NIAS

R1 - 09

NIAS Study - 2009

Iran's Safir Launch Vehicle

Rajaram Nagappa
S. Chandrashekar
Lalitha Sundaresan
N. Ramani

International Strategic and Security Studies Programme
NATIONAL INSTITUTE OF ADVANCED STUDIES
Bangalore, India

Iran's Safir Launch Vehicle

NIAS Study - 2009

Rajaram Nagappa
S. Chandrashekar
Lalitha Sundaresan
N. Ramani

International Strategic and Security Studies Programme
NATIONAL INSTITUTE OF ADVANCED STUDIES
Bangalore, India

July 2009

Published by

National Institute of Advanced Studies
Indian Institute of Science Campus
Bangalore - 560 012

ISBN 978-81-87663-82-9

Typeset & Printed by

Aditi Enterprises
Bangalore - 560 023
Ph.: 080-2310 7302; Mob: 92434 05168
E-mail: aditiprints@rediffmail.com; aditiprints@gmail.com

Iran's Safir Launch Vehicle

Executive Summary

Iran joined a select group of nations having indigenous satellite launch capability, when it orbited its Omid satellite on the night of February 02, 2009 on board its indigenously developed launch vehicle Safir 2. The event was widely covered in the media and images and video footage of the launch have been posted on the internet.

According to the media information Safir is a two stage launch vehicle and Omid is a 27 kg ‘store and forward’ communication satellite with a life of 2 to 3 months. The satellite is placed in 248 x 378 km and orbits the earth 15 times a day.

The first stage

The launch images confirm the first stage pedigree with the North Korean Nodong missile. The fin shape, the jet vane control system and the exhaust plume signature of the Nodong and Safir first stage are quite similar. North Korea has sold and transferred the technology of this missile to Iran, where it is known as Shahab 3B. *(It may be noted that the Pakistani missile Ghauri has a similar linkage to Nodong missile).* From the nozzle exhaust signature, it is clear that a single engine (and not a cluster of 2 or 4 engines) is employed for the first stage. The following inferences are drawn on the basis of the North Korean Nodong missile heritage:

- The stage uses a hypergolic propellant combination comprising AK -271 (27% N_2O_4 + 73% HNO_3) as oxidizer and TM-185 (20% Gasoline + 80% Kerosene) as fuel.
- The diameter though not directly measurable can be inferred to be about 1.3 m.
- The stage uses jet vanes for steering. This system originally employed in the Scud missiles was adapted by the North Koreans for their Nodong missiles.

From measurements on the Safir images the length of the first stage is about 15 m. This length includes the engine, the oxidizer and fuel tanks. Our earlier measurement of engine length on the Shahab 3 missile was seen to be 2.25 m. Taking this length for the Safir engine and making allowances for the engine-tank interface as well as the space between the oxidizer and fuel tanks, the total tank length is estimated to be 11.8 m—longer than the tank length of 9.3 m in Shahab 3A and 11 m in Shahab 3B, resulting in improved propellant loading. From this, the propellant and the total stage mass have been estimated to be 18.6 tonnes and 21.6 tonnes respectively.

The second stage

Observation of the Safir launch vehicle images indicated that the diameter of the second stage is the same as the first stage. The total length of the second stage including the interface with stage 1, the engine and the nozzle is about 4.2 m. After accounting for the engine and the other elements this provides for only a length of 1.7 m for the propellant and oxidizer tanks. This translates into a propellant mass of 2.77 tonnes and a stage mass of 3.11 tonnes.

Images of the stage show that it is two-engined single axis gimbaled configuration. The stage is approximately one fourth the length of the first stage.

The Omid satellite and Safir Interface

The measurements made on the payload section up to and including the heat shield indicate a length of about 1.78 m. The satellite is accommodated in this part of the vehicle. According to Iranian sources the satellite is a ‘store and forward’ communication satellite. It is cubical in shape with dimensions of 40 cm x 40 cm x 40 cm. Its mass is stated to be 27 kg. It is battery powered without any solar panels. The satellite mass, additional appendages and the heat shield mass are estimated to be 80-100 kg.

Vehicle dimensions and possible configuration

Based upon the measurements the total length of the Safir 1 is about 20.9 m. The corresponding Length to Diameter ratio works out to 16.08. The estimated dimensions and the mass details are summarized in Table 1.

