Safir—Iran Hops Off the SCUD Bandwagon

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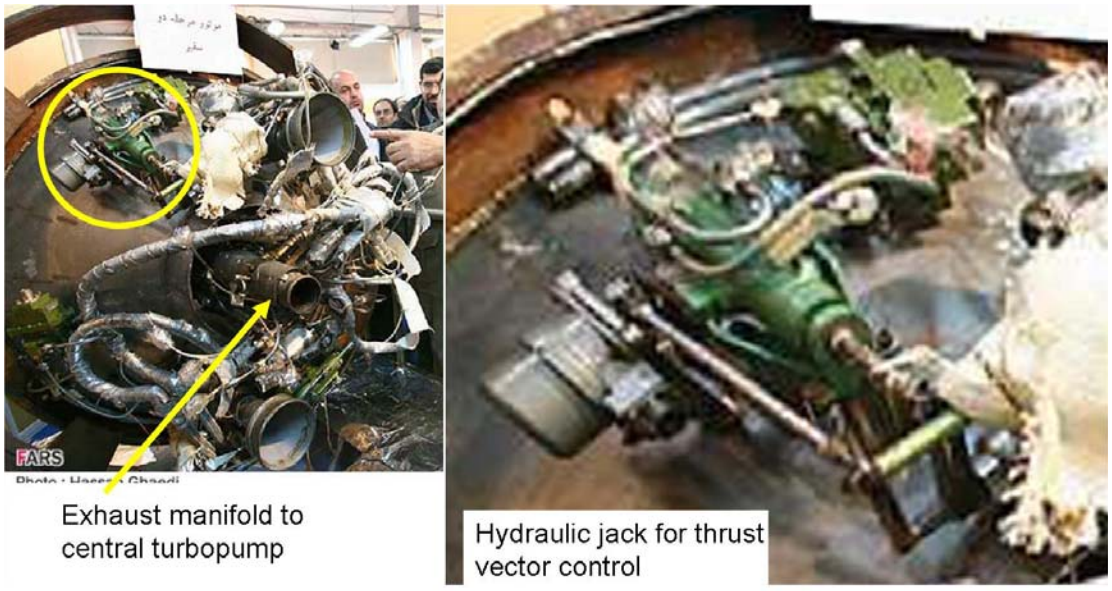
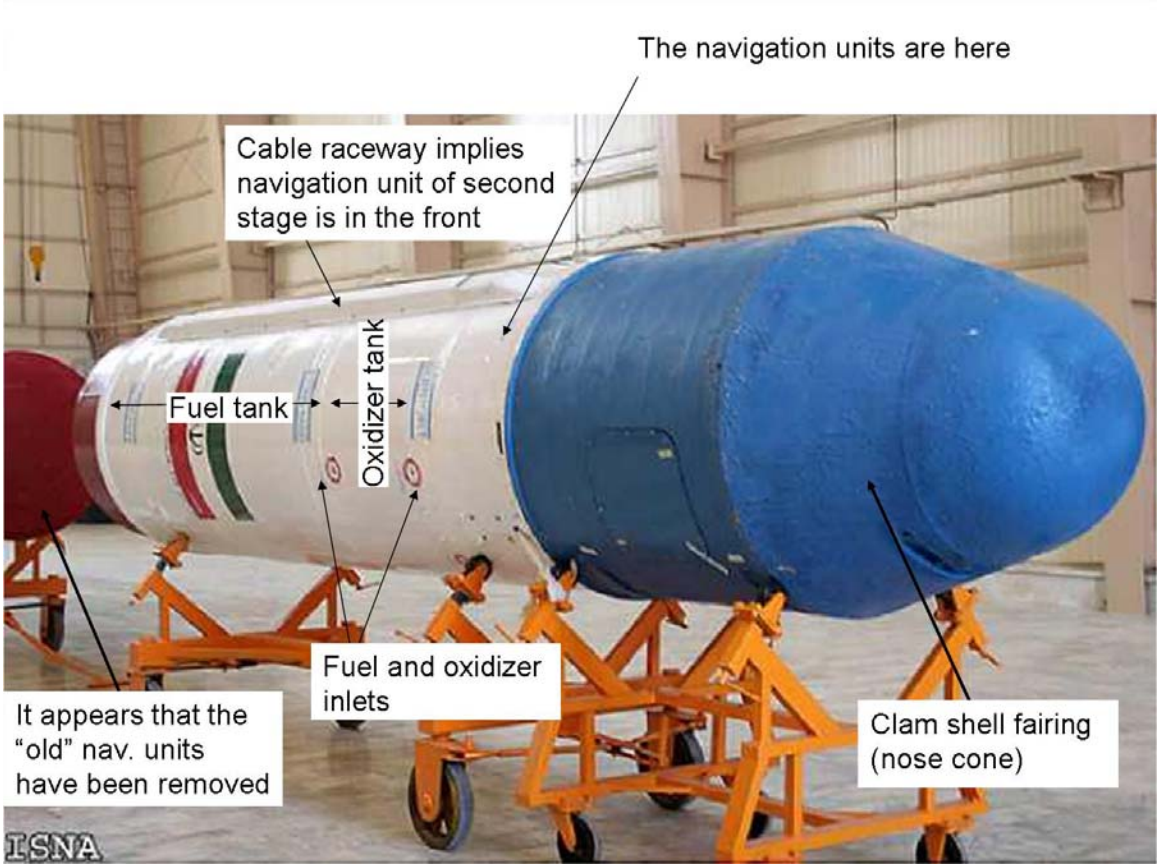
President Ahmadinejad of Iran has a much appreciated habit of going to his country's most advanced centers of technology and having his picture taken in front of the most interesting items there. Not only does this serve to advertize the advances Iran is making in a variety of technological fields (his 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 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. If Iran could deal with this problem, it would be another major advance for them!

However, the second stage central turbopump 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 fuels into the turbopump as that gets started. After all, SpaceX's Falcon 1 uses the exhaust from its turbopump to control unwanted rotation. It turns out that the fact that the Safir was seen to fail by the USS Russell, it has been reported that the Russell saw the second stage veer wildly off course, might give us some clues as to not only how the second stage failed, but if there was a coast period built into the trajectory (and indicate if Iran was trying to ignite a liquid propellant motor in free fall.)

The Russell, based in the Gulf of Oman, can only observe the Safir with its radar after the rocket has risen a considerable distance above the Earth's surface. In fact, if the Safir's second stage ignited at the time of the first stage burnout, and used the acceleration of the first stage to push the fuel into the second stage turbopump, then it would be almost three degrees below the Russell's horizon and invisible. If, on the other hand, the Iranians tried to ignite the second stage in free fall, then the Russell could have observed the attempt about 2 degrees above its horizon.

Why did the Safir second stage veer wildly off course? Two possibilities immediately suggest themselves: 1) the new TVC system failed and 2) the attitude control/determination system failed. Either of these, and in deed some other possibility, is possible. However, since we know it failed after a long coast period, I tend to favor the failure of the attitude control/determination system.