# Safir—Iran Hops Off the SCUD Bandwagon


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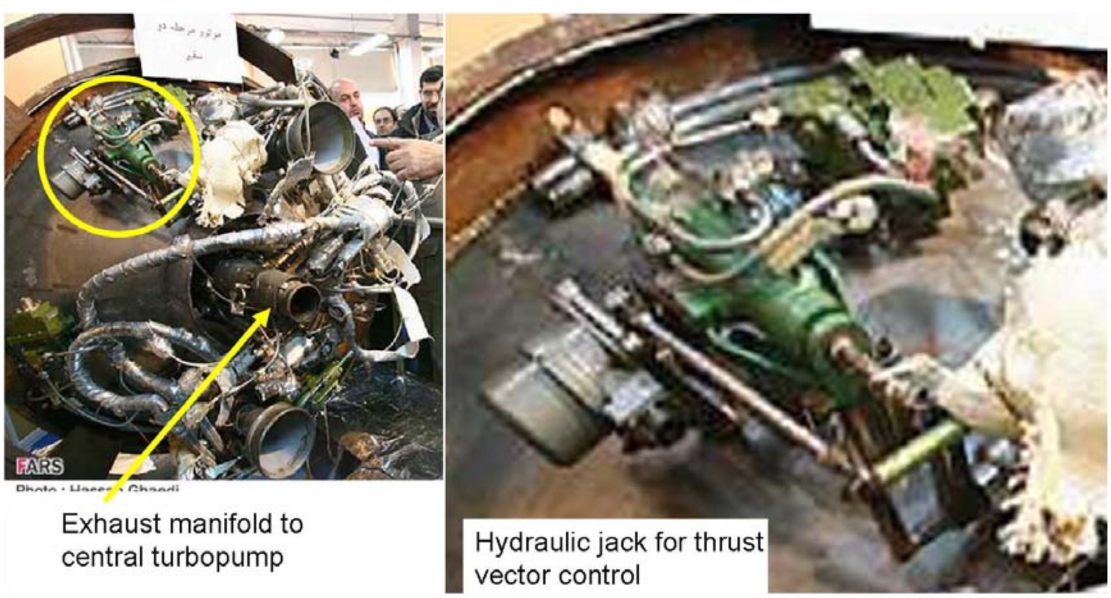
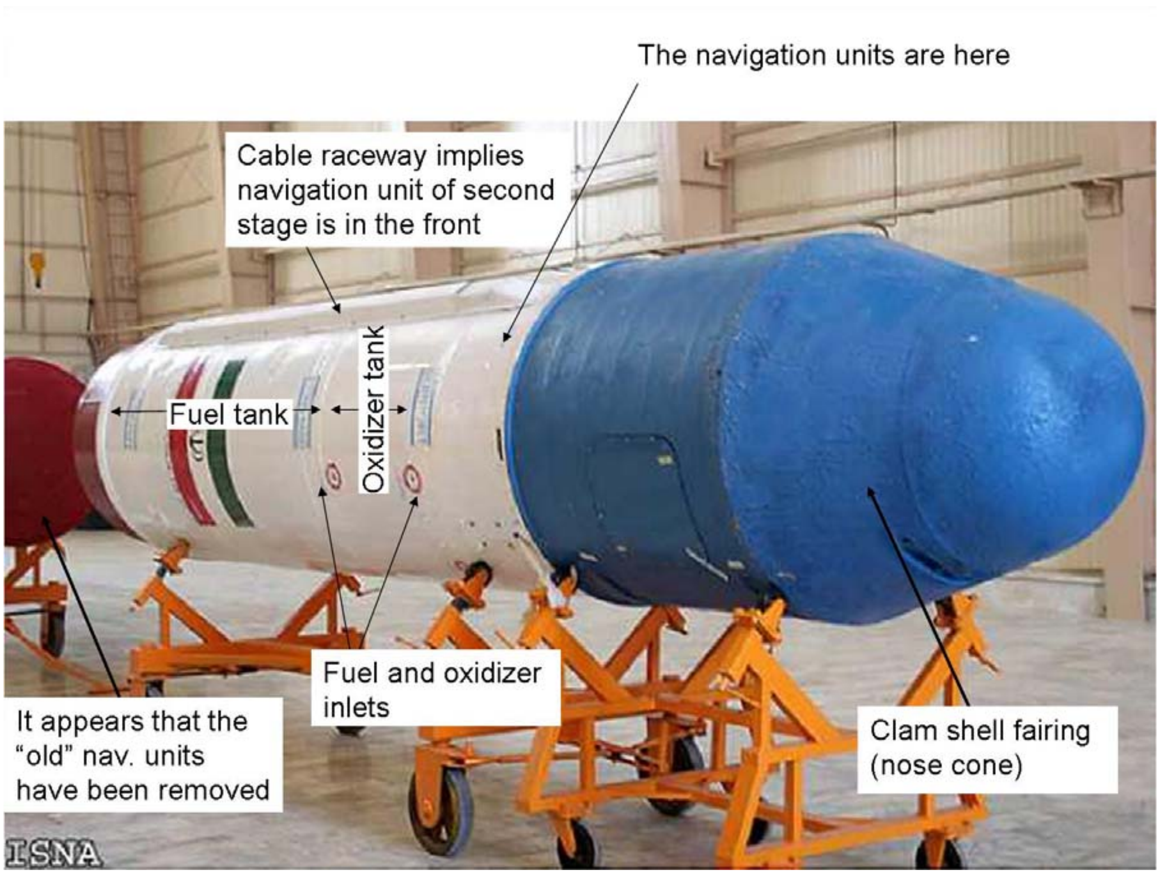
President Ahmadinejad of Iran has a much appreciated habit of going to his country's most advanced centers of technology and having his picture taken in front of the most interesting items there. Not only does this serve to advertize the advances Iran is making in a variety of technological fields (his visit to the Natanz enrichment facility comes to mind), but it provides a wonderful opportunity to analyze just how far Iran has developed! In the case of his visit to the Iranian Space Center last February, the images posted on his website provide convincing evidence that Iran is breaking off of the SCUD-type rocket technological arc and developing a number of important advances in rocket technology.