Table 1: Safir mass and dimension details

Parameter	Value
Total Length	20.9 m
Diameter	1.3 m
First stage length	15.05 m
Second stage length	4..07 m
Payload fairing length	1.78 m
First stage propellant mass	18600 kg
First stage mass	21628 kg
Second stage propellant mass	2770 kg
Second stage mass	3110 kg
First stage control	Jet vanes
Second stage control	Gimbal two axes + other 3rd axis
Propellant (both stages)	Oxidizer: AK - 271 Fuel: TM - 185

Launch Centre and Orbit

The launch centre is located in the province of Senman about 230 km south east of Teheran. The coordinates of the centre are at 35° 14’ 04" North and 53° 55’ 20" East. Google pictures clearly indicate the various features of a typical launch site.

The US Space Command has reported two objects in orbit. The objects correspond to the upper stage and the satellite. The available orbital element information suggests Iran has done a launch in the South East direction.

Two stages or three stages?

Media reports have stated that the Safir is a two stage vehicle.

Using the values of stage and propellant masses shown in table 1, we have checked whether the two Safir stages could provide the orbital injection velocity of 7670 metres per second (7.67 km per second) required for an approximate 400 km circular orbit which is very similar to the orbit achieved by the Omid satellite. Even with the benefit of the additional velocity component due to the earth's rotation of about 250 metres per second, there is a shortfall of around 1.5 km per second for attaining orbital velocity.

It is clear that for Iran to orbit a satellite with the given orbital parameters, a third stage that can provide an additional velocity of at least 1500 metres per second is essential. This additional velocity could be provided by a solid or a liquid stage. One candidate system is the Chinese PKM FG-47 solid rocket motor. This motor has a diameter of 540 mm and a total length of 850 mm. The total assembly of motor, adapter and satellite would be about 1.5 m long and could comfortably fit in the 1.78 m long heat shield.

Missile Capability

The launcher can easily be converted into a two stage missile. Using the derived values of stage and propellant masses and assuming a 1000 kg warhead, the achieved range works out to 2400 km. This would enable Iran to target all parts of the Middle East, parts of Europe and certainly large parts of India from a south eastern location.

Conclusion

With the launch of the Safir/Omid mission, Iran has demonstrated core launch vehicle technology capabilities.

Iran's Safir Launch Vehicle

Introduction

On February 2, 2009 Iran successfully placed its Omid satellite in low earth orbit with its indigenously developed launch vehicle Safir-2. This event singled out Iran as one of the nine countries in the world with a demonstrated satellite launch capability.

The event itself was not a surprise as Iran had attempted a space launch in August 2008 and the Iran Space Agency (ISA) had announced its plans to launch Omid by March 2009.

Pictures of the launch vehicle and videocasts are available on the internet and these have been examined to assess the vehicle configuration, dimensions and performance.

Background

Like with many other space faring nations, the Iranian space effort is also an offshoot of its missile programme. Iran has both solid and liquid propelled missiles either procured or indigenously manufactured. Initial procurement in the mid 1980's comprised artillery rockets from China and Scud B from Libya and North Korea. In addition to procurement of missiles, the agreement with North Korea[1] also included setting up of industrial infrastructure in Iran for missile maintenance, assembly and manufacture of Scud missiles.

The Scud B's with a range of 300 km with 1000 kg warhead came to be known as Shahab 1 in Iran. North Korean assistance was also used for improvements and the realization of Shahab 2 capable of carrying an 800 kg warhead over a range of 500 km.

Towards the end of 1989, Iran acquired from China, a fairly large number of CCS-8 (M-7/ Project 8610) short range missiles capable of achieving a range of 150 km with a 190 kg warhead. China has also provided technology and plant equipment[2] for the production of solid propellant rockets.

In the early 1990's Iran undertook a joint development project with North Korea for the improvement of the Nodong missile system. The resulting product was named Shahab 3. Both the Shahab 3 and Pakistan's Ghauri are derived from the Nodong. Iran has set up the industrial infrastructure at Isfahan and Sirjan for manufacturing the Shahab missiles and has been flight testing them since the year 2000. Iran is reported to have added its own modifications and the resultant Shahab 3B according to one source has the following features and capabilities:

---

1 Robin Hughes, "Iran's Missile Developments—Long Range Ambitions", Jane's Defence Weekly, Sep 13, 2006.

2 Iran Missile Program at http://www.globalsecurity.org/wmd/world/iran/missile.htm

Length	16.5 m
Diameter	1.3 or 1.58* m
Launch weight	17410 kg
Warhead	Separating type
Range	1300 km with a 1200 kg payload

*(*Though Jane's Defence Weekly quotes the diameter as 1.58 m, most investigators believe the diameter is in the range of 1.3 to 1.35 m)*

Safir 1 Launch Vehicle and Omid Satellite

The Safir 1 launch vehicle, which Iran flew successfully on Feb 02, 2009, is a follow up of earlier attempts in February 2008 and August 16, 2008. The Iran Space Agency has not provided any detail except that the satellite called Omid is a telecommunication satellite, orbiting the earth 15 times a day. Figure 1 depicts the vehicle on the launch pad.

