3rd World Missile Development - A New Assessment Based on UNSCOM Field Experience and Data Evaluation*

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Abstract

In 1998, missile development in the 3rd world showed an alarming progress, when Pakistan, Iran and North Korea fired rockets of significant ranges. Of these only North Korea is considered as a major player with experience from reverse engineering and development. Hands-on experience in UNSCOM's R&D missions in Iraq, the analysis of rocket development history and experience from long time industrial work reveal the basic aspects of these countries' activities and capabilities. The data extracted from the open information allow detailed descriptions of the different systems. This results in a new assessment of the missile status in these countries, which points to the necessity of further enforcement of proliferation limitation.

1998 marked three important events in the 3rd world's intermediate and long range missile activities - the April 6 launch of Ghauri in Pakistan, the test of Shahab 3 in Iran on July 22 and the flight of a multistage rocket by North Korea (DPRK) on August 31. Although the results of these flight demonstrations and the respective missile status are still subject of discussions, it becomes obvious that weapons with the described performance characteristics represent a reality and cannot be considered as a mere possibility of the distant future. Furthermore strong indications exist that the tests in three different countries can be traced to one single source.

But some benefit also originate from the experiments. Previously, the information status on the rockets was poor, but the new facts, data, photos and videos result in a better understanding of the systems. It gives not only insight to the performance capabilities of the missiles, but also allows to draw conclusions about the origin, resources, interrelations and future developments in these countries.

The focus must concentrate on North Korea, Iran and Pakistan, while other countries like Syria or Libya play just a minor role at the moment.

The situation with Iraq is different and more complex. At present, the relevant activities are rather slow by external political means and foreign military power, but will most likely gain momentum when the environment changes and the sanctions are lifted[1]. Thus, Iraq must be still considered as a potential major missile and weapon manufacturer and exporter on the long run.

Iraq's relevant work started during the 1980/88 Gulf War, had just been interrupted for a short period after the 1990/91 Gulf War cease-fire and, at present, still runs, but on a limited scale. The knowledge of missile activities in this country is well known thanks to public information and UNSCOM inspections. This allows the establishment of a better insight into the means, procedures and progress associated with missile development and production, which must be considered as typical for these countries.

3rd World Missile Valuation

The western view on missiles in undeveloped countries is characterised by certain prejudices. These result from little reflected application of the western situation to 3rd world technology: preference and concentration on sophistication and performance rather than simplicity and availability, inferiority of liquid propellants compared to solids and ease of reverse engineering. Thus, 3rd world activities are mostly considered to be inferior.

Nevertheless, in some cases there is also a completely conflicting standpoint, which does not only result from the lack of proper information but is also influenced by purposeful exaggeration. In these instances either incredible large numbers of weapons or significant technical performances, comparable to the most advanced Soviet and western systems, are supposed[2].

*Unclassified

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[1]The December 1998 bombardment of Iraq will probably delay the work for several years. However, further UNSCOM-inspections will be unlikely resulting in a significant set-back of the analysis of this country's work.

[2]Examples are the "use" of SS21 warhead technology for Iraq Scud CB warheads or the storage of Scud missiles in Sudan.

It is this unbalanced judgement, which makes a consistent treatment hard to be found and explains why the allocated or projected activities plus associated time scales sometimes seem not to fit to those experienced in other countries.

An appraisal of 3rd world missile's capabilities on the first hand requires the analysis of published data for weapon reconstruction. But more important are those conclusions which can be drawn from the technical findings plus the observed methods and procedures for missile development and production. These allow to enlighten the background and trace the road which these countries follow in order to prove themselves as a competent missile manufacturing and exporting institution.

Focus North Korea

Several countries of the 3rd world are engaged in rocket activities to establish their own medium to long range missile capability. While some of these are particularly interested in modern, western style designs, most of the advances of the recent work seem to be associated with liquid propellant rockets and North Korea. Therefore, especially the missile programs of this country have to be addressed.

A joint China-DPRK missile program, which had stated in 1976 and was terminated in 1978 for political reasons, is generally viewed as a training period prior to the start of North Korea's independent rocket development and production program, providing North Korea with sufficient expertise to proceed with all the successful activities, which are going to follow in the next two decades.

