Technical Addendum to the Joint Threat Assessment on the Iran's Nuclear and Missile Potential

The Sejjil Ballistic Missile

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A Technical Analysis of the Sejjil Ballistic Missile: Supplement to the Joint Threat Assessment Appendices

Implications for the Joint Threat Assessment (JTA) Report

The JTA Report issued on May 19, 2009 did not provide an analysis of the capabilities of Iranian long-range solid propellant ballistic missiles. It was noted that there were reports that Iran had developed a solid propellant missile with a range of 2000 km, but the available data was insufficient for a serious analysis. On May 20, 2009, one day after the JTA report was released to the public, Iran successfully tested a solid propellant two-stage ballistic missile known as the Sejjil. Information that is now in the public domain, including testimony given to the Congress by Secretary of Defense Robert Gates on the technical characteristics of the Sejjil, makes it possible to provide an accurate and detailed assessment of the military and technical implications of this ballistic missile.

The Sejjil ballistic missile is a two-stage vehicle that is powered by solid propellant rocket motors. Preliminary estimates indicate that the first and second stage rocket motors differ little from each other, except that the second stage is shorter than the first. We estimate that the overall weight of the Sejjil would be about 21 tons when carrying a one-ton warhead. The Sejjil should be able to carry a one-ton warhead to a range of about 2200 km, giving it essentially the same range and payload characteristics as a liquid-propellant ballistic missile based on the technology of the Safir space launch vehicle. This means that within a few years the Iranians will have an operational system capable of delivering a 1000 kg warhead to a range of roughly 2000 km.

The JTA Report estimated that if Iran decided to build and deploy nuclear weapons, it could take six or more years to produce a nuclear warhead compact and light enough to fly on a ballistic missile. It concluded also that within that time Iran could produce a liquid propellant ballistic missile capable of delivering a 1000 kg nuclear warhead to 2000 km range. The crucial factor determining how long it would take Iran to develop and deploy nuclear-armed missiles is the time it would take to build a nuclear warhead of the right size and weight. The successful test of the Sejjil ballistic missile does not change that timeline.

On the basis of the Sejjil launch, we have estimated the size and weight of a ballistic missile that would have roughly the 5000 km range needed for Iran to be able to deliver 1000 kg nuclear warheads, when and if they are available, to Northern and Western Europe. This estimate assumes roughly the same level of solid propellant and casing technology demonstrated in the two-stage Sejjil missile. It assumes that the first and second stages of the Sejjil missile would be launched by a new and heavy first stage. In order to construct such a rocket stage with the same propellant and casing technologies used in the Sejjil, Iran would have to make major advances in understanding how to produce a much larger solid propellant rocket motor. It would also have to solve the other technological and production problems listed in paragraph 3.20 of the JTA Report.

If Iran eventually reaches a point where it could build such a large solid propellant rocket motor, we estimate that the resulting missile stage would have to weigh about 45 tons. The resulting vehicle would be a three stage missile with an overall weight of 65 tons or more. The weight of the American Minuteman III and the Russian SS-27 is about 35 tons. The large weight of a postulated solid propellant missile based on the technology demonstrated in the Sejjil launch would result in a missile that for all practical purposes would not be mobile. Although the Sejjil is an important alternative path to building long-range ballistic missiles, it does not demonstrate technologies that could rapidly evolve into ballistic missiles with ranges that could threaten Northern and Western Europe. It could also not evolve rapidly into a ballistic missile that could threaten the continental United States.

What are the implications of the May 20 test for the JTA Report? The first point to note is that the Sejjil test does not alter our estimate of when Iran might develop short-range and medium-range nuclear-armed ballistic missiles. It does not alter the JTA Report's conclusions about the long-term nature of the ICBM threat. Nor does it change our recommendations regarding the proposed missile defense deployments in Europe.

The most important change is that the test shows Iran to be capable of exploiting solid propellant technology. It is not yet clear whether Iran will take a strategic decision to emphasize solid propellant ballistic missiles over liquid propellant missiles as they continue developing their ballistic missile forces. Perhaps the Iranians have not yet made up their minds on this point. Solid propellant missiles have advantages over liquid propellant missiles – they are quicker to launch and can more easily be deployed in silos or on mobile launchers. These two characteristics can make them less vulnerable to preemptive attack. However, when the missiles and their carrier vehicles are large, cumbersome, and heavy, mobile systems can be hard to operate, and hiding them is not a simple task. The Sejjil and its carrier vehicle probably weigh 40 to 50 tons and an IRBM based variant along with its carrier vehicle would be gigantic, weighing roughly 130 to 140 tons. An Iranian solid-propellant ICBM that uses the same rocket propellant technology demonstrated by the Sejjil would be substantially larger than the US MX ICBM. It would require a carrier vehicle that would be proportionately larger than that used to transport the MX. As with the MX, such an enormous ICBM could only be moved using huge and specialized carrier vehicles on roads constructed specifically to accommodate such vehicles. Missile silos have become increasingly vulnerable to precision-guided munitions, and precision guided munitions can be expected to be in the arsenals of many nations as the technology becomes available worldwide. As such, although the successful launch of the Sejjil on May 20 is an important step in Iranian missile development, it does not mark an immediate or dramatic shift in the nature of the potential missile threat from Iran.

If anything, the test flight of the Sejjil reinforces the threat to the Middle East by providing Iran with an alternative (and perhaps quicker) path to the development of missiles capable of striking targets across the Middle East. This reinforces the argument made in the JTA Report that the urgent task is to secure US-Russian cooperation in resolving the crisis in the Middle East resulting from the Iranian nuclear and missile programs before a threat emerges to the whole of Europe and to the United States.

It is almost certain that Iran obtained substantial and extensive technological help from abroad in developing the solid propellant rocket motors for the Sejjil. The test firing of May 20 underscores the urgency of the JTA Report's recommendation that the international community take steps to deal more effectively with the transfer of missile technology. This is an area in which US-Russian cooperation is of great importance.

Technical Analysis

In order to provide further information for interested readers to understand the capabilities of the Sejjil in greater detail we now describe those characteristics of the Sejjil that are relevant to our assessment.

The photograph shown in Figure 1 shows contrails from a launch-barrage of relatively small short-range solid propellant tactical ballistic missiles that have all been launched within a time period of a few seconds. These contrails consist of tiny solid particles that are combustion products associated with solid propellant motors. The contrails are, in effect, columns of dust-like particles that efficiently reflect sunlight much like the droplets of water do in clouds.

The collection of photographs in figure 2 shows the launch of a SCUD-B liquid propellant ballistic missile. As discussed in the JTA appendix on Iran's ballistic missiles, the propellant used by the SCUD-B is a mix of 80% kerosene and 20% gasoline (called TM-185 by its Russian inventors) combusting with an oxidizer that is a mix of 27% nitrogen tetroxide and 73% nitric acid (called AK-27 by its Russian inventors). As can be seen in the photographs, the exhaust plume initially has a reddish brown color (see photographs 2A and 2B) that is characteristic of this propellant combination. As the missile continues in flight, there is essentially no contrail behind the missile except for a very faint and hardly visible hint of soot from the incomplete combustion of a very small fraction of the burning fuel.