Figure 1: Safir Launch Vehicle

The US space command has reported two objects—one in an orbit of 248 by 378 km with a 55.1° inclination and the other in an orbit of 245 by 439 km with an inclination of 55.6°. One of these must be the spent upper stage and the other the Omid satellite.

Video footage[3] provided by Iran shows the erection of the launch vehicle on the launch pad, the launch, some operations on the satellite integration, commentary and an animated flight sequence. The animated flight sequence shows Safir to be a two stage vehicle. Both the stages have identical diameters. The blue coloured fairing on the top that houses the satellite is also of the same diameter. The satellite is a store and forward communication satellite with a life of 2 to 3 months. From the animation sequence, the fairing is jettisoned during the second stage

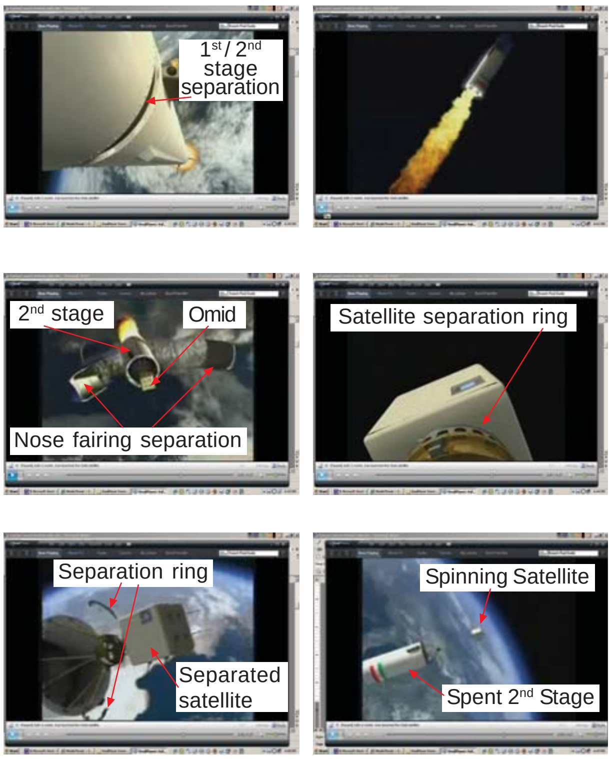

Figure 2: Safir Mission Sequence

[3] Safir 2 Iran launched the Omid satellite at http://www.youtube.com/watch?v=M8oOOmBIICA&feature=related

Figure 3: Clam-shell type nose fairing

Figure 4: 1st Stage Jet-vane Control

thrusting. The satellite appears to be attached to the adaptor with two semi-circular bands using explosive bolts. In the animation, the two segments of the band are seen to separate, followed by satellite separation and the satellite is seen to be spinning after separation. The flight sequence grabbed from the video is shown in figure 2. The fairing is of the clam-shell type and in two halves as shown in figure 3. Further, the first stage control uses jet-vanes for affecting pitch, yaw and roll control as is evident from the static display shown in figure 4a. Further evidence is available by an examination of the flight image in figure 4b, which shows the numbered fins and the projection of the vanes into the exhaust.

The second stage is of the same diameter as the first stage, but of much shorter length. The length of the stage is about one fourth of the first stage. Figure 5 shows the engine pictures reproduced from Norbert Brugge's paper[4] indicating that the stage is powered by twin engines.

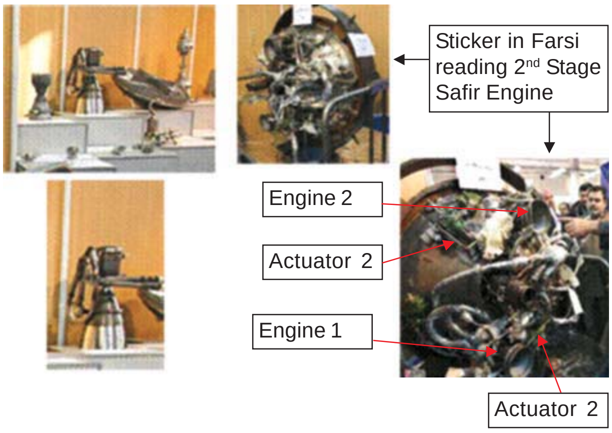

Figure 5: Stage 2 engine

Twin engines provide double the thrust of a single engine and can be configured to be fed by common tanks. Additionally, by gimballing the engines, thrust vectoring can also be achieved. In the figure above one set of actuators can be made out which provide gimballing in one plane. With such a pair of actuators, either pitch or yaw along with roll control could be managed. One requires two plane gimballing or a 4-engine configuration for managing 3-axis control. As one does not see evidence of 2-plane gimballing, we can surmise that some independent reaction control system has been incorporated for control in the third direction.