The most important photo shows Mr. Ahmadinejad, standing next to a piece of equipment labeled in Farsi as "Second Stage." It appears to be a static test version of a two engine cluster where the engines share a common turbopump. This in itself is an important technological advance! However, by itself, it would not indicate that Iran was advancing beyond SCUD technology. Also visible below the mess of piping (which is very disorderly, another indication that this is just a development model for use on a static test stand) is what appears to be two hydraulic jacks, one associated with each of the engines. These could clearly be used for moving the associated rocket engine back and forth to control the direction of each engines thrust—something that is known as thrust vector control or TVC. (In another photo, such jacks are seen displayed on a table other components that could be associated with TVC; a display reminiscent of the centrifuge components displayed for Mr. Ahmadinejad at Natanz.) This change to a gimbaled engine TVC is the first important advance beyond SCUD technology that we can positively attribute to Iran, North Korea, or pre-war Iraq!



SCUD missiles, and their direct descendents such as the Shahab-3 (or Nodong as its North Korean variant is known as), which the Safir uses as a first stage, use graphite jet vanes fixed to the bottom of the missile and stuck into the exit exhaust.  When the guidance unit detects an unwanted tilt to the rocket, or when the pre-programmed pitch program calls for a change in direction, a signal is sent to the servos that control the angle of these jet vanes and the rocket is set back on the proper course.  However, sticking these vanes into the exhaust robs the missile of about 5% of its thrust.  They also limit the size of the rocket engine.  The next stage of development of TVC is to mount the engine on a gimbal and actual tilt it in the appropriate direction.

These jacks, however, appear to be only for tilting the engines along a single axis and would, therefore, be difficult to control both pitch and yaw.  It would be more appropriate for Iran to mount four of these rather small engines on the second stage; one pair of engines mounted opposite each other across the central turbopump could act in coordination to control pitch while the other pair controlled yaw.  That, of course, would also increase the thrust of the second stage and is what I assume for modeling the capabilities of the two-stage Safir.




