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The Assumed KN-08 Technology

Addendum to the April 18, 2012 Paper “A Dog And Pony Show”

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On April 15, 2012, North Korea presented six road-mobile KN-08 Intercontinental Ballistic Missiles (ICBMs) at a parade in Pyongyang. As was concluded in the paper “A Dog And Pony Show”, the presented missiles were mock-ups. There is speculation that these mock-ups are based on an existing design that uses technology allegedly available in North Korea, namely engines and manufacturing technologies of the Soviet R-27/SS-N-6 Sea Launched Ballistic Missile (SLBM) or the North Korean Nodong missile. Various technical and programmatic aspects indicate that this is highly unlikely.

Figure 1: The Six KN-08 TELs at the Parade

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KN-08 Dimensions

The following dimensions are rounded. The exact length of each stage is hard to define – the indicated stage separation positions vary, depending on the analyzed mock-up.

The presented mock-ups have a total length of more than 17 m. First stage length is perhaps 7.5 m, second stage length is less than 5 m, third stage length is more than 2 m, and warhead length is more than 3 m.

First and second stage diameter is less than 2 m, perhaps down to 1.8 m. Third stage diameter is probably 1.3 m. For further considerations, diameters of 1.9 m and 1.3 m are assumed.

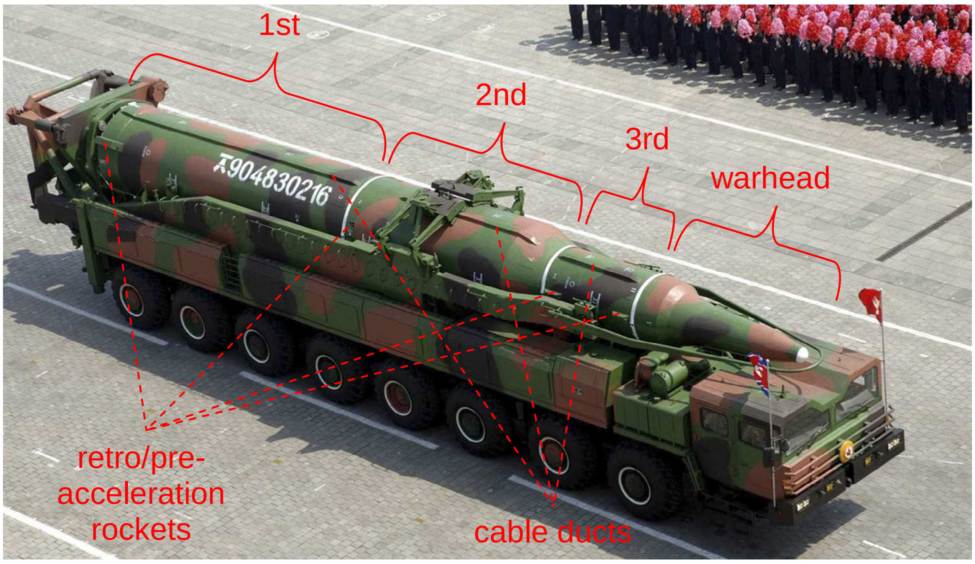

Figure 2: The KN-08 Missile

General Design Issues

Rockets are always optimized for performance, and designed as simple as possible, since every unnecessary feature is a source of potential failure. Only severe restrictions can lead to different design approaches that lower the system performance, or increase system complexity. One restriction is the availability of rocket engines, for example. "Nice to have"-features are sometimes found at Western designs, but only if additional costs and durations do not play a decisive role for the program. This is unlikely to be the case for a missile program in North Korea – program delays and exploding costs due to unnecessary features are most likely not well received by the leadership, and thus avoided if possible.

Due to technical constraints and physical laws that have significant effects on the missile system’s performance, solid-fueled ICBMs are usually designed with three stages, while liquid-fueled ICBMs only have two stages to achieve the best performance. There are very few exceptions, but these were designed due to certain design restrictions or requirements. The Soviet/Russian R-29RM/SS-N-23, for example, is a liquid-fueled SLBM with three stages and intercontinental range that was evolved out of the two stage R-29 SLBM family, carrying a very heavy payload of almost 3 t. If a new liquid-fueled ICBM is designed from scratch, as would have been the case with the KN-08, engineers would normally opt for a two stage design.

Cable Ducts

It seems that the earlier remarks (see “A Dog And Pony Show”) on the KN-08 cable ducts, also called cable raceways, led to some misunderstandings.

Cables are always routed along the outer side of a rocket’s hull over a certain distance, for both solid- and liquid-fueled missiles. It is too complicated to route the cables through the combustion chamber (solid-fueled rockets) or through the tanks (liquid-fueled rockets) for various reasons: A spark might ignite the propellants, the breach in the tank wall/combustion chamber wall is a potential source for leakage, and so on. Once outside the airframe, these cables are protected by a cover – this is the visible cable duct. The existence of the cable duct itself is therefore irrelevant for analysis because there always is a cable duct. However, the positions of the cable duct’s endings are important, because these positions hint at the missile’s inner configuration. The cables are routed back into the airframe as soon as possible for several reasons – the cable covers are unnecessary extra mass, for example, as are the cables themselves if you have them extending to the aft skirt of the rocket stage and then leading back up again inside the airframe.