The first step towards missiles is thought to have begun in 1983 with reverse engineering of Scud B missiles, since North Korea could not receive these systems from the Soviet Union[3]. The basis were rockets and launchers, supplied in small quantities from Egypt in the same year, although some sources state the year 1976 as the delivery time. After being used for manufacturing preparation these missiles (or newly manufactured ones) were flight tested in 1984. Production line installation followed in 1985 with pilot production in 1986 and start of export to Iran and Syria one year later. During this seven year's period just 3 Scud B missiles were successfully flight tested altogether, which seemed to be sufficient for both manufacturer and customer[4]!

The next step in 1988 was the development of the extended range Scud C, followed by exports two years later based on just three flight tests[5].

Nearly in parallel, the development of the larger missile Nodong 1 started, which presumedly also led to exports, but on a limited scale. Just one test was performed in 1993 with reduced range[6]. The work culminated in the 31st August firing of a multistage system, which resembles the larger next generation missile beyond Nodong, the 2.500 km Taepodong, but in a satellite carrier modification.

In addition to these activities, Iran and Syria are thought to have bought production lines for the described missiles, but the status is unclear.

According to this view, North Korea represents the most important player in 3rd world missile activities with a broad technological basis, starting with reverse engineering and extending to indigenous development and production capabilities.

Pakistan and Iran are considered to be the beneficiaries of North Korea by procurement of missiles and technology. Especially Nodong and its successors have to be mentioned here with the related components and indigenously in these countries or by North Korea supported modifications.

North Koreas capabilities seem to represent the key factor not only for the technology used for missiles with the mentioned performance, but also for the future threat, which is likely to be faced.

Therefore, any technical evaluation must compare this general view with the missile history to arrive at a solid, non-speculative conclusion. In addition, the basic aspects of missile realisation procedures have to be pointed out so that their specifics and these countries' capabilities can be properly adjusted.

Long Range Missile History

It is generally assumed that North Korea has started with "simple and quick" reverse engineering and has expanded this experience to indigenous missile development. However, for a better judgement of the achievable progress and the associated problems, which are typical for this type of procedure, it is necessary to recall the early rocket history after World War 2 and that of Iraq during the last two decades, which is more applicable and therefore important.

The German A4 was the first large rocket from which all further liquid systems stem. This technology spread out mainly to the USA and Soviet Union and then to countries like China, India and Japan. The observed diffusion process, based upon extensive support, is typical for this work.

Only North Korea looks quite exceptional. This country seems to have progressed without substantial ballistic missile support from outside, except some Scud B missiles and launchers from Egypt[7].

[3]All the mentioned times are more or less educated guesses, derived from some information on tests, delivery and so on.

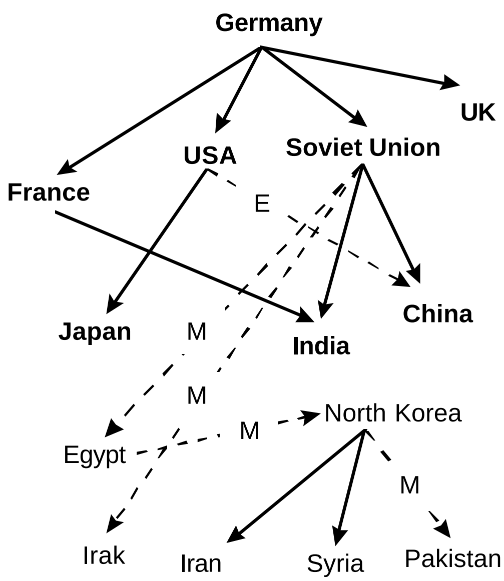
[4]There might have been some failures prior to and after these 3 tests in 1984, but the situation remains unclear.

[5]3 tests in 1993 have not been clearly identified yet - Scud B or C missiles - with a rather short range.

[6]Two additional tests are difficult to assess - either failures, launch pad explosions (highly unlikely) or misinterpreted static tests of complete missiles - and 2 cancelled tests.

[7]For the missile activities considered, the HY-1 production line

Liquid Propellant Missile Activities after WW 2*



*Legend: w/o letter indicates extensive support by experts, training, hard- and software; E: experts only; M: missiles only

Besides the described connections between these countries and the technical aspects of their work, the focus must concentrate on the main topic of interest: missile production and not development or just technology.