The photographs shown in figure 3 shows the unambiguous difference between a contrail generated by a liquid propellant ballistic missile and a solid propellant ballistic missile. The photographs marked A through C show the launch of a Sejjil missile at different times as it rises from its launcher. In photograph A, it can be seen that even at the beginning of ignition the exhaust plume displays as bright white, characteristic of a cloud of particles illuminated by the sun. Within roughly 1.5 seconds (see photograph B) the missile has traveled about 15 m and displays a bright white contrail that is the result of sunlight reflecting off the cloud of solid particles in its exhaust plume. The large gray-colored cloud spread above the ground around the launch location is dust and sand that is being kicked up by the high velocity exhaust gases from the rocket's exhaust plume. Photographs C shows the rising Sejjil missile roughly 2 seconds after launch, and photograph D shows the Sejjil later in powered flight.

The photograph in figure 4 shows the Sejjil exhaust plume left behind after roughly 50 seconds of powered flight.

Figure 5 shows the results of measurements of the observed launch of the Sejjil missile as a function of time. The photographs along with measurement scales from which this data was generated are attached at the end of this addendum. The measurements indicate that the initial acceleration of the Sejjil is about 1.6 times the G of gravity. This leads to the conclusion that the thrust of the first stage rocket motor is about 55 to 56 tonnes. Since the second stage is almost certainly a shortened version of the first stage and the rate of fuel consumption is proportional to the internal surface area of the burning solid-propellant fuel, this indicates that the second stage thrust should be around 21 to 22 tonnes.

The estimated performance characteristics of the Sejjil first and second stages are shown below in Table 1.

Estimated Performance Characteristics of the Sejjil Missile Rocket Stages

Stage	Full Weight (kg)	Burnout Weight (kg)	Thrust (kgf)	Structure Factor	Specific Impulse (sec)	Burn Time (sec)
Stage 1	14,720	2210	55,600	0.15	220 (SL) 250 (Vac)	50
Stage 2	5780	870	21,800	0.15	250	50

Table 1

Figure 6 shows a line drawing of the Sejjil ballistic missile along with line drawings of all of the other long-range ballistic missiles that are deployed or available to either Iran or North Korea or both (recall that the Iranian Shahab 1, Shahab 2, and Shahab 3 are the same missiles as the North Korean SCUD-B, SCUD-C, and Nodong).

The Sejjil is the fifth missile from the right. The fourth missile from the right is the Shahab-3M or Kavoshgar single stage liquid propellant ballistic missile. The sixth missile from the right is the two-stage liquid propellant Safir satellite launch vehicle that was used to launch a 27 kg satellite into low earth orbit in February 2009. As discussed in the JTA appendix on Iran's ballistic missiles, the Safir could be modified with a different upper rocket stage so that it could carry a warhead weighing roughly 1000 kg to a range of about 2000 km.

Figure 7 shows that the range versus payload characteristics of the Sejjil ballistic missile are essentially the same as the range versus payload characteristics of the Safir satellite launch vehicle if the Safir low-thrust upper stage were replaced with a second stage that has a SCUD-B rocket motor. Such a replacement for the upper stage would have sufficient thrust to accelerate a roughly 1000 kg warhead onto a long-range ballistic trajectory. As can be seen, both missiles have nearly the same range/payload characteristics.

Figure 8 shows a photograph of the Sejjil ballistic missile on a mobile carrier vehicle shortly before it is to be launched. To the right of the photograph is a line drawing (not to the same scale) of the two-stage Sejjil ballistic missile and a *postulated* three stage ballistic missile derived from a new and large solid propellant first stage that is used to lift the upper two stages of the Sejjil. Note that the two-stage Sejjil missile shown in the photograph already requires a carrier vehicle of quite substantial size. A vehicle that would carry the postulated three stage solid propellant ballistic missile would have to carry roughly 3 times the total weight of the two-stage Sejjil and it would have to be roughly twice the length of the carrier vehicle used for the Sejjil. Such a vehicle cannot be expected to move such a rocket with ease or speed.

Figure 9 shows close-ups of the Sejjil launch vehicle. This close-up was constructed from a video that observed parts of the Sejjil missile as it rose during powered flight vertically through the field of view of the camera. The video frames were carefully "stitched" together to obtain a detailed photograph of the missile.

The detailed photograph reveals that the first and second stage propulsion control sections are essentially the same. The pods at the back of the first and second stage are for hydraulic systems that control jet planes that are immersed in the rocket exhaust of each of the two stages. A careful analysis of both the first and second stage leads to the conclusion that both stages are likely to have been manufactured using the same techniques, except that the first stage is physically longer than the second stage. Table 1 provides our performance estimates for each of the two stages:

In summary, the Sejjil ballistic missile has range and payload characteristics that are rather similar to the Safir satellite launch vehicle if the Safir were modified to be a ballistic missile. The level of solid rocket propellant technology demonstrated in the Sejjil does not indicate that this technology can be easily used to construct a larger long-range solid propellant missile that could threaten Northern or Western Europe. The technology is even less suitable for building a long-range ICBM. Nevertheless, the appearance of the Sejjil as a potential component in Iran's ballistic missile arsenal indicates that there has been technology transfer to Iran that could be used by Iran to build a wide variety of solid propellant ballistic missiles with ranges in the 1000 to 2000 km range. Every effort should be made to identify the sources of this technology and to find ways to shut it off.

