made on the Shaheen 2 images. The dimensions are based on the assumption that the diameter of the missile is 1 metre.

Table 11: Measurements on the Shaheen 2 Missile

Parameter	Image 15 March 2004	Image 16 March 2005	Image 17 March 2005	Image 18 March 2005	Image 20 April 2006	Image 24 April 2006
L/D ratio	11.88	12.18	12.05	12	12.68	12.45
Length	11.88 m	12.18 m	12.05 m	12 m	12.68 m	12.45 m
Warhead + if	3.18 m	3 m	3.2 m	3.04 m	3.38 m	3.32 m
Stage 2 grain	2.18 m	2.36 m	2.25 m	2.08 m	2.18 m	2.14 m
Stage 2 total	3.53 m	3.72 m	3.45 m	3.54 m	3.65 m	3.59 m
Stage 1 grain	4.36 m	4.27 m	4.45 m	4.41 m	4.56 m	4.5 m
Stage 1 total	5.18 m	5.45 m	5.40 m	5.41 m	5.65 m	5.54 m
Diameter	1 m	1 m	1 m	1 m	1 m	1 m

The first two launches of the Shaheen 2 appear to be very similar from the data in Table 6. The 3rd launch of the Shaheen 2 seems to be a slightly stretched version. This trend seen in conjunction with other trends we have seen for the Shaheen 1 and the Abdali point to an increasingly sophisticated and customized system engineering capability.

With a larger Shaheen 1 booster stage being available, Pakistan can also develop a variant of the Shaheen 2 that would increase the range and bring a large part of India within the ambit of a Pakistani missile.

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