A completely defined, with respect to performance accurately specified, reliable and qualified missile is indispensable for deployment with the armed forces and also export. This requires the continuous, flawless operation of a series production line and not just proof-of-principle systems, technology demonstrators or test articles, resulting from lab manufacturing and assembly. Such missiles are really insufficient since the efforts for proceeding from development to series production are enormous[8] and involve significant risk. Therefore, an evaluation must be based on the countries' missile production capability.

The difficulty in missile realisation can easily be assessed by looking at the Egypt missile program during the 50ies, in which German Sänger/Pilz group was involved. In spite of their experience with missile and rocket technology the results of this venture were discouraging.

A long range missile program may certainly benefit from an existing space launching capability. But the requirements in the missiles' real world are more demanding so that the space launcher aspect does not represent a real criterion for the missile question. Any assessment must clearly distinguish between missile and space launcher, production and development. It is the missile plus production aspect which counts while all the other combinations are much easier to accomplish.

Missile Activities in the Soviet Union

The early Soviet rocket history underlines the difficulty and time requirement. At the end of World War 2 the USA had seized nearly all remaining A4 missiles plus many components and, more important, invited the key personnel.

Thus, the Soviet Union had a more difficult start. They could use only what was left: the complete production line, many of the drawings and a number of components. On the basis of parts from the main assembly place and the previous suppliers, Russian and German workers and engineers were able to manufacture A4 missiles, so that nearly 2 ½ years after the war the first Soviet built A4, designated later R1, was launched. It took another 2 ½ years for the Soviet Union to start with the deployment of the Soviet version of this German missile.

This indicates that even with hardware, documentation, production equipment and experienced personnel, roughly 5 years are needed from program initiation to series production for this simplified reverse engineering procedure.

The programs in parallel or thereafter with indigenously developed missiles - Scud A, SS4, ... - took much longer and needed between 7 to 10 years for completion[9]. Generally, large numbers of missiles were flight tested during the development and production initiation periods.

China's Early Missiles

A similar picture holds for China, when this country started its missile efforts supported by the Soviet Union from 1956 on.

It first began with the mentioned R1 and later R2. With Soviet Union help and the installation of an R2 production line, China launched its first China manufactured missile at the end of 1960 - several years after program initiation - and assigned training missiles to the army in 1961. On the basis of Soviet SS3 drawings and notes this missile was flight tested in 1964 and operational in 1966. The first semi-indigenous Chinese missile DF3 - based upon the Soviet SS4 -, entered service in 1971, characterising again the long time period required for missile realisation.

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from China is of little importance.

[8]In the German A4 program several 10.000 changes were incorporated between the first flight tests in 1941 and series production in 1944. And, in spite of this large number of these modification, the missile was still in an unsatisfactory state at the end of World War 2.

[9]An indication of the time required for a major missile components - engines - (without previous technical and development experience) can be established from the activities of the Kusnezow design bureau for the rocket motors of Soviet moon launch vehicle N-1. The projected time was 5 years, but it took roughly 12 year from start to perfect engines. While the Soviet moon program failed, the same motors will now be used for future US launchers.

It should be noted, however, that besides the Soviet support Chinese rocket experts returned from the USA contributed also to this progress.

Iraq's Experience

Contrary to the Soviet Union and China, Iraq had to perform the missile work practically on its own using Soviet delivered Scud B missiles. This Iraq case yields a perfect yardstick for an assessment of North Korea's missile activities[10].

During the 1980/88 Gulf War, Iraq initiated two programs for missiles with liquid propellants: one for Scud B range increase - Al Hussein - and another one for establishing a Scud B production capability. Both show typical characteristics.

The completion of the Al Hussein task - tank lengthening for increased propellant loading, warhead weight reduction, centre of gravity shift and guidance adjustment for longer burning time - took from 1986 to 1988 with app. 10 test flights.

Reverse engineering was the basis for Scud B production. The first activities seem to have started in 1984/1985[11] resulting in a program in 1986 and at the end of 1990 - 4 ½ years later -, Iraq had accomplished several objectives: indigenous manufacturing and assembly of airframes and most of the engine components (besides turbopump and regulator procurement according to Iraq specifications from abroad, the in-country manufacturing situation is unclear) with integration to complete rocket motors. There was not any for guidance manufacturing or assembly capability.

Static motor and flight tests with the described hardware showed mixed results.