Figure 1

Figure 2

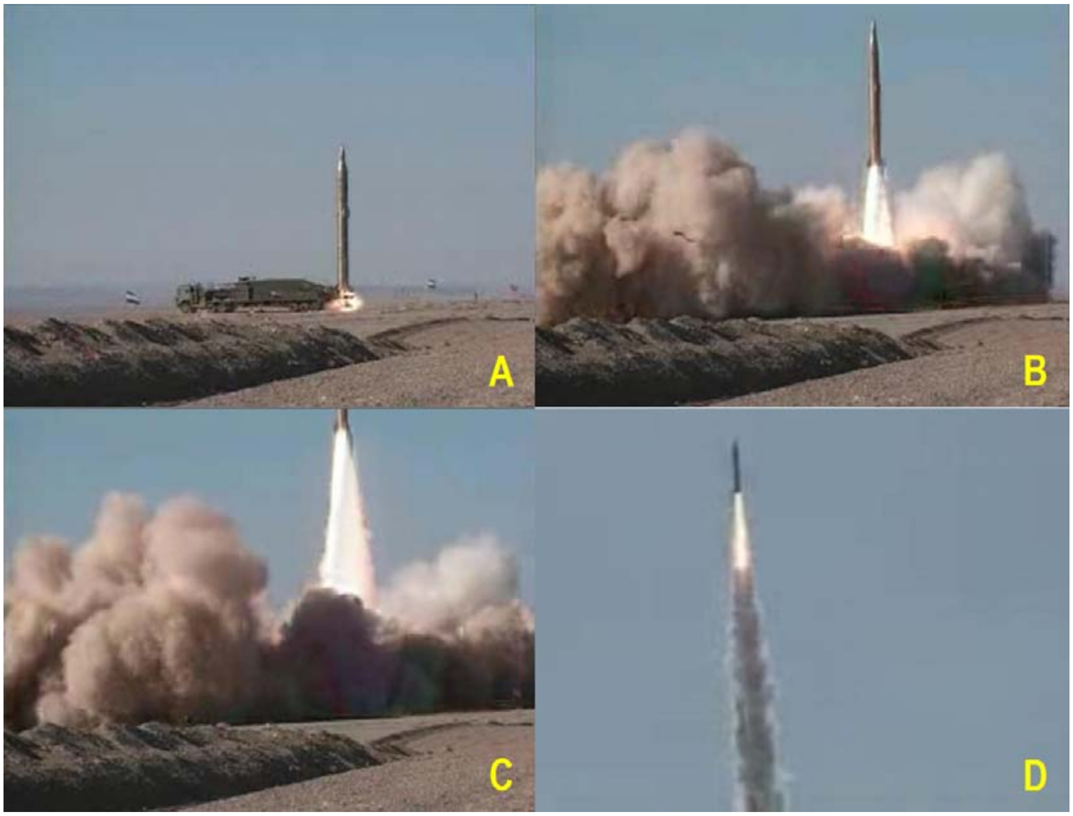


Figure 3

Figure 4

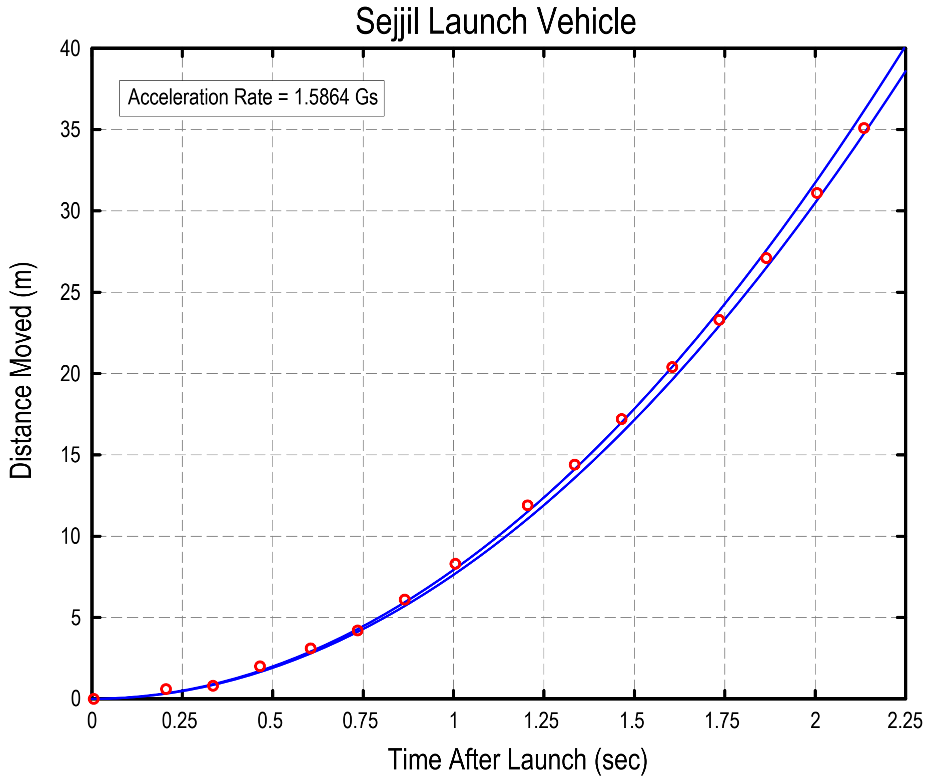


Figure 5

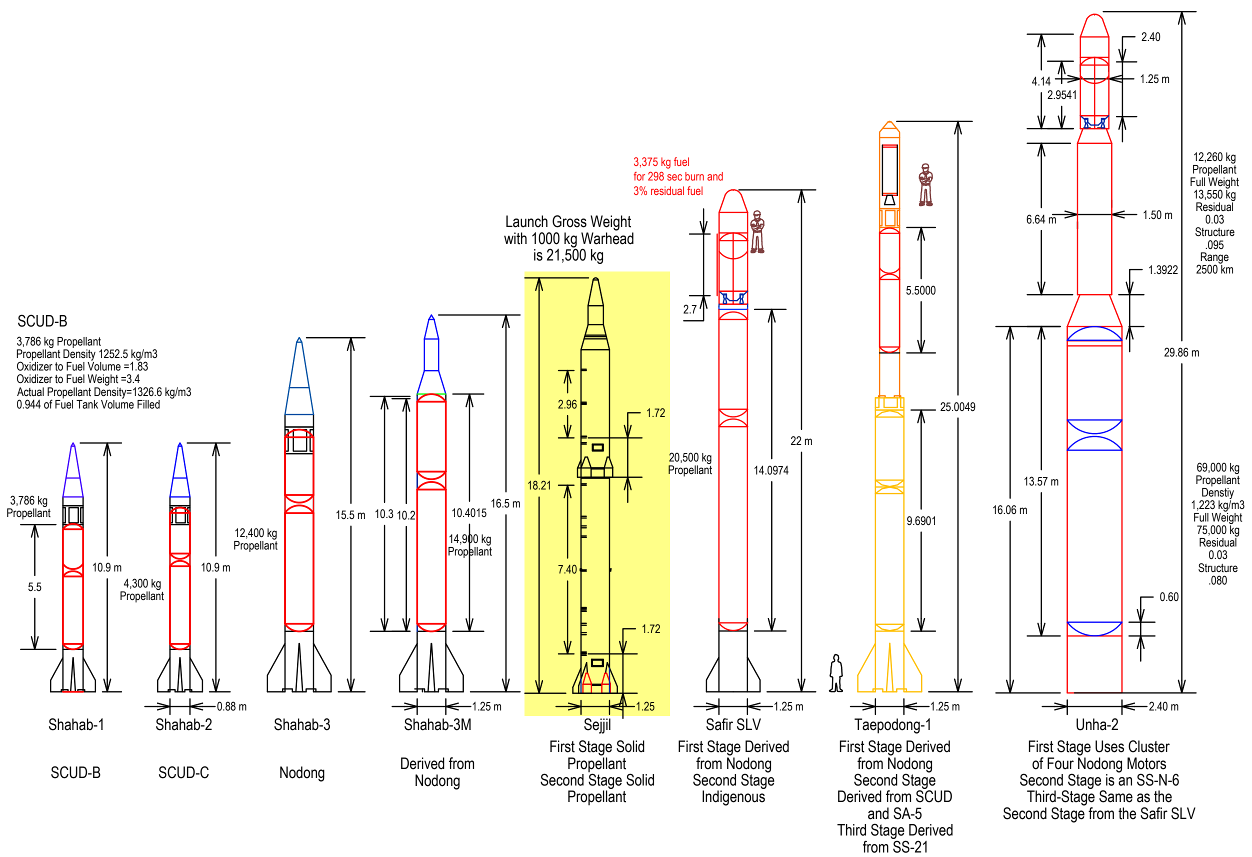