Again, there are exceptions. The cable ducts at the Soviet UR-200 (or the R-36), for example, lead down to the very end of the aft skirt. But the skirt is not the back end of the rocket – the engines are not fully covered by the skirt and stick out of the rocket. This is done to save weight. Therefore, the cables are still routed “back inside” quite a distance from the rocket’s back end. The UR-200 (and the R-36 as well) was developed for silo use – no protection against dust and dirt and weather was required, allowing for an “open skirt” design with exposed engines.

(The same situation can be observed at the UR-200′s upper stage: On first glance, it seems that the cable leads down all the way to the end of the aft skirt. This is not true, though: Actually, the cable is routed back into the missile at the end of the tank section – the conical section is part of the upper stage and houses the propulsion unit.)

A cable duct that extends to the aft end of a liquid-fueled rocket stage’s hull is therefore a good indication for a submerged engine design (meaning that the tank extends down to the very end of the missile, and the engine is integrated in the tank and submerged within the propellants). This complex design solution is only used at SLBMs that have to be designed as compact as possible to offer highest performance while fitting into the submarine launch tubes.

Use of Nodong Technology

The so-called “Nodong technology” is closely related to the Soviet R-17/Scud B missile.

The propellants, inhibited red fuming nitric acid (IRFNA) and kerosene, are storable and suited for road-mobile missile use.

The structural design of the Nodong is analogue to the R-17/Scud B: The tanks are made of steel sheets with steel ribs, but without stringers. Aluminum is used for the instrument section’s stringers, the ribs are made of aluminum or steel, all covered with a thin steel skin. The same approach is used for the engine section (see Figure 3).

Figure 3: Back End of a Scud B Missile

Modifying Nodong engines into a submerged design would be a highly complex, nightmarish engineering task. There is no known case of a successful conversion of a non-submerged design into a submerged design – developing a completely new engine seems to be the easier option. Therefore, it seems plausible to assume that any Nodong engines in the KN-08 are not submerged.

In that case, the propellant tank sizes would be smaller, since the engines require more than 2 m of space. With less propellants, range would decrease significantly.

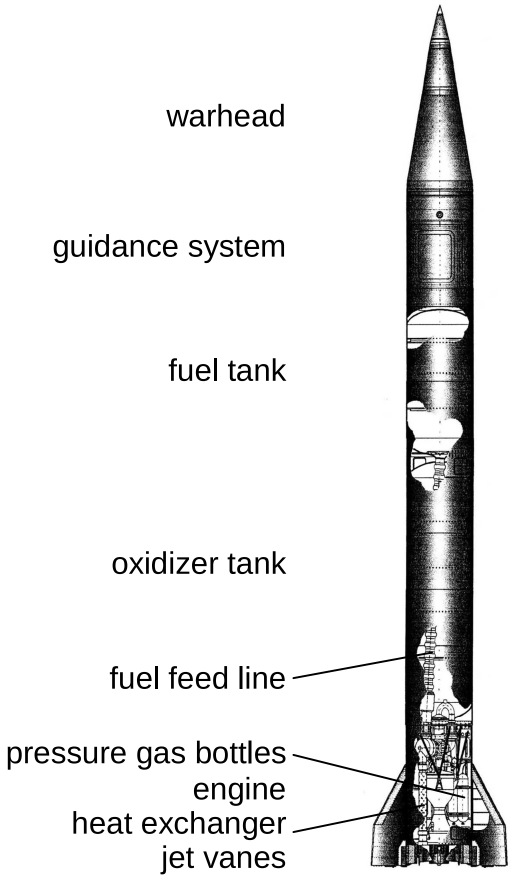

Figure 4: Scud B Missile

Additionally, it would be a challenge to house more than one Nodong engine in a diameter of less than 2 m.

Assuming nonetheless that the KN-08 had two Nodong engines in the first stage, one Nodong engine in the second stage and a smaller Scud/Nodong-related engine in the third stage (all engines non-submerged), the missile launch mass would be around 30 t. In theory, such a missile could cover up to 4,000 or 5,000 km with a light warhead. With extreme lightweight design, featuring an aluminum airframe, the range might be more than 6,000 km.

Use of SS-N-6 Technology

The so-called "SS-N-6 technology" is closely related to the Soviet R-27/SS-N-6 missile.