The Omid satellite is of simple construction and is shown in figure 6. The satellite is a cube with dimensions 40 cm x 40 cm x 40 cm and a mass of

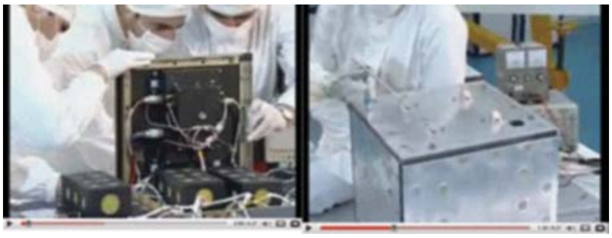

Figure 6: Omid Satellite

[4] Norbert Brugge, "Iran's first space launch vehicle Safir IRILV" at http://images.google.co.in/imgres?imgurl=http://www.b14643.de/Spacerockets 1/Pictures/Safir-5.jpg&imgre...

about 27 kg[5]. Along with the adaptor and separation ring, the satellite mass can be expected to be about 35 kg. From the figure it can be seen that the satellite structure has no decks or body mounted solar cells. The satellite appears to be powered by batteries only. The satellite life is quoted as only 2-3 months which is consistent with power being provided only by batteries. The payload is a store and forward communication payload. The satellite is probably spun after release from its adaptor and the orbital period is of the order of 100 minutes.

Objectives of the Study

The main objectives of this study are:

- Examine the North Korean linkage and determine the dimensions of the Safir vehicle
- Estimate the tank volume, the propellant and structural mass.
- Estimate the performance and probability of orbit insertion with two stages
- Examine the possible third stage options
- Comment on the launch centre and launch trajectory
- Comment on Iranian vehicle development capability and future trends
- Study the implications of the Safir launch for the Iranian missile programme

Estimation of Safir Vehicle Dimensions

A number of images of the vehicle on the launch pad are available in the media. These have been studied and the dimensions have been estimated using image analysis software. Some level of cross check is also available from the images of the Shahab 3 missile from which the Safir first stage is derived. The Soviet Scud Missile and technology were available to a number of countries including North Korea. The Nodong[6] missile of North Korea is a scaled up version of the Scud missile (scaled up from 0.88 m diameter to 1.3 m diameter). North Korea has exported the missile and missile technology to Pakistan, where the missile is called Ghauri and to Iran, where the missile is known as Shahab 3. Iran has subsequently modified the missile by increasing its length and modifying the reentry vehicle[7] and this variant is called Shahab 3B. The diameter of Nodong[8] is quoted as being between 1.3-1.35 m by many sources. The supporting evidence for the Nodong connection is the similarity in the fin configuration and the jet vanes used for the stage control system, besides the overall dimensions. This is depicted in figures 7.

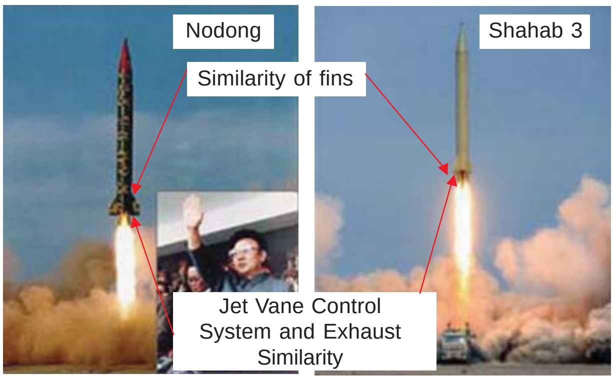

Figure 7: Nodong and Shahab 3 comparison

For determining the dimensions of Safir, images shown in figure 8 have been examined.

---

[5] Alon Ben-David, "Concern mounts as Iran takes great leap forward", Janes Defence Weekly, 06 Feb, 2009

[6] Geoff Forden, "Safir when ready—Iran sets its sights on long-range capability", Jane's Intelligence Review, 18 S2p, 2008

[7] Pedro BD and Tom Cooper, "Shahab 3: an Advanced IRBM", Arabian Peninsula and Persian Gulf Database, Dec 18, 2003 (http://www.acig.org/artman/publish/article_396.shtml)

[8] Nodong Technical Details at http://www.fas.org/nuke/guide/dprk/missile/nd-1.htm