Figure 6

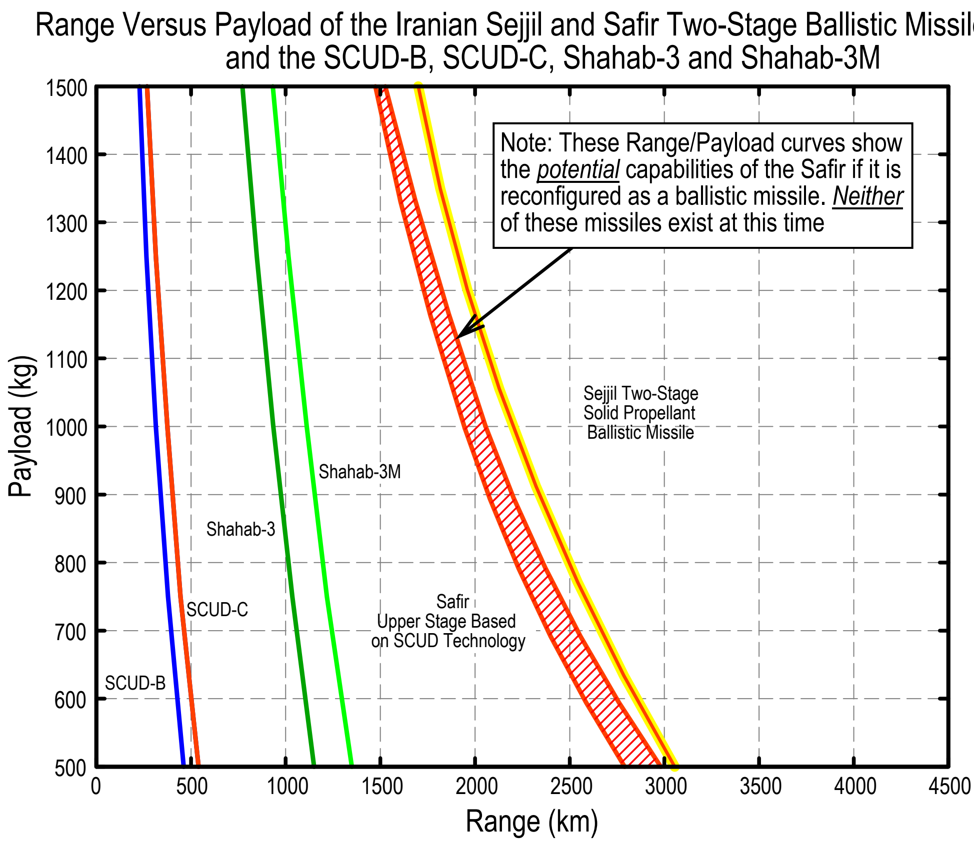


Figure 7

Figure 8

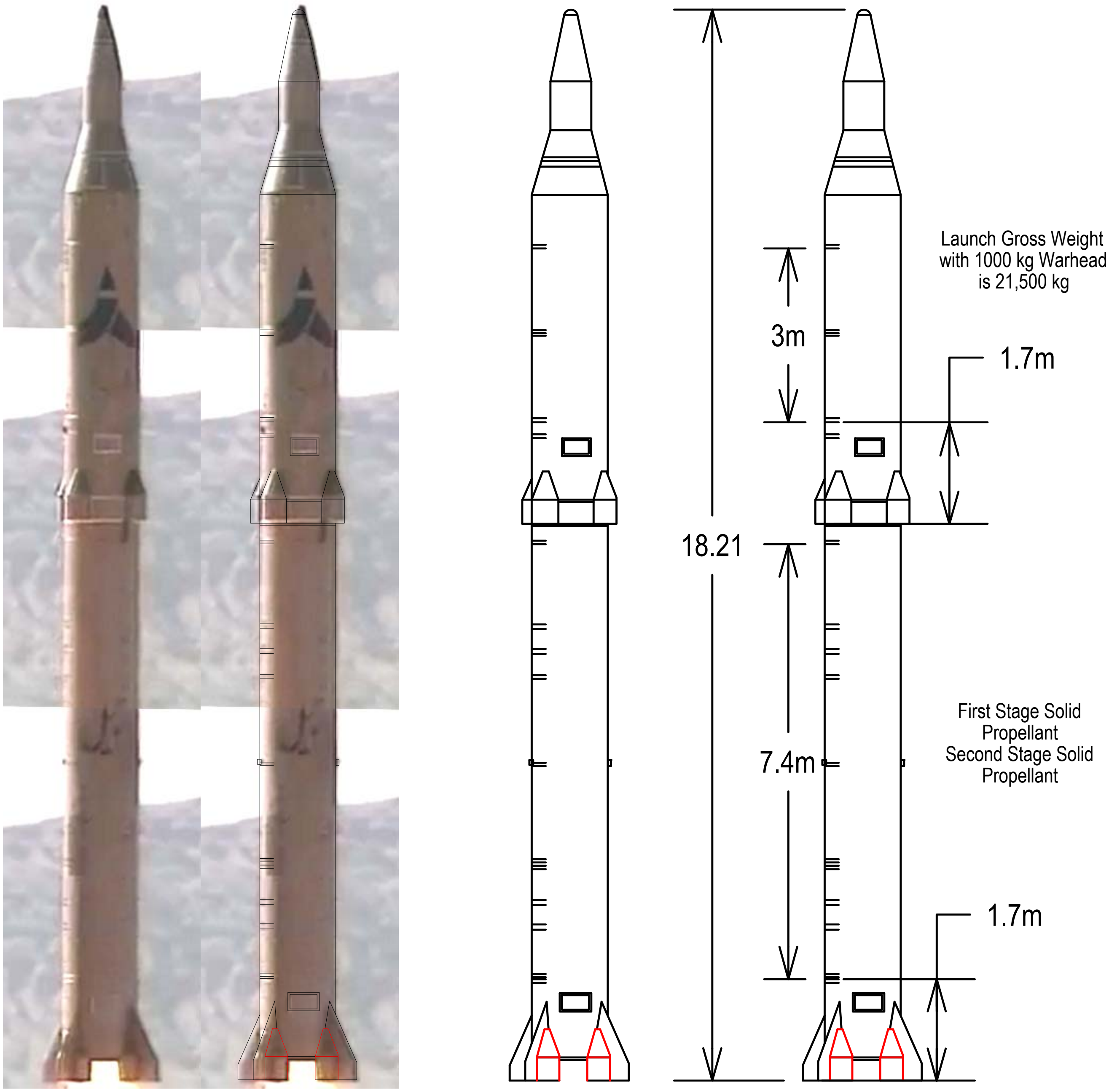
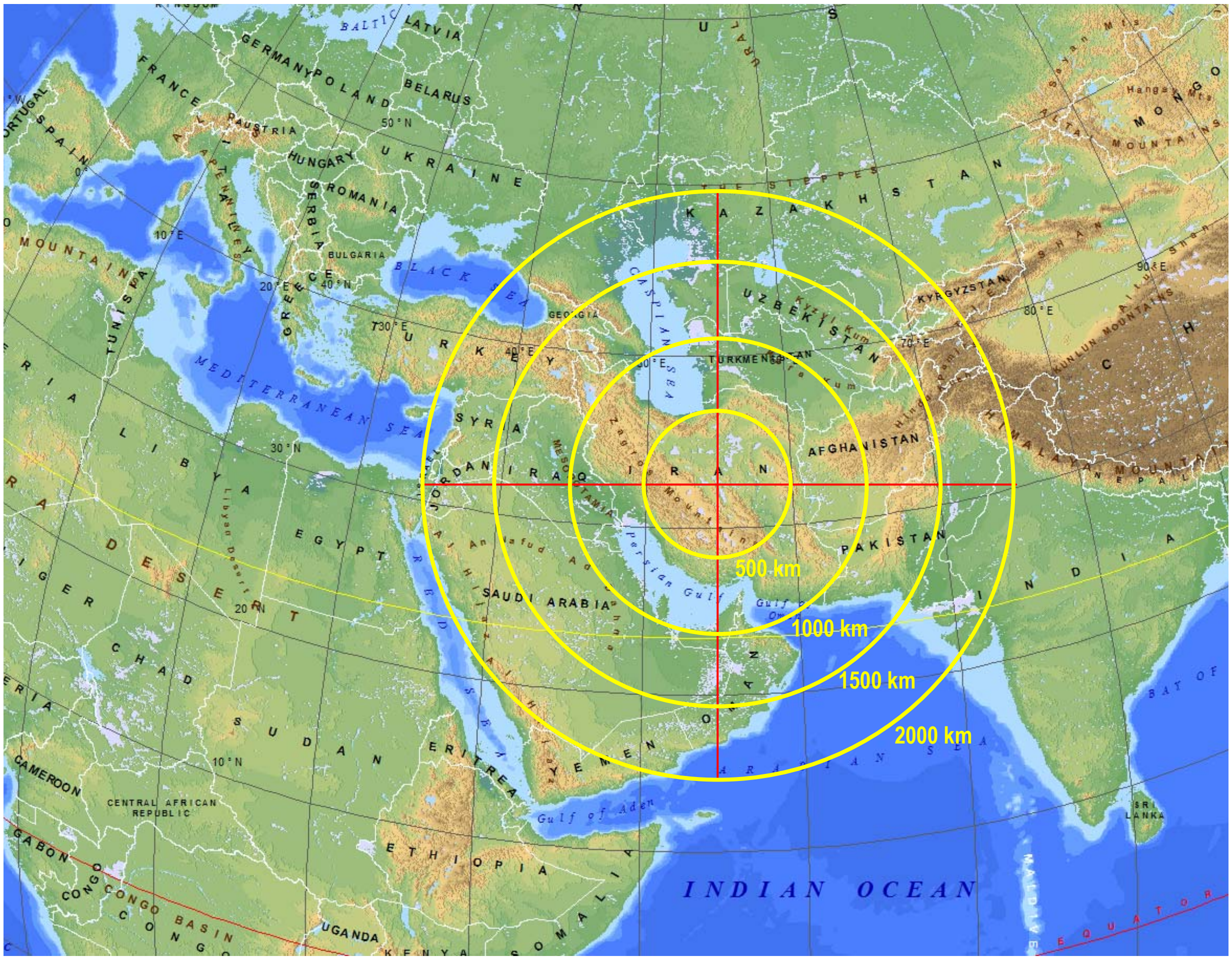

