Launch of Pakistani Shaheen-II (Hatf-VI) Ballistic Missile on November 13, 2014: An Analysis

Rajaram Nagappa, S. Chandrashekar, N. Ramani, Lalitha Sundaresan and Viswesh Rammohan
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A launch of the Shaheen II (Hatf-VI) ballistic missile was carried out by the Pakistan Army Strategic Forces Command on 13 November 2014. The Inter Services Public Relations (ISPR) issued the following press release in connection with the launch (emphasis by the authors):


Pakistan today conducted a successful Training Launch of Intermediate Range Shaheen-II (Hatf-VI) Ballistic Missile. The successful launch was the culminating point of the Field Training Exercise of Army Strategic Forces Command which was aimed at ensuring operational readiness of a Strategic Missile Group, besides re-validating different design and technical parameters of the weapon system. Shaheen-II Missiles is capable of carrying nuclear and conventional warheads to a range of 1500 km.

Today’s launch, having its impact point in Arabian Sea, was witnessed by Director General Strategic Plans Division, Lieutenant General Zubair Mahmood Hayat, Commander Army Strategic Forces Command, Lieutenant General Obaid Ullah Khan, Chairman NESCOM, Mr Muhammad Irfan Burney, senior officers from the strategic forces, scientists and engineers of strategic organizations.

Addressing the participant troops and scientists at the launch area, the Director General Strategic Plans Division, Lieutenant General Zubair Mahmood Hayat, congratulated them on achieving yet another milestone towards consolidation of full spectrum credible minimum deterrence. He appreciated the operational preparedness and readiness of Army Strategic Forces Command, which made the successful launch of Shaheen-II Weapon System possible. He showed his full confidence in the existing robust Strategic Command and Control System. He further reiterated that Pakistan is a peace-loving nation having no aggressive designs against any one. Pakistan’s Strategic Forces are fully capable of safeguarding security of the Mother Land against any aggression.

The successful test launch and achievement of this Range milestone has also been warmly appreciated by the President and Prime Minister of Pakistan who congratulated the scientists and engineers on their outstanding achievement.

What is significant about this launch is that it is taking place after a gap of nearly six and half years. The last announced Shaheen-II launch had taken place on 19

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and 21 April 2008. The range claimed in those flights was higher at 2000 km\(^2\). A related issue is that the launch was conducted over the Arabian Sea and the Notice to Mariners/Airmen issued in advance identified missile launch window and the coordinates of the impact zones. With the available information from open sources an analysis is carried out of this flight and where relevant comparison is carried out with the launch of April 2008.

1. **Press Statements**

Press statements relating to 2008 and 2014 flight tests describe Shaheen-II as capable of carrying both conventional and nuclear warheads. The 2008 statement reinforces the delivery of warheads with “high accuracy”, but this distinction is missing in the 2014 statement. The major distinction is in the toning down of the range of the missile from 2000 km to 1500 km. The 2008 press releases describe Shaheen-II as Pakistan’s longest range ballistic missile system with a range of 2000 km, whereas the November 13, 2014 press release describes Shaheen – II missile as capable carrying strategic and conventional warheads to a range of 1500 km.

Statements on the flight objectives are as under:

19 April 2008: Process of validation and technical improvements to consolidate and verify various land based strategic missile systems

21 April 2008: First training launch of Long Range Ballistic Missile Hatf VI (Shaheen – II) Weapon System. The launch was conducted by the Army Strategic Forces Command and marked the culmination of the field training exercise.

13 November 2014: Training launch; culminating point of the Field Training Exercise of the Army Strategic Forces Command

The ISPR press statements pertaining to the 2008 and 2014 launches are compared in the following table.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Press Statement</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test objective</td>
<td>Validation and technical improvement to</td>
<td>Training flight Revalidation of different design and technical parameters of the weapon system The claim of culmination of field training exercise is perhaps premature in terms of the limited number of tests</td>
</tr>
<tr>
<td></td>
<td>consolidate and verify various land based</td>
<td></td>
</tr>
<tr>
<td></td>
<td>strategic missile systems</td>
<td></td>
</tr>
<tr>
<td>21 April 2008</td>
<td>13 Nov 2014 flight</td>
<td></td>
</tr>
</tbody>
</table>