The propellants, NTO and UDMH, are storable but suited only for use in conditioned environments – under standard conditions, the NTO oxidizer freezes at -11 °C (12 °F) and boils at +21 °C (70 °F). Using this propellant in a road-mobile missile risks local damage with catastrophic consequences, in winter as well as in summer. Even assuming that additives might move the boiling point to +30 °C, this is still far from the usual requirement of +50 °C for operational use of road-mobile missiles (as defined, for example, for the R-17/Scud B, the SS-21/Tochka, the SS-23/Oka, or the SS-26/Iskander missiles). And additives would also have a negative effect on performance.

The Soviets never used NTO in an open, road-mobile missile design. There were good reasons not to do this.

The SS-N-6 features extreme lightweight design with aluminum isogrid structures (see Figure 5) that are produced in a highly complex process involving chemical etching. The delicate structure is designed for maximum weight savings, with the SS-N-6 only intended for deployment in a protected submarine launch tube. It is not suited for the harsh conditions of unprotected road-mobile use.

Figure 5: SS-N-6 Interior with Tank Structure and Top of the Engine

Ignoring these restrictions, a KN-08 missile designed with SS-N-6 technology would already offer ICBM capability with only two stages. Such a missile would be comparable to the Soviet two stage R-29R/SS-N-18 SLBM, which had a length of less than 14 m, a diameter of 1.8 m, and a launch mass of around 33 t, offering ICBM range with a heavy warhead of more than 1 t.

Further ignoring this over-engineering aspect of building a three stage missile where two stages would be sufficient, there is again an issue with the available space for more than one engine in the KN-08 diameter. Additionally, contrary to non-submerged engines, the thrust load of the SS-N-6 engine is transmitted at the lower end of the engine. This requires a complex new design of the rocket's aft section to transmit the thrust of more than one SS-N-6 engine, and do this without noteworthy bending of the bottom.

Figure 6: SS-N-6 with the Submerged Engine

A SS-N-6 propulsion system consists of one main engine and two independent small vernier engines. The sea level thrust of the SS-N-6 main engine is around 23 t. The two small vernier engines deliver a combined thrust of around 3.5 t at sea level. The combined thrust of two main engines is too low for the missile (ballistic missiles usually accelerate with 1.8 g or more at launch), and three main engines hardly fit into the KN-08 diameter, even assuming major engine modifications. The same problem arises for two complete SS-N-6 propulsion systems (main engine plus two vernier engines).

There also is an issue with the position of the small stage separation/acceleration rockets that are visible at some of the mock-ups (see Figure 2). These rockets are fired just after staging, and are intended to either pull a spent rocket stage away from the rocket, or to pre-accelerate the remaining liquid-fueled rocket, to settle the liquid propellants and avoid gas bubbles being sucked from the tank into the engine at startup. If the KN-08 really was a liquid-fueled missile with a submerged engine design, these little rockets were mounted right at the tank walls. The risk of structural damage is high enough that every sound engineer would try to avoid this. (This is different for solid-fueled missiles, for example the Iranian Sejil – their combustion chamber walls are more robust and can easily handle the loads of retro rockets.)

There are several more problems that an engineer would encounter if he designs the KN-08 with SS-N-6 technology. Ignoring all these problems and the previously mentioned restrictions, a SS-N-6-derived KN-08 with three SS-N-6 engines in the first stage, one SS-N-6 engine and two vernier engines in the second stage, and two vernier engines in the third stage would weigh around 35 t. In theory, such a missile could cover more than 10,000 km range with a light warhead.

KN-08 and Unha-3

It seems likely that the KN-08 mock-ups were intended to create the impression of an ICBM that is based on SS-N-6 technology, even though the design looks more like a high-end solid-fueled ICBM. In both cases, the rocket would be far superior to the known North Korean satellite launcher (see Table 1) that so far failed at every launch attempt (Taepodong 2 in 2006, Unha-2 in 2009, Unha-3 in 2012).

Table 1: Unha-2/-3 and KN-08
(all numbers are rough estimations)

	Unha-2/-3	**KN-08**
Length [m]	30	18
Launch Mass [t]	85	35
Range (ballistic launch) [km]	6,000+	ICBM
Payload to LEO [kg]	500	700
Launch Site	stationary	mobile
Preparation Time	weeks	minutes

If real, the KN-08 could be quickly launched from anywhere, easily carrying a heavier satellite into Low Earth Orbit (LEO) than the Unha-2/-3.

Therefore, the question arises why the North Koreans would spend so much effort on the Taepodong 2/Unha program, using outdated technology, when they already have a far superior rocket up their sleeves.

Summary and Conclusion

A KN-08 design based on Nodong technology has limited range and performance. A KN-08 design based on SS-N-6 technology offers impressive range and performance, but creates massive operational problems, and production is extremely challenging. Considering the presented KN-08 design, none of the two options makes much sense from a missile engineer's perspective.

Perhaps the mock-ups were intended as a message, to underline the satellite launcher role of the Unha rocket by claiming that the KN-08 program covers the long range missile role. Anyway, the KN-08 remains mysterious. Any further developments should be closely monitored.