18.21
3m
1.7m
7.4m
1.7m
Launch Gross Weight with 1000 kg Warhead is 21,500 kg
First Stage Solid Propellant
Second Stage Solid Propellant

Figure 9

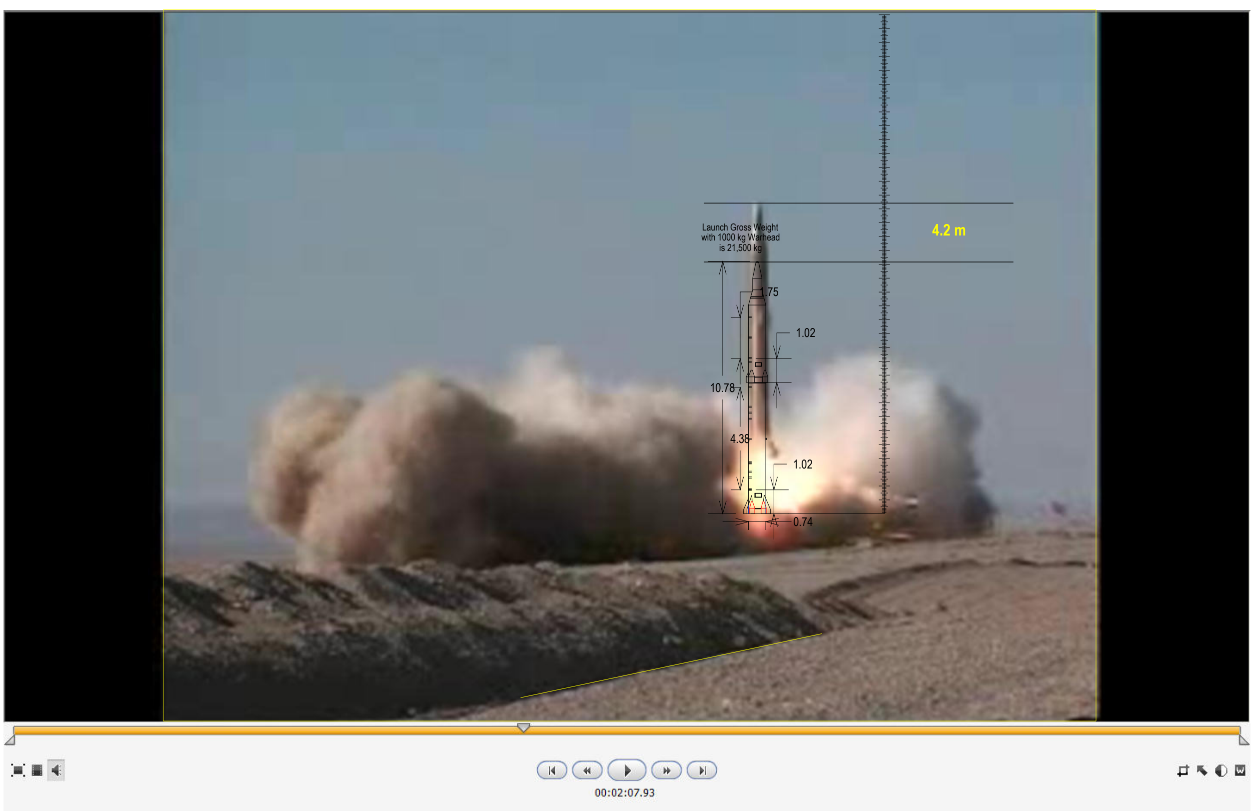

500 km
1000 km
1500 km
2000 km
IRAN
IRAQ
SYRIA
JORDAN
SAUDI ARABIA
EGYPT
TURKEY
GEORGIA
TURKMENISTAN
UZBEKISTAN
KAZAKHSTAN
KYRGYZSTAN
AFGHANISTAN
PAKISTAN
INDIA
YEMEN
OMAN
SUDAN
ERITREA
ETHIOPIA
LIBYA
CHAD
TUNISIA
GREECE
BULGARIA
ROMANIA
SERBIA
HUNGARY
AUSTRIA
UKRAINE
BELARUS
POLAND
GERMANY
LATVIA
FRANCE
SPAIN
CAMEROON
CENTRAL AFRICAN REPUBLIC
GABON
CONGO
UGANDA
KENYA
SOMALIA
SRI LANKA
NEPAL
MEDITERRANEAN SEA
BLACK SEA
CASPIAN SEA
Persian Gulf
RED SEA
Gulf of Aden
ARABIAN SEA
INDIAN OCEAN
BAY OF
EQUATOR

Observed Sejjil Altitude with Time During Launch (Page 1 of 9)