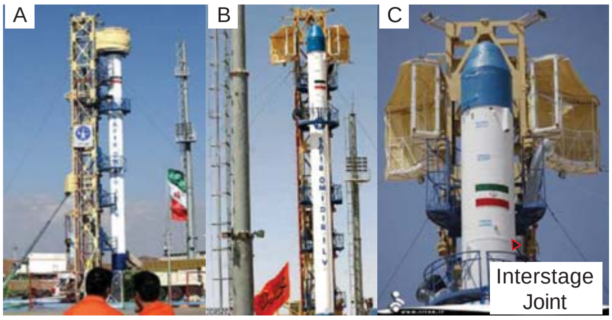

Figure 8: Safir 1 Pictures[9]

The Iranian flag painted on the rocket is used as a reference point. From figure 8A, the distance between the reference point and the base of the vehicle can be determined. Figure 8B provides the distance from the reference point to the nose fairing and figure 8C provides the distance between the reference point and the interstage joint. Taking the diameter as 1.3 m, it is possible from these measurements to determine the overall length of the vehicle, the base shroud length, the first stage length, the length of the second stage and the length of the nose fairing. These dimensions are shown in table 1 below.

Table 1: Estimated Safir Dimensions

Component	**Length, m**
Base Shroud	1.52 m
First Stage Length (including Base Shroud)	15.05 m
Second Stage	4.07 m
Nose Fairing	1.78 m
Total	**20.90 m**
Vehicle Diameter (assumed dimension)	1.30 m
Vehicle Length/Diameter	16.08 m

Our measurements on available images of the Shahab missiles have provided lengths of the Shahab 3a and Shahab 3b tankages to be 9.3m and 10.9 m respectively. The tankage for Shahab 3b is a stretched version of the tank used for the Shahab 3a. A further extension of the tank length has taken place for the Safir. The tank length of the first stage of Safir is estimated to be 11.8 m.

Estimation of tank volume and vehicle parameters

Once the dimensions of the tank are fixed up, it is possible to estimate the propellant and the structural mass required for working out the performance of the vehicle. From the Scud/ Nodong connection, it is known that the stage burns AK-271 (27% N_2O_4 + 73% HNO_3) as oxidizer and TM-185 (20% Gasoline + 80% Kerosene) as fuel. The mixture ratio for this hypergolic propellant combination is 4.65. Stage structural factors of 14% and 11% respectively are assumed for the two stages and based on this, the propellant mass and the overall stage mass is arrived at as indicated below:

- First Stage Propellant Mass 18600 kg
- First Stage Dry Mass 3028 kg
- Second Stage Propellant Mass 2770 kg
- Second Stage Dry Mass 342 kg

Performance Estimation

The AK 271/TM185 propellant combination is capable of yielding a sea-level specific impulse of 230 seconds for the first stage. However, there are drag losses associated with the jet vanes and therefore the effective specific impulse will be lower and assumed to be about 226 seconds.

[9] Norbert Brugge, "Iran's first space launch vehicle Safir IRILV" at http://images.google.co.in/imgres?imgurl=http://www.b14643.de/Spacerockets 1/Pictures/Safir-5.jpg&imgre...

The second stage is capable of yielding a higher specific impulse in the region of 245 seconds as the stage can employ larger expansion ratio nozzles. The payload mass is taken as 90 kg comprising 27 kg for the satellite, 45 kg for the fairing and the balance for the appendages like mounting adaptor and separation system.

The ideal velocity possible from these two stages is estimated to be 2840 m/sec and 3988 m/sec respectively summing up to a total of 6828 m/sec. If we account for the contribution due to earth's velocity and losses due to drag and gravity, the actual velocity achieved will be about 5500 m/sec. This is well short of the velocity requirement of 7674 metres/sec to achieve orbit.

There is therefore a requirement of a third stage to make up this velocity shortfall. As the satellite is only 40 cm tall and the nose fairing 1.78 m long, there is adequate space of more than a metre in which a third stage could be comfortably accommodated.

The candidate systems for the third stage could be a pressure fed liquid engine burning the same propellant combination as the lower stages or a solid rocket stage. If one uses the AK 271/TM185 propellant combination for the third stage also and if a pressure fed system can be configured with a 10% structural mass, one requires just about 50 kg of propellant to provide the additional velocity increment of about 2200 m/sec for orbital insertion. With such a liquid system one can even configure the third stage for a higher propellant mass of say 100 kg, to make up for any marginal under-performances in the lower stages.

Another candidate upper stage could be based on a solid rocket system such as the Chinese perigee kick motor FG-47 with a diameter of 540 mm and a total length of 850 mm. The estimated propellant and dry mass of this motor are 135 and 25 kg. A possible scheme for housing a solid third stage and satellite in the fairing is shown in figure 9.