The engines shown in this photograph are small and clearly different from either SCUD or Volga (the engines used for both the SA-2 SAM and the Iraqi Al Samoud).  The question is, would Iran develop a new engine for the same sorts of fuel the SCUD uses or would they develop a new engine that used a more powerful fuel/oxidizer combination.

While this cannot be determined from the picture, it makes the most sense to me that they would develop a new engine for UDMH/IRFNA combination. This has a significantly improved specific impulse and, again, is what I use to model the performance of this rocket. The dimensions of the second stage can be determined from comparing its length to width and using a diameter of 1.25 meters (there is, of course, some disagreement about this value!) These dimensions, which yield a total length of 3.5 meters for the second stage (not including the nose fairing) are illustrated on the picture below:

Could this two stage rocket put something into orbit? My calculations, with the optimistic assumptions I've made, indicate no, it couldn't. However, it can reach an altitude of roughly 200 km with a speed of 6.5 km/s (it would need a velocity of roughly 7.5 km/s at that altitude to reach orbit). That's actually very impressive! A small solid-propellant third stage inside the nose fairing with a light satellite on top could reach orbit. However, to get there, I had to assume that the second stage coasted for about 110 seconds from first stage burnout to second stage ignition. This causes considerable problems for a second stage since it would require it to ignite without the benefit of a force pushing the fuel and oxidizer into the second stage turbopump.

Even if there was no coast period, it appears—because of the lack of a visible interstage venting—that the second stage probably separates from the first stage before igniting. This represents a major difficulty for any liquid propellant second stage. Once in free fall, the fuel and oxidizers tend to float away from the turbopump inlet, causing at best a decrease in fuel/oxidizer flow and at worse a failure to pump anything to the combustion chamber. If Iran could deal with this problem, it would be another major advance for them!

The second stage central turbopump, however, provides a natural solution to this! If the solid propellant gas generator causes enough "exhaust" out the central manifold, it might be enough to push the fuel and oxidizer into the turbopump as that gets started. Turbopumps have been used for similar purposes. For instance, SpaceX's Falcon 1 uses the exhaust from its turbopump to control unwanted rotation, which shows that they can generate a significant thrust.

It has also been reported that the Aegis cruiser, the USS Russell observed the failure of the second stage and that it, in fact, is said to have flown wildly off course. There are a number of possible causes of such a failure: first, the thrust vector control system—the new method of steering the second stage that Iran was developing using hydraulic jacks to move the engines back and forth—could have failed. That might have caused the second stage to swing increasingly wildly as it unsuccessfully sought to damp down some perturbation that was originally a very small error. Another possibility is that the altitude determination/control system on the second stage failed. For instance, the second stage could have picked up a slight tumble during separation—perhaps by being knocked slightly by the first stage as they moved apart—and if either undetected or uncorrected, could have caused the second stage to blast off in some random direction. And, of course, the failure might have been caused by some third possibility.

It might be possible for the US government, with its radar observations, to analyze the causes even better than the Iranian scientists who launch the Safir.  Unfortunately for this analysis, it does not appear that we can say anything further as to the nature of the failure. The Russell should have been able to see the Safir as it came above the horizon at about 100 seconds into its flight, regardless of what type of trajectory it was on.  That was seconds after the first stage should have burnt out.  If the Iranians had attempted an orbital insertion after a long coast period, than the Russell could have observed almost all of the coast and the second stage ignition at high altitude.  It is doubtful that the Russell could have used its radar to imaged the second stage but it is possible they could infer the existence of a tumble if they had seen a wildly changing radar cross section.  If, on the other hand, the Iranians had attempted a second stage ignition immediately after separation, the Russell would have seen that almost from the beginning.

As I mentioned, the real reason the Safir failed might be different from either of the two possibilities mentioned above.  However, it is clear that Iran is using the Safir as part of its development of a number of important missile technology advances, advances that go far beyond what North Korea, with what continues to appear to be SCUD-technology, has demonstrated.  In particular, ICBMs developed using SCUD-technology would have to be enormous.  By escaping the SCUD-technology arc, Iran appears much more likely to develop ICBM capabilities.