Prior to the 19 April 2008 test, Pakistan had flown the Shaheen – II on four occasions – at the rate of one launch per year between 2004 and 2007. One would consider these as developmental flight tests based on our earlier studies\(^3\). Test number 5 of 19 April 2008 also appears to be a development test based as it seems to incorporate technical improvements and is used for validation. Both tests 6 and 7 indicate the culmination of the field training exercise. If test number 6 of 21 April 2008 did indeed serve as the culmination of the field training exercise, there would have been no necessity to repeat the phrase subsequently. The fact this is repeated at the end of the November 2014 test indicates that the field training exercises were not over; or the long delay between the 2008 and 2014 tests forced repetition of the field training exercise. It must be noted that the Shaheen-II is a two-stage system; its integration & checkout is more involved; and would necessitate a reasonable number of training exercises. Two trials spread over a period of six years are quite inadequate to declare the system fully operational.

2. Image analysis

Examination of the images from the 2014 and 2008 launch showed no discernible differences in the images externally. A closer examination using the image analysis software however, showed some differences in the overall length. The derived lengths of the missile and its components based on a missile diameter of 1.4 m are shown in table 2 below:

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<table>
<thead>
<tr>
<th>Total length, m</th>
<th>2014 image</th>
<th>2008 image</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st stage length, m</td>
<td>8.19</td>
<td>7.99</td>
</tr>
<tr>
<td>2nd stage length, m</td>
<td>4.91</td>
<td>4.48</td>
</tr>
<tr>
<td>RV length, m</td>
<td>4.28</td>
<td>3.82</td>
</tr>
</tbody>
</table>

Table 2: Missile dimensions

The images of the missiles of the 2014 and 2008 launch are shown in figure 1. The dimensions in the table above are derived from these images.

![2014 launch](image1) ![2008 launch](image2)

Figure 1: Images from Nov 2014 and April 2008 launch of Shaheen-II

It can be seen that the first stage dimensions match closely in the two images but there is difference of about 0.4 m in the measurement of the 2nd stage. There is also an increase of about 0.46 m in the RV length. There are reports that Pakistan has incorporated ‘Post Separation Attitude Correction System (PSAC)\(^4\) in the Shaheen – I RV. If the report is correct, similar system could be used in Shaheen – II also which, could explain the increase in the length of the RV – about 0.5 m increase in length is adequate to house a small liquid propellant system.

3. Identification and Analysis of Missile Launch Location

The ISPR release does not mention the launch site or the payload mass. It however, states that the range capability of the missile is 1500 km. It is possible to deduce the launch location as the stage/RV impact corridor coordinates are provided in the NAVAREA warnings issued by the Hydrographer, Pakistan Navy. The NAVAREA IX\(^5\) warning is reproduced below:

**SECURITE**

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\(^4\)https://www.facebook.com/RadioActiveFriends/photos/a.203282853170229.1073741826.200749186756929/369856143179565/ accessed on 06 December 2014

111215 UTC NOV 2014

NAVAREA NINE (.) 306 (.) ARABIAN SEA (.) PAKISTAN (.) CHARTS PAK 33, 58 (INT 7019) BA 4071 AND 4705 (.)

2. MISSILE FIRING WILL BE CARRIED OUT BETWEEN 0600 TO 0900 UTC ON 13 AND 14 NOV 2014 IN AREA BOUNDED BY FOLLOWING COORDINATES:

A. (1) 25-10.63N 066-21.24E
   (2) 25-02.31N 066-36.83E
   (3) 24-16.71N 066-04.30E
   (4) 24-25.03N 065-49.03E

B. (1) 14-40.15N 059-26.80E
   (2) 14-29.64N 059-46.29E
   (3) 13-43.56N 059-16.77E
   (4) 13-54.61N 058-56.74E

ALTITUDE 436000 METRES

3. SHIPS AND CRAFT ARE TO KEEP WELL CLEAR AND NOT TO ENTER ASSIGNED DANGER AREA ON ABOVE SPECIFIED DATES AND TIME (.)

4. CANCEL THIS MESSAGE ON 141100 UTC NOV 2014.

5. CANCEL NAVAREA NINE WARNING 302 OF 2014.

The following inferences can be drawn on the basis of the launch image and the NAVAREA warning:

- Missile launch window was between 11 AM and 2 PM PST on 13-14 November 2014. The actual launch took place on 13 November.
- Missile was launched from or in the vicinity of the Somniani Rocket Testing Range located Northwest of Karachi.
- The coordinates at ‘A’ represent the corridor into which the spent 1st stage falls.
- The coordinates at ‘B’ represent the corridor within which the 2nd stage/Reentry Vehicle impact (it can be assumed that both the spent 2nd stage and the RV fall in the corridor B).
- The centres of the corridor represent the nominal impact point of the spent stages and RV
- Extension of the line joining the centres of the two corridors in the northerly direction should lead to the launch location.
- The centre of the corridor ‘B’ corresponds to the range of the missile.
Google Earth imagery was used to mark the impact corridors and determine the corridor centres. Initially, it was assumed that the missile was launched from Somniani Range. It was found that from Somniani to the first impact point requires a heading of 243.8° followed by a change of heading to 212° to reach the second impact point. This would call for reorienting the missile heading at the start of the 2nd stage operation and it was felt that mission planners would prefer to avoid such maneuvers (from both reliability and energy conservation points of view). Also as the Shaheen missile system is a road-mobile system, its launch need not be tied to fixed launch stations like Somniani. Therefore areas falling along the extension of the line joining the two impact points close to the coast were explored and one could find one such location at 25°20’49.02” N, 66°39’16.73” E.

The historical imagery offered by Google Earth of the site was checked and one could find evidence of facility upgradation at regular intervals. The series of images shown in figures 2 to 7 reflect this.

![Figure 2: 04 Feb 2004](image1)

![Figure 3: 04 Feb 2004 (close up view)](image2)

![Figure 4: 07 Dec 2010](image3)

![Figure 5: 30 Jun 2013](image4)
The images are all taken in the area surrounding 25°20′48.76″N, 66°39′16.72″E. The observations from examination of the images are summarized in table 3.

<table>
<thead>
<tr>
<th>Image Date</th>
<th>Observation</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 04 Feb 2004      | • Concrete pad measuring 48m x 78m  
                   • Rail tracks along the length of the pad  
                   • Mobile assembly hangar measuring 10 m (W) x 13.5 m (L)                                                                                       | Buildings are located 1.1 km to the west of the pad. These buildings probably house the offices and units of the launch control centre                                                                   |
| 31 July 2009     | • Concrete pad length is increased to 120 m.  
                   • The mobile assembly hangar length almost doubled ≈ 25 m                                                                                      | The increase in length of the pad and assembly hangar signifies longer missile integration and launch                                                                                                    |
| 07 Dec 2010      | • Seven TEL’s are seen parked on the pad (six are side-by-side and one is separately parked)  
                   • Three more vehicles are seen at the western end of the pad  
                   • The TEL bed dimensions are approximately 2.4 m wide and 5 m long                                                                           | The Shaheen-I stage is about 7m long (without the RV) and can fit on these TEL’s with some overhang. The presence of so many vehicles is intriguing, especially as there is no report of any missile launch during Dec 2010/Jan 2011. |
| 30 Jun 2013      | • Addition of 2nd concrete pad measuring 130 m x 90 m  
                   • Larger mobile hangar measuring 11 m x 37 m seen on the new pad  
                   • Mobile hangar not seen on the 1st pad  
                   • 2 TEL’s (articulated tractor – Launch of Ghauri missile^6 on 28 Nov 2012 ended in failure with parts of the debris falling in the village of Dadu, Sind Province. The extension of the pad immediately after this event, supports the thinking that a) |                                                                                                                                                                                                   |

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6 Rajaram Nagappa, *Pakistan’s Ghauri November 2012 Missile Test*,  
<table>
<thead>
<tr>
<th>Image Date</th>
<th>Observation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>trailer type) are parked on the 2nd pad. The TEL's are longer measuring about 10 m as bed length and 13 m till the beginning of the driver cabin. The width is 2.3-2.4 m</td>
<td>Pakistan has decided not to put civilian population at risk by carrying out development launches on land and b) the extension is for supporting Shaheen-II launch. The dates support such an interpretation. Intriguingly, the dimensions of the missile like image adjacent to the hangar are close to the Shaheen-II dimensions.</td>
</tr>
<tr>
<td></td>
<td>On the east side of the hangar, there is an image which resembles an assembled missile measuring 17.2m long by 1.3/1.4m wide</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3: Observations from Google Earth imagery**

It is meaningful to conclude that Pakistan found it safer to use the vast expanse of the Arabian Sea available for conducting development launches and not risk missile flight over populated areas. Questions arise regarding some of the observations made in the table, the answers to which are only speculative.