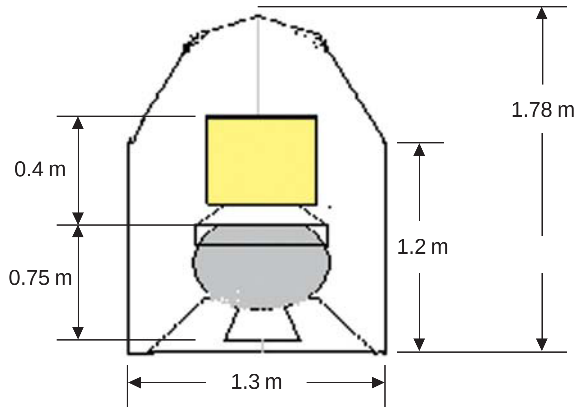

Figure 9: Solid 3rd stage+ satellite scheme

The delivered specific impulse of this motor is stated to be 285 sec. However, to accommodate it within the nose fairing, the nozzle can be truncated at a lower expansion ratio. The specific impulse is consequently taken as 270 sec.

To summarise, the details of the 3 stages are shown in table 2.

Table 2: Stage Details of the Safir Launcher

	Type	Propellant	Isp	Dry Mass	Propellant Mass	Diameter	Length
Stage 1	Liquid	AK-271/ TM-185	226 sec	3028 kg	18600 kg	1.3 m	15.05 m
Stage 2	Liquid		245 sec	342 kg	2770 kg	1.3 m	4.07 m
Stage 3	Solid	AP/HTPB/ Al	270 sec	25 kg	135 kg	0.54 m	0.80 m

Launch Centre and Launch

The Iran Launch Centre[10] is located in the province of Senman about 230 km southeast of Teheran. The coordinates of the Centre are at 35°14' 04"N / 53° 55' 20"E. Google Earth pictures in this area show specific locations, but as these images are taken on Sep 26, 2004 they do not show the same level of completeness as reported by other investigators. The launch centre details are shown in figures 10-12[11].

Figure 10: Senman Launch Site (35°14'04"N, 53°55'20"E)

Figure 11: Launch Preparation

Figure 12: Senman Launch Centre

The orbital inclination of the satellite is about 55°. From the launch centre, the satellite would have to be launched either on a South East trajectory or on a North East trajectory over Central Asian territory as depicted in figure 13.

Figure 13: Safir Launch Trajectory

The available orbital information is suggestive of a South East launch even though our preliminary check has not located the standard range safety notifications for this region. The earlier Shahab / Shahab 3 missile tests would have proved the reliability of the first stage as well as issues concerned with the stage impact and range safety parameters and provided the necessary measure of confidence. A launch in this direction (as well as that in a north east direction) also accounts for an additional velocity of about 250 metres per second arising from the earth's rotation.

Iranian Capability

With the launch of Safir, Iran has demonstrated a significant capability in launch vehicle related technologies. Though some of the elements like jet-vane control system are out of date, the design of the second stage using multiple gimbaled engines is a major step. One could therefore infer that Iran already has /or can in future achieve the following capabilities:

[10] "Spy photos reveal secret launch site for Iran's long range missiles", The Times, April 11, 2008.

[11] The Times, April 11, 2008, "Spy photos reveal secret launch site for Iran's long range missiles" www.timesonline.co.uk/tol/news/world/middle_east/article3724048.ece.

- Extend the gimballing technology to the booster stage also and do away with the not so efficient jet-vane steering system.
- Achieve larger lift-off thrust capability by clustering engines for the booster stage.
- Achieve two-plane gimballing for obtaining pitch, yaw and roll control. Alternately, they could go for a 4-engine cluster with one plane gimballing to achieve three axes-control.
- Change over to more efficient earth storable propellant systems like N_2O_4/UDMH.
- Iran also has competence in solid rocket motors and already fields the Sajjil missile which has a diameter of 1.2-1.3 m. They can be used as strap-ons for uprating the lift capability of satellite launch vehicles.
- Expertise in the thermal protection system for the nose fairing is another important milestone. The thermal regime is less hostile in the ascending phase than during re-entry, but some expertise is already there which can be used for obtaining lighter and efficient structures.
- Management of stage separation and staging events.

The Omid satellite however, seems to be very simple and the store and forward communication payload in the current internet age can be termed irrelevant. Through this launch Iran apparently wants to showcase its capability to orbit a payload. The absence of solar cells for power generation is intriguing. Is this due to a technology gap or is it due to the non-availability of solar cells and other power conversion/management devices? However, avenues for cooperation in satellite development, as well as procurement of components, devices and ready built payloads from China, Russia and other countries are available for civilian satellite purposes and this need not become a major bottleneck. In this connection, it should be noted that Iran's first satellite Sinah-1, was a 160 kg remote sensing satellite built by the Russian firm Polyot and launched onboard the Kosmos 3M vehicle in October 2005.