Nearly 70 Soviet supplied Scuds were used for these activities, 10 of which were attributed for range increase, while the rest - app. 60 missiles - was consumed for reverse engineering.

The post war situation in Iraq with a smaller missile, which followed the pre-war activities in smaller scale, underlines this experience. The MTCR tolerated Ababil 100/Al Samoud program is mainly based upon reverse engineering of the SA-2 missile engine, an airframe similar to SA-2 and the use of guidance components available from other Russian supplied equipment. After 5 years a few launches were accomplished. The test articles use Iraq-manufactured airframes and control components - jet vanes, actuators, shut off valves -, the rest - engines, guidance - stem from Russian products. The results consist in the demonstration of a proper working propulsion system and a stable flight.

In spite of the pre-war Scud experience, after 4 years of intensive activities the situation with the SA-2 motor is still in an unsatisfactory state and the guidance completely relies on available hardware.

However, due to import restrictions, astonishing progress was achieved in some areas - substitutions for vacuum bracing furnace - indicating that sanctions may not interrupt those activities.

The scrap at the machine shops plus dismantled missiles and rocket motors indicate that many dozens Soviet built engines were used during the reverse engineering process, duplicating the Scud reverse engineering situation and experience.

One has to summarise that in spite of the enormous efforts for many years, the two reverse engineering programs did not proceed to the point where a complete indigenously manufactured missile was in sight: major and important components could not be produced nor was there any flight demonstration of a relevant missile. A sufficient and proper specified, reliable product, which could be used for export, was well beyond Iraq's capability![12]

Keeping the educational situation in mind, considering the lacking external technical support and taking the industrial basis of Iraq into account, the described activities of Iraq, the time periods and results must be considered as a typical scale for 3rd world's capabilities. These figures correspond well with those from Russia and China.

Reverse Engineering Characteristics

Reverse engineering is much easier than indigenous development of a complete missile: the risk involved concerns only the manufacturing processes but not the final result. Still it is a rather difficult task and by far not as simple as it is normally considered[13]. Russia and China had to depend on extensive external support and the availability of sufficient documentation to built the foundations for their indigenous missile efforts with liquid propellants. When solid rockets came into the game the progress was even slower, since the Soviet Union and China needed more than 20 years to develop a sound basis for missiles of this type.

Reverse engineering of a guided missile is not accomplished just by drawings, prepared from one or two samples, and straightforward translation into production. It requires a number of important steps: the measurement and definition of all dimensions plus tolerances, identification of materials, determination of manufacturing procedures and provision of the necessary production processes, establishment of the important internal performance parameters with means for calibration and stepwise replacement of original components by indigenous manufactured parts during the later part of reverse engineering effort. Such lengthy

[10] The main difference consists in the number of missiles available for reverse engineering - a few in North Korea and large quantities in Iraq.

[11] Two missiles of a 1984 Soviet delivery were probably used for initial sample definition.

[12] The results of the joint Argentina/Egypt/Iraq Badr 2000/ Condor/Vector program are of similar quality - not any flight test after 10 years.

[13] Even reverse engineering of simple pyrotechnic devices require typically 2 years from start to qualified product delivery.

procedures are necessary to arrive at performance characteristics nearly identical to the original missile.

But one has to keep in mind that this final product is likely to differ from the reference in many details, since experience and orientation of the executing institution may not result in identical solutions. Therefore, reverse engineering of a missile cannot be done without a complete understanding of the subject. This method for missile realisation is rather reliable but not easy at all.

Typical Figures for License, Reverse Engineering and Development

	Lic	Rev Eng	Dev
Industr. ressour.	small	medium	large
Person. ressour.	small	large	large
Finan. ressour.	medium	medium	large
Risk	small	medium	large
Time [y]	1-3	5-7	7-10
Samples*	few	7-10/20-50	few
Test flights	-	10-20	20-40
Telemetry	no	yes	yes
Qual. tests	3	5	7
Firing table	no	yes	yes
Lot acc. tests	1/100	1/100	1/100

*Reverse engineering requires 7 - 10 samples for drawings plus manufacturing process identification and 20 - 50 samples for the subsequent activities.

Compared to license production efforts, which may need 1 to 3 years depending on the scope of equipment, experience and components availability, missile production on basis of reverse engineering probably requires 5 to 7 years, while an indigenous development program (including new engines) without extensive previous experience is even 2 to 4 years longer.