One question is regarding the number of vehicles seen in figure 4. With no launch around that time, are the vehicles participating in a practice exercise? Even if yes, why so many? Is there a missile storage location close by where the missiles were delivered?

The other question relates to image adjacent to the hangar in figure 6. This looks like the image of a missile and the overall dimensions appear close to Shaheen-II. Why is it placed outside the hangar? Is it a mockup for the forces to practice assembly, handling and checkout procedures?

**4. Missile Performance**

The two impact zones are determined using the centre of the coordinates given by the NAVAREA IX warning. Using the tools in the Google Earth, it is possible to get a measure of the ground distance between two points and the heading. The first impact zone is shown in figure 8.
The first impact zone represents the represent the spent 1st stage impact point. The point is located at a distance of **82 km** and towards a heading of **213°**. In the same fashion the second impact point was determined. At the end of the second stage burn, the RV is separated and the spent second stage as well as the RV continue on their ballistic path. The separation point is above the atmosphere and the flight path of both the systems is quite close. Their flight path is expected to deviate on reentry, as the drag is different on both the systems. The performance of the RV is better predictable as it is a streamlined body and the centre of the impact location is taken as the RV impact point. However, the spent 2nd stage is also expected to fall within the impact corridor. The RV impact point is shown in figure 9.
The RV impact point is located at a distance of **1364 km** from the first impact point and also at a heading of **213°**. The total distance from the launch location to the RV impact point is **1446 km**, which is quite close to the claimed range of 1500 km.

Shaheen – II missile propulsion details estimated by us are shown in Table 4 below.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propellant Mass</td>
<td>7.31 t</td>
<td>3.23 t</td>
</tr>
<tr>
<td>Stage Mass</td>
<td>8.60 t</td>
<td>4.04 t</td>
</tr>
<tr>
<td>Specific Impulse</td>
<td>264 sec</td>
<td>278 sec</td>
</tr>
<tr>
<td>Burn Duration</td>
<td>50 sec</td>
<td>55 sec</td>
</tr>
</tbody>
</table>

**Table 4: Shaheen-II parameters**

Trajectory simulation was attempted with the software *QuoVadis* developed at NIAS using inputs from table 4 with a RV mass of 1000 kg. The highlights of the results are as follows:

i. The maximum range achievable by the missile is **2133 km**. It may be recalled that the missile range was claimed to be **2000 km** in the earlier announcements.
ii. In the trajectory simulation, a shorter range equal to 1442 km could be demonstrated using a lofted trajectory. This matches with the range of 1446 km achieved in the Shaheen-II flight.

iii. The first stage impact point computation is mismatched to the extent of 20 km from the centre of the first impact corridor. The computed impact point is however, well within the impact corridor.

5. Discussion

Based on available information, it would appear that the Shaheen-II launched on 13 November 2014 performed a successful flight. The Shaheen-II flight occurred after a gap of 6.5 years. The range of 1500 km indicated in the press release fits with the announced impact zones. The following questions come to mind:

i. It is quite likely that the design range of the missile is only 1500 km. NAVAREA warnings for the 2008 flights are non-existent and therefore it can be surmised that these flights were carried overland from Tilla Range. The 2000 km range claimed for these flights could therefore be overstated.

ii. If this is so, our estimate of the propellant and inert mass of the stage motors should also be wrong. If the propulsion parameters are overestimated by us, it would mean either a) the diameter of 1.4 m of the missile is in error or b) the design is not very efficiently carried out.

iii. Alternately, the propulsion parameters derived are nearly correct and the actual range of the missile is approximately 2133 km. A lofted trajectory was attempted in the November 2014 flight to get a lower range.