Safir as a Ballistic Missile

The Safir launch vehicle can be converted to a ballistic missile with ease as the technologies are common. For employing it as a ballistic missile, the third stage can be dispensed with and the entire envelope of the nose fairing can be used for the warhead. Our estimates show that as a missile the vehicle will be able to carry a 1000 kg warhead to a range of 2400 km. From the Senman launch centre, the missile would be able to target parts of Rumania and Hungary in East Europe and the Indian cities of Vadodara, Jaipur and Delhi will also be within the range of the missile. By launching from a southern point near the Persian Gulf, the range can be extended to cover Mumbai, Bangalore and Hyderabad. A launch from the Northwest tip of Iran will bring Warsaw under the range of the missile. The missile ranges from different locations of Iran are shown in figures 14-16.

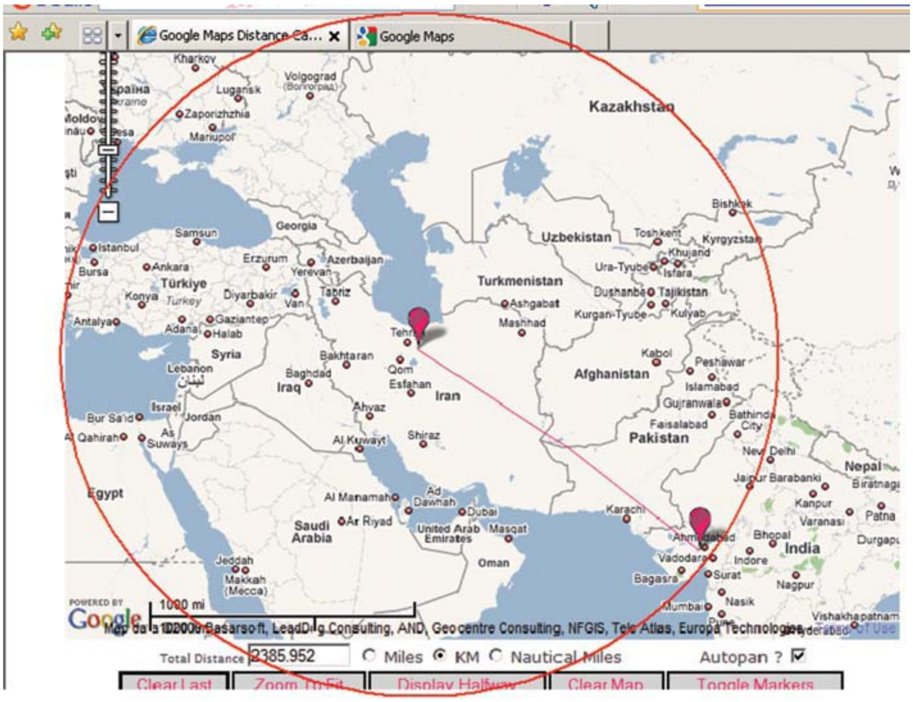

Figure 14: Coverage range of Safir from Senman

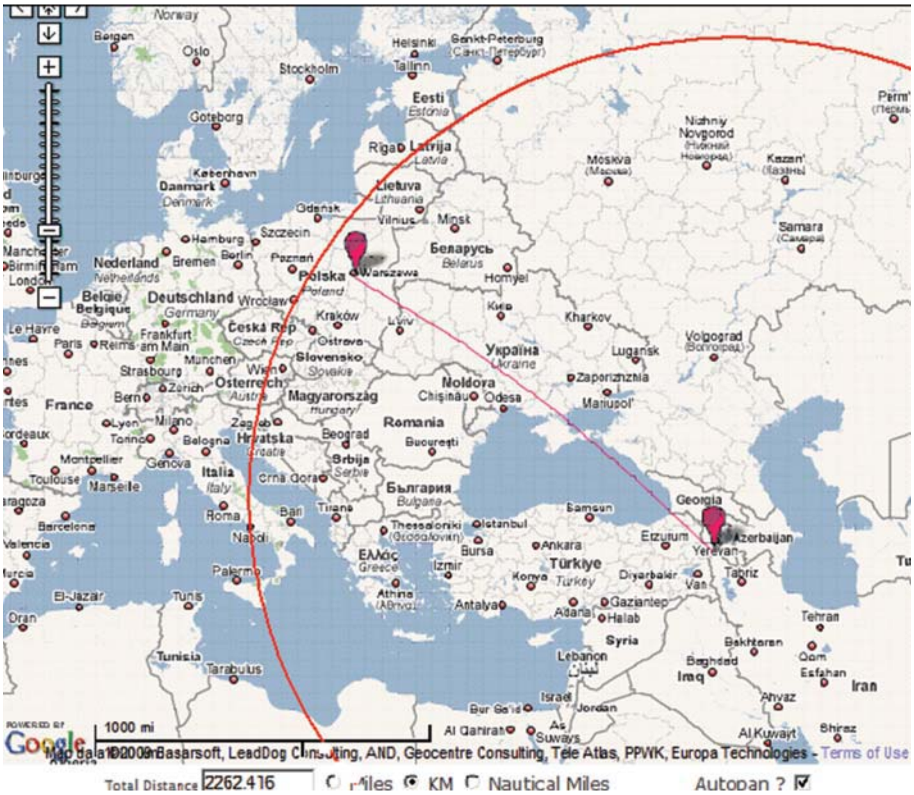

Figure 15: Warsaw is 2312 km from Tabriz

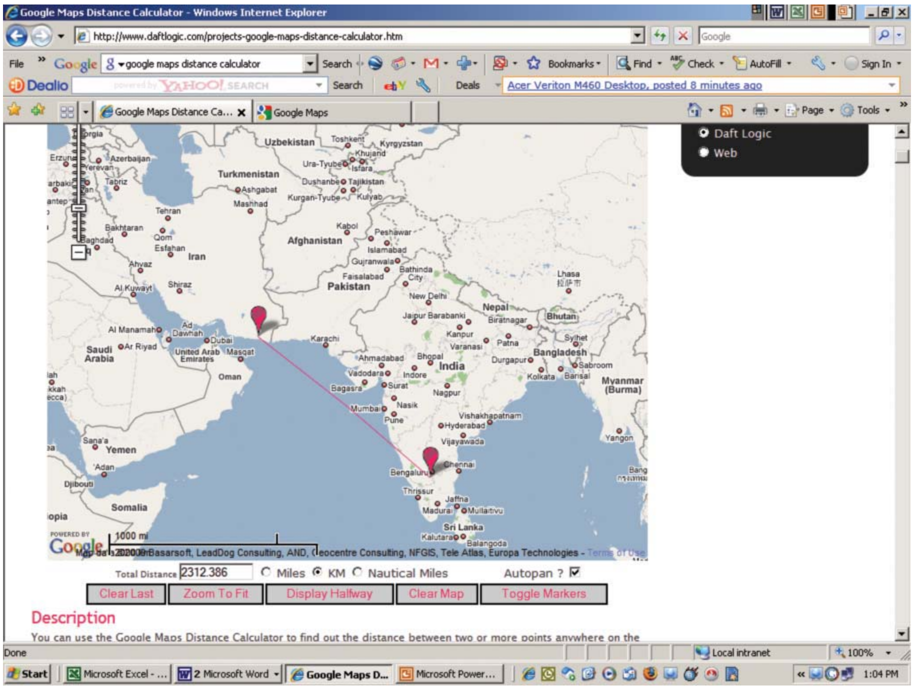

Figure 16: Bangalore is 2225 km from Chahbar

Conclusion

The possible architecture of Safir satellite launch vehicle has been examined from the available images and information. Image analysis techniques have been used to determine dimensions and the performance of the vehicle. We believe that a two stage Safir vehicle as claimed in the animated video clipping is not adequate to achieve the required orbital velocity. A third stage is definitely required and this stage is contained in the nose fairing. Iran would have most