Beyond the mentioned time scales for missile realisation and the associated problems one aspect is very clear: without extensive flight testing during the initial work, production preparation and qualification, neither a sensible reverse engineering nor a development program is possible[14]. The reliability of design and product can only be assessed by flight testing under operational conditions. Even during full size production, a limited, but certainly not zero lot acceptance flight testing is indispensable, especially when these products are to be exported. There is no other assessment method. A non-sufficient flight tested system is of rather limited value, especially when the systems are to be exported. Flight testing for functioning, performance and accuracy is the decisive element in any missile program.

Number of Tests for Selected Deployed Missiles

Missile	Country	Tests for	Number
A4	Germany	Dev/Prod	400
A4/R1	SU	Rev Eng	200
Redstone	USA	Dev/Prod	37
Jupiter	USA	Dev/Prod	57
Lance	USA	Dev/Prod	156*
R11(Scud A)	SU	Qual	35**
Jericho	Israel		7***
Prithvi	India		min 15

*Reliability 95%.
**Initial reliability 83%.
***Many of the test activities were obviously performed outside of Israel.

Consequently, the observed test activities are a clear indication about the rocket's origin and purpose.

For a sensible development and production program the number missiles to be tested may be less than a few dozen, but must be still rather large. Negligible flight tests are a clear sign for procurement only, while a licence production program will require some tests, which volume depends heavily on the kind of foreign support - assembly of delivered components up to installation of complete production line for all parts. Otherwise, such systems serve just for technology demonstration purposes with limited military value and can certainly not be used for export.

Assessment of DPRK Activities

Compared to the described experience in Russia, China and Iraq North Korea's activities look very unique and exceptional. This originates not only from this country's small background with the industrial, financial and resources situation. Completely fended for itself, without practical experience in liquid propulsion plus guidance and foreign technical support these programs are characterised by fast progress, extremely limited flight testing and 100% perfection.

After contacts with Iran in 1983[15], the reverse engineering period for Scud B including first sample manufacturing (for 3 flight tests) is normally assessed to cover a time of only 1 to 2 years. This differs not only completely from the experience in Iraq, Soviet Union and China. More important, no additional flight testing was observed, not to mention any malfunctions.

Production line set up is estimated to have followed within two years for roughly 50 to 100 missiles/year[16]., which again seems to be performed without any flight test.

All this seems to be identical to procurement activities for complete missiles, assembly of components or licence production with limited North

[14] 90% reliability with 90% confidence requires app. 30 tests, which corresponds to the observed test numbers.

[15]Since the information on North Korea's activities are limited the various dates given should be used only as an indication.

[16]According to this production rate, the present (year 1999) NK Scud arsenal must be more than 1000 missile.

Korean involvement rather than reverse engineering.

Reverse Engineering Comparison

	NK-Scud B	others
Sample size	few	20 - 50
Foreign support	none	extensive
Time [y]	1 - 2	5 - 7*
Init. flight tests	3	several
Prod. line tests	0	several
Malfunctions	0	few
Telemetry	no	yes
Qual. test	0	few
Prod. tests	0	1/100
Export	yes	yes

*Time required with foreign support.

The Scud C work follow the Scud B performance with respect to efficiency, time and testing. The program for a completely new airframe design and material, flight controller adjustment and warhead is assessed for the 1988/89 period. After development, qualification with 2 (of course successful) flight tests and production line installation, export started two years later, which again differs significantly from the experience in Iraq.

Scud Range Increase

	North Korea	Iraq
Major topic	New airframe/ material	Tank lengthening
Time [y]	2	2
Dev Tests	2	10
Malfunctions	0	several

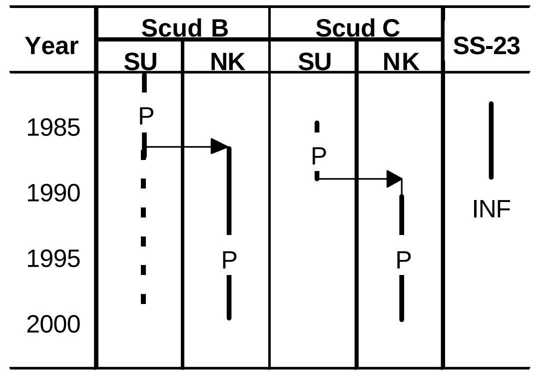
It must be stated that the North Korean Scud C activities look much more comparable to that for procurement or licence manufacturing than that for an indigenous development program.