iv. Accepted practice is to qualify a missile system for its nominal performance. What is the reason therefore for trying a lofted trajectory, in a developmental mission, especially as there is no range constraint?

v. The long interval in the resumption of the Shaheen-II flight is indicative of a major technical issue, which may have taken time to resolve.

vi. The possibility of technical problem is corroborated by a recent report emanating from Hong Kong. The report is reproduced below:

Hong Kong report says China specialists helping Pakistan on missile development

Text of report published by Hong Kong Information Centre for Human Rights and Democracy on 14 November

Hong Kong Information Center for Human Rights & Democracy, a Hong Kong-based fax service which reports on dissidence, on 14 November published an article that quotes a former missile expert as saying that Chinese specialists have been frequenting Pakistan to help work on the project of Shaheen-II, a missile that

7 ISSSP is grateful to Dr. Mark Fitzpatrick of IISS, London for sharing the complete text of the Hong Kong report.
Pakistan has successfully test-fired recently. The article says the missile, which is capable of carrying nuclear warheads to a range of more than 1,000 kilometers that covers many Indian cities, is an upgraded version of the Chinese M-18.

Source: Information Centre for Human Rights and Democracy, Hong Kong, in Chinese 14 Nov 14

vii. Shaheen-II, unlike the other missiles in the Pakistani arsenal is a two-stage system. Design and performance issues could arise in respect of a) sequencing of staging events, b) transfer of control at the end of first stage burn, c) vehicle bending modes and structural design, d) management of vehicle vibration – e.g. issues relating to control system/structure interaction, e) thermal management of reentry heating to name a few. If the April 2008 flights had brought out any such inadequacies, the planning of the corrective action required, its realization and implementation could explain the long timespan in the resumption of the missile flight. It is possible that remedial action has not reflected in changes to the overall configuration and dimension and therefore is not discernible in the images of the flight vehicle.

viii. The changes may however, have impact on the inert mass of the vehicle and the throw weight, thus impacting the performance.

ix. Procedural issues, lack of priority or financial/resource constraints could also be causative factor for the delay.

To get a handle on the range reduction, a sensitivity study was carried out. The study showed a 10% increase in mass of the RV would impact the range to the extent of 130 km. Range reduction to the extent of 500 km would require the RV mass increase by 40%. Introduction of the PSAC system referred to in section under the heading of Image Analysis could explain the increase in RV mass. Such a system will provide the RV with maneuverable capability and also some margin for range increase. Systems like PSAC employ a liquid bipropellant system and will comprise propellant tanks, gas tank for pressurization and a bank of thrusters. Such a system can account for some increase – but not to the extent of \( \approx 400 \) kg.

In short, the long time gap can only be explained assuming that the Shaheen-II flight of April 2008 exhibited some major anomaly in one or more of the subsystems (e.g. issues relating to staging, control, vehicle flexibility and coupling effects, reentry thermo-structural) and it has taken Pakistan a long time to diagnose, correct (perhaps with Chinese help) and qualify the corrective measures. The corrective measures in turn may have impacted on the inert mass and consequently on the performance. Additionally, if the PSAC has also been incorporated, the development and qualification of such a system would have taken up time, besides adding mass to the missile throw weight.

Flights of April 2008 as well as the November 2014 flights have been termed by ISPR as culmination of field training exercise. Missile systems training exercise as a routine are carried out regularly and appropriate frequency to keep the field
crews in a fully prepared condition. Even by these standards, 6.5 years is a long and gap and a series of flight tests need to be done before ‘training culmination’ stage is reached.

6. Conclusion

The Shaheen – II flight. Of 13 November 2014 is analysed. A launch location west of Somniani range is identified and corroborated with assessment of the historical images. The flight over open areas of the Arabian Sea seems to be a logical outcome after the failure of Ghauri flight launched over land in November 2012. The range of the missile has been simulated and matched with the impact location given in the NAVAREA IX warnings. Though a lofted trajectory simulation shows good match with the known impact locations, reasons for justifying such a trajectory is elusive. Reasons for the long gap are difficult to explain in the absence of confirmatory data and can only be speculated to be a combination involving technology issues, correction, requalification and use of PSAC as well as availability of resources and priorities.