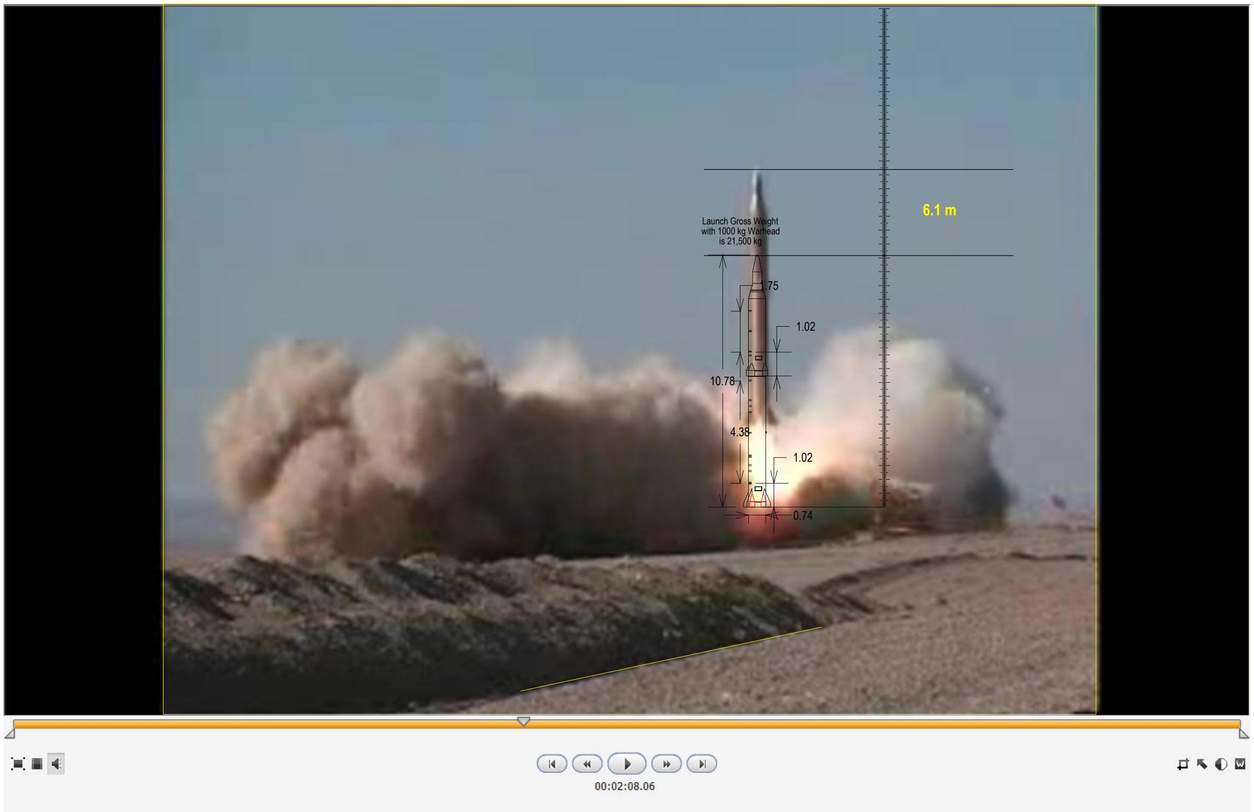
Observed Sejjil Altitude with Time During Launch (Page 2 of 9)

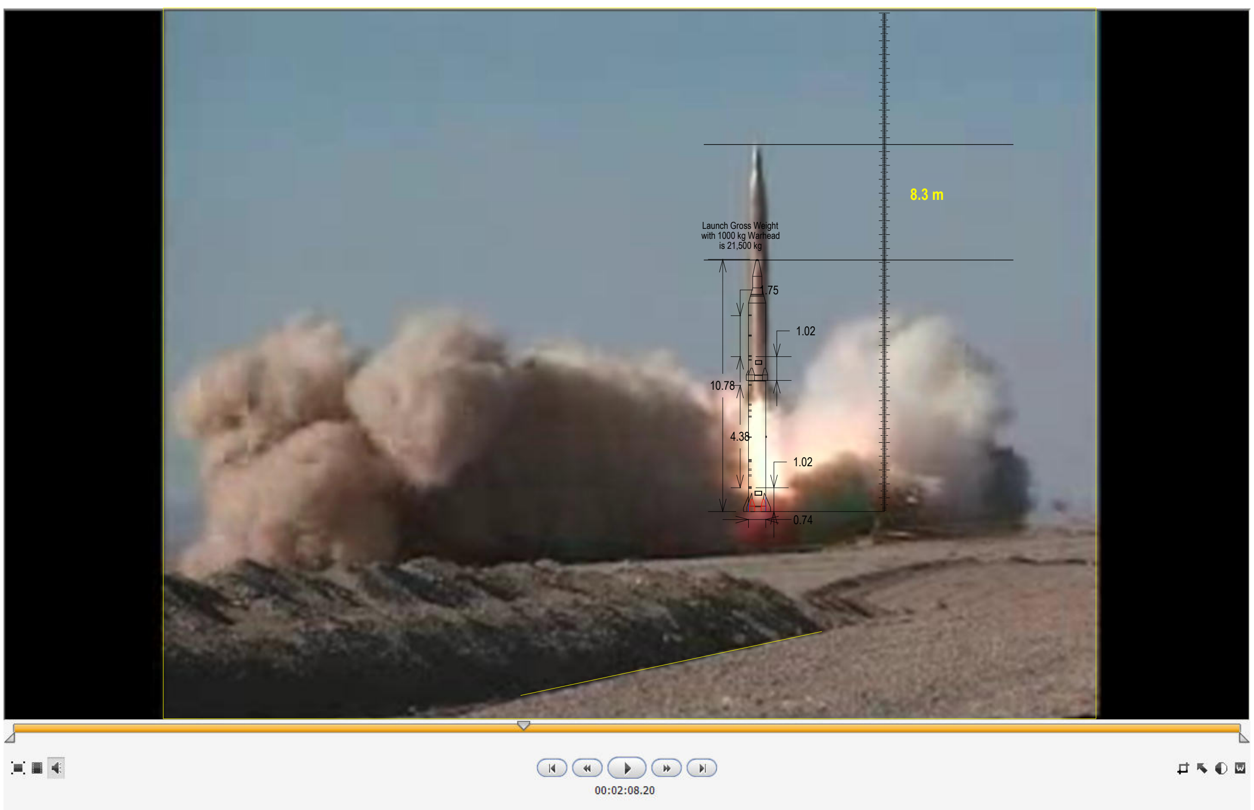
Observed Sejjil Altitude with Time During Launch (Page 3 of 9)

Observed Sejjil Altitude with Time During Launch (Page 4 of 9)