In addition to these technical facts, some interesting coincidences with the Soviet missile history should not be overlooked.

According to some sources on Soviet missile production, since 1986 Scud B missiles were not longer in production or at least at a reduced rate - replaced by SS-23 - , which is approximately the same period where the first Scud B exports from North Korea seem to have began.

For the Scud C also a striking agreement with activities of the Soviet Union must be noticed. The Soviets had developed an extended range Scud[17], which seems to be identical with the North Korean design. After limited military use this program was terminated with the INF treaty and the end of the Soviet engagement in Afghanistan, which is approximately the period when North Korea started its Scud C activities.

Soviet and North Korean Activities and Possible Connections



The Nodong program initiation is assumed for the same period as for the Scud C activities. The progress must have been very fast, since initial test activities were already observed in 1990 with unclear results, followed in 1993 by the up to now only (of course successful) flight test with reduced range. After this test, exports are thought to have been initiated and in 1998, the mentioned Pakistan Ghauri and Iran's Shahab 3 demonstrations took place.

Missile Development Comparison

	NK-Nodong	others
Time [y]	4	7 - 10*
Use Exist. Hardware		
Engines	no	yes
Guidance	probably	yes
Flight Tests	1	10 - 20
Malfunctions	0	few
Telemetry	no	yes
Firing table tests	0	3 - 7
Qual. test	0	few
Prod. tests	0	1/100
Fraction of flight tested missiles	extremely small	0,1-0,2
Export	yes	yes

*7 - 10 years should be considered as typical figures for countries with their first indigenous missile development program and limited resources.

There is a remarkable aspect with the design of this missile. Nodong is based on a single engine and not a cluster of two Scud motors[18]. Considering the North Korean experience with the Scud engine and its availability, a cluster would be the normal configuration to avoid development efforts and risk. Thus, there must have been a significant reason for this decision.

These facts and the test characteristics clearly indicate that Nodong represents a proven, reliable

[17]The Scud C design driver was obviously a competition with the 500 km range SS-23 missile.

[18]Prithvi is a good example for the use of such a design principle - two Russian SA-2 engines.

and well specified design, not originating from North Korean activities. North Korea can only be involved in the Nodong program with procurement of complete missiles or licence production with a rather limited scope.

More than 5 years later, the next major step followed with Taepodong, demonstrating that a 2-stage system with significant performance is now available. Again, this new system worked perfectly, except for the 3rd stage[19], which is no vital part of the missile.

It is the summary of several facts, which must be used for a conclusion: quick reverse engineering on the basis of a few missiles, extremely low number of test flights for the various missiles, no production acceptance tests, extremely short realisation periods, absence of malfunctions, independent duplication of the Soviet Scud C design, "deus ex machina" Scud-pantograph Nodong and successful 2-stage Taepodong test in a satellite carrier mode.

Pakistan and Iran complete this picture.

Pakistan and Iran

Pakistan had not any previous experience in guided liquid rockets. Nevertheless, according to the official statements, Pakistan needed just a few years to finish the preparations for the first Ghauri flight. Here, some remarkable aspects have to be noted: near-military operational launch conditions, test area located close to India's Cashmere border, test across inhabited areas to full range, successful flight, ...

Ghauri represents, of course, an operational missile procured from abroad. On basis of these information and the previous assessment, it must be completely excluded that Pakistan did anything beyond procurement. There is just one conclusion: Ghauri resembles North Korea's Nodong without any modifications.

The situation with Iran and Shahab 3 is not very clear, but does not seem to be too different to that of Pakistan. Iran's experience with liquid rockets and guided missile is small and it is possible that Iran either received the complete system from North Korea or it had connections to Russia, procuring missiles[20] or main components and manufacturing simple items plus assembly according to Russian specifications. At the moment Iran is not in the position to indigenously manufacture complete missiles of this type.

This again indicates that Russia is the central point in missile activities and North Korea acts as a trading or technology transfer agent for complete systems or components.

These makes the usually assumed North Korean missile scenario completely unlikely or false and requires a new assessment of the situation.

[19]No general accepted picture of the 3rd stage exists.

[20]The Russian letters on Shahab indicate this source.