probably launched the vehicle on a North-Eastern trajectory to achieve the orbital inclination of 55.5°. Iran has assimilated the missile technologies procured from abroad (North Korea, China and Russia) and improved upon them. Iran today has indigenous capability in both solid and liquid propellant rockets/missiles. It would appear that the Iranian claim of launching satellites for disaster management and strengthening communication in the coming years is possible and has to be taken seriously.

The Safir launch indicates that the first two stages of this launcher can be modified to create a missile with a range of around 2400 km with a 1000 kg payload. This would bring the entire Middle East as well as parts of Europe under the range of Iranian missiles. From locations in the South east of Iran such a missile could in principle reach Bangalore.

International Strategic & Security Studies Programme

The International Strategic & Security Studies Programme at NIAS promotes and conducts research that addresses the strategic and security concerns of India. It has over the years carried out a number of studies in technology dominated areas of international security - nuclear weapons and missiles. NIAS has also facilitated exchange of knowledge and views between interested groups working around the globe on issues related to international security. The programme focuses on the region with a special emphasis on China and Pakistan.

International Strategic and Security Studies Programme
NATIONAL INSTITUTE OF ADVANCED STUDIES
IISc Campus, Bangalore - 560 012, India
Tel: 2218 5000, 2218 5087   Fax: 2218 5028
Email: r.nagappa@gmail.com