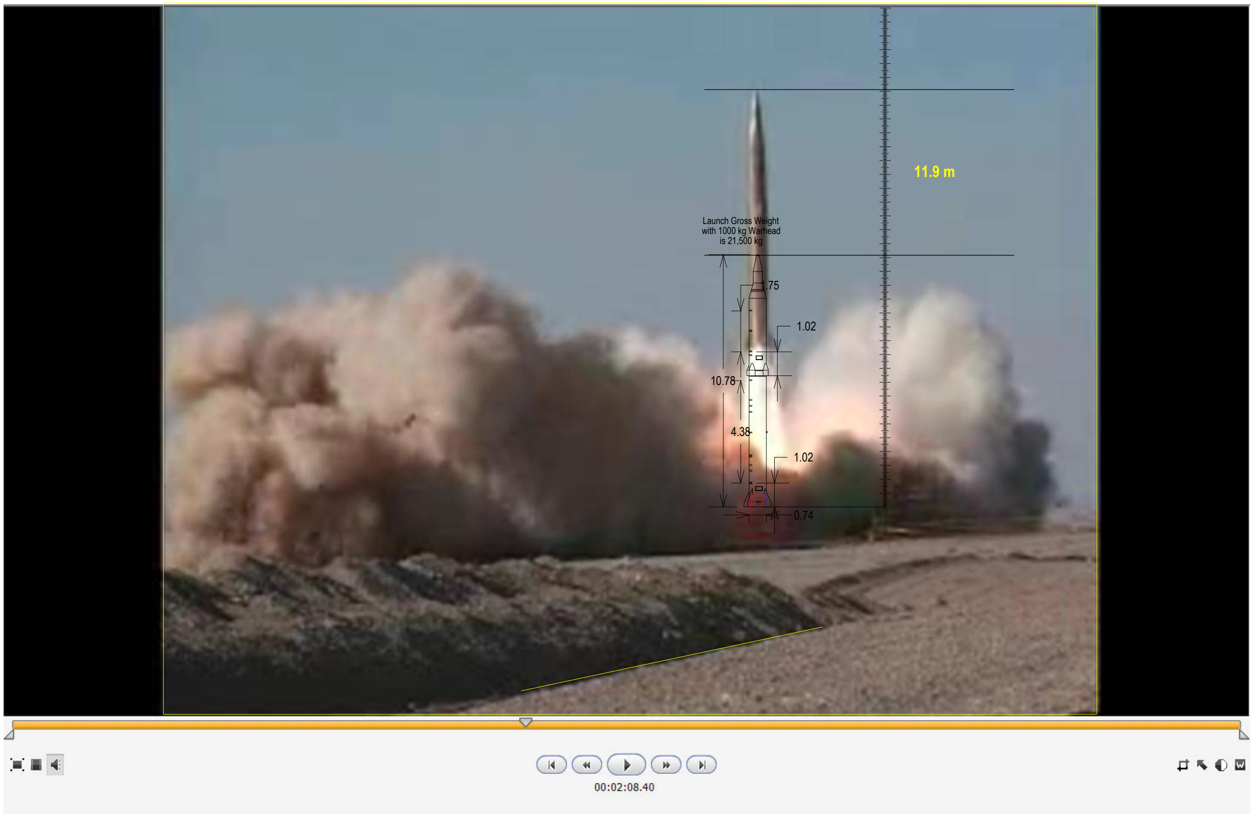


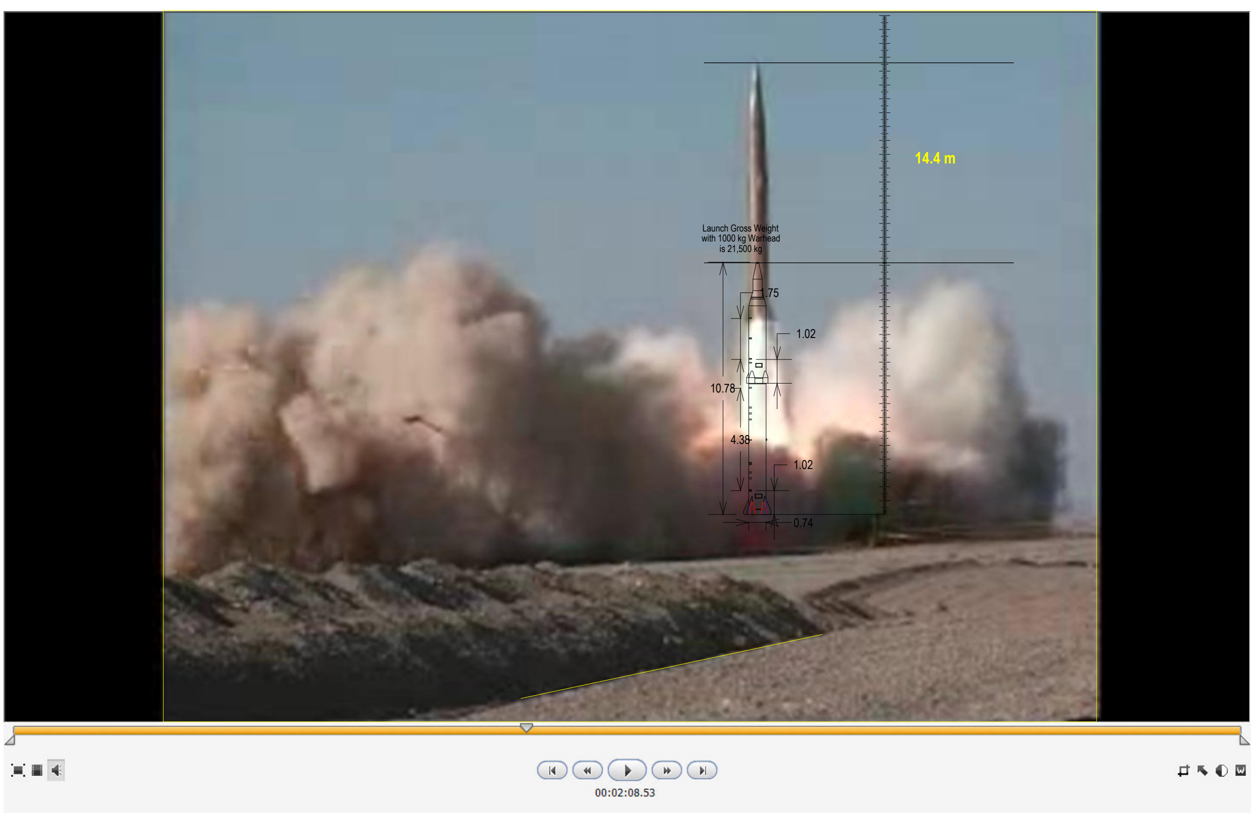
Observed Sejjil Altitude with Time During Launch (Page 5 of 9)



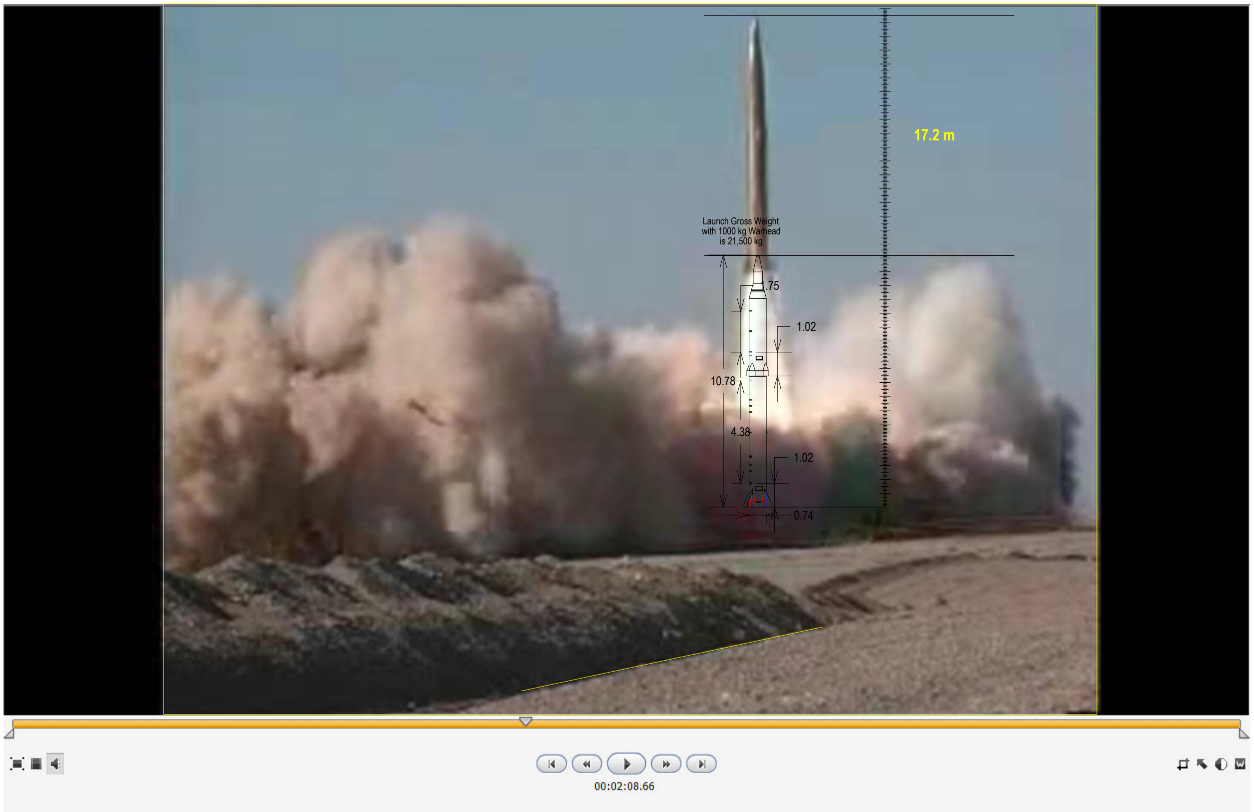


Observed Sejjil Altitude with Time During Launch (Page 6 of 9)