The North Korea-Russia Cooperation

North Korea received extensive foreign support, making real reverse engineering and any indigenous development activities unnecessary. The applied technologies clearly indicate that nearly everything comes from Russia! The program steps, technical details and engineering solutions trace the activities to this country. There are no indications for a connection to China since that country never manufactured Scud Bs or missiles of a similar type. North Korea did not perform any major independent work in the missile area.

Besides these indications, this assessment is supported by a number of other events: North Korean connections to Russian missile design offices, Russian experts in North Korea, Iran - Russia missile co-operation, mainly for Shahab, Scud exports from Russia after 1993 to Armenia, ...

It must be concluded that various Russian companies - not necessary the Russian government - and North Korean authorities are closely co-operating in the missile programs. From these institutions, North Korea received everything necessary to manufacture or assemble missiles. The precise role and contribution of North Korea has yet to be established, but the available information allow to construct a possible scenario of the connections and activities.

It started after Iraq's missile attacks during the first Gulf War with the 1981 Iranian request to the Soviet Union for Scud missiles, which was rejected due to the already existing Iraq connections. Therefore, in 1983 Iran approached North Korea to finance reverse engineering of these missiles. But the activities in this country turned out not to be successful. Consequently, North Korea approached the Soviet Union for support in this matter, received the necessary help and by this way, North Korea finally satisfied Iran's request. The Soviet rationale behind this arrangement was that Scud missile production would come to an end soon - Scud B successor SS-23 -, making new customers highly desirable[21].

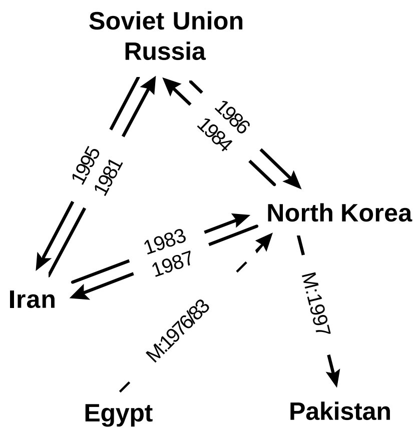
The Iranian need after the Gulf War for missiles with longer range - the practical minimum range is roughly 1.500 km to cover the distance from Iran to Israel[22] - is likely to have pushed for the same procedure with Nodong. But this missile differs in so far as it was never deployed with the Soviet armed forces and also not in quantity production, had technical shortcomings and could also be managed directly from Russia. Since the range and accuracy of this missile in its original version is not sufficient compared to Iran's re-

[21]It is also possible that the Iran-North Korea connection was initiated by the Soviet Union in order to deliver missiles to Iran besides the already existing Iraq relations without disturbing this connection and being identified as the main source.

[22]A 1.500 km missile keeps Iran's launch positions out of Israel's Jericho range.

quirements, modifications are necessary which need further work and support.

Probable Connections between Russia, North Korea and Iran



The indications are that North Korea is involved in both programs only in those parts which tend towards low technology - airframe, engine components and missile assembly. However, a complete manufacturing of Scud missiles can also not be excluded. The required equipment was provided by the Soviet Union. While the participation in Scud B and C program seems to be more extensive for various reasons, the involvement in Nodong is probably quite limited: complete (!) engines and guidance from Russia, while airframe and other items stem from North Korea, based on Russian drawings and specifications.

It is not very likely that North Korea acts just as a weapon trading institution, since export of Scud and larger missiles from Russia is prohibited, but even this alternative cannot be excluded completely.

DPRK Missile Evaluation

On basis of this assessment, it is sensible to describe the missiles and to summarise its presumable history. Two missiles are discussed in more detail: Nodong and Taepodong[23]. Additional remarks on Scud B and C must not be given.

But the general perspective of this work must also be addressed, to arrive at a better understanding of the potential connected with these activities in North Korea.

Nodong

Nodong is the common western designator for the large Scud-type single stage missile of North Korea. The shape and apparent design resembles Scud very closely, indicating that there are some connection and commonalties with that missile.

[23]Western designators, DPRK names unknown.

Reconstruction Basis

The Ghauri launch video plus the various Pakistan information including the photos and the data with the pictures on Shahab 3 from Iran represent an excellent basis for assessment and reconstruction. Using the various information on Russian missile technology and rocket design rules a number of data and information