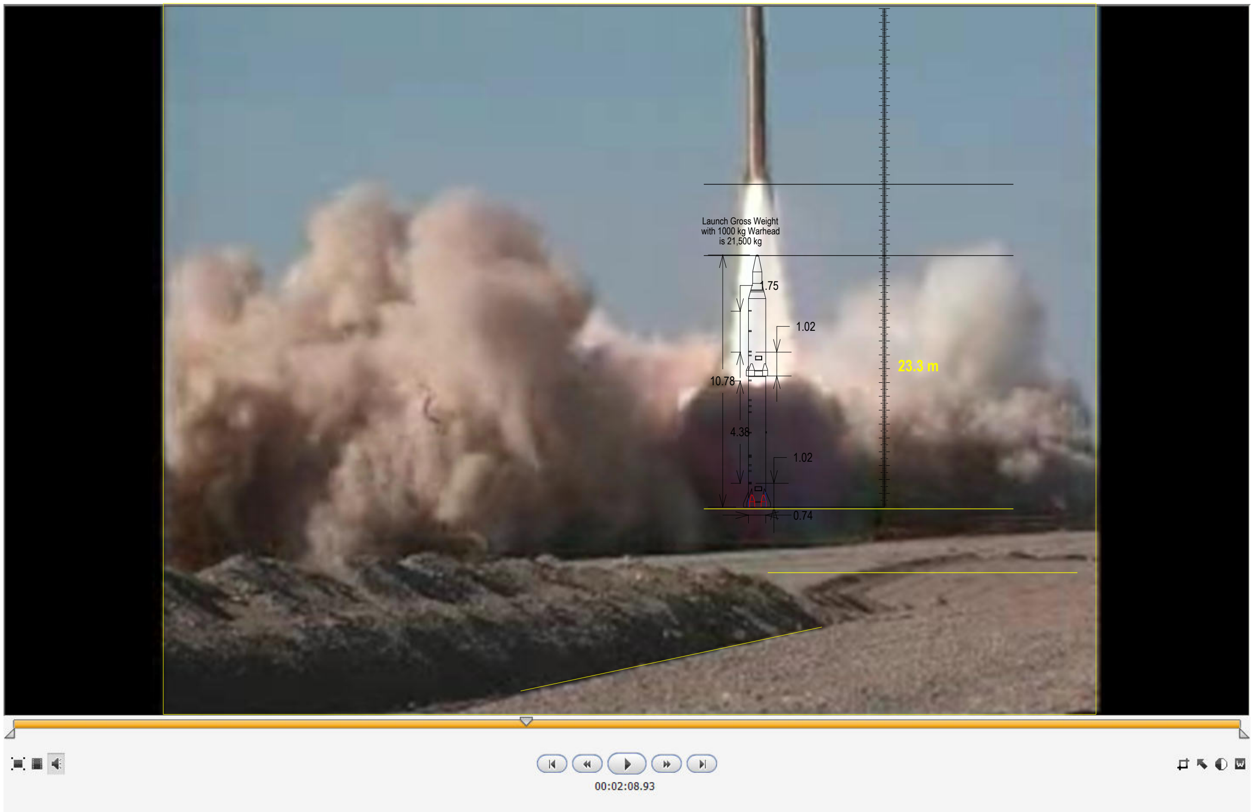


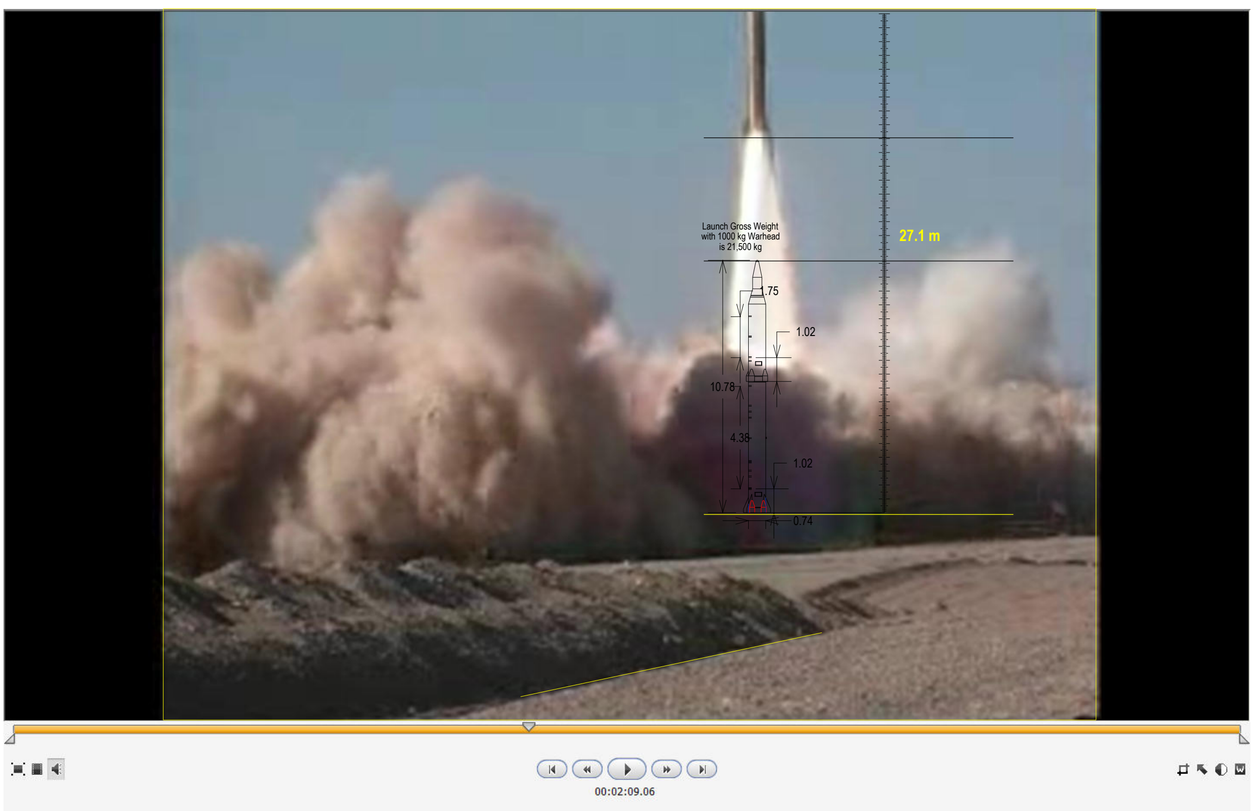


Observed Sejjil Altitude with Time During Launch (Page 7 of 9)



Observed Sejjil Altitude with Time During Launch (Page 8 of 9)





Observed Sejjil Altitude with Time During Launch (Page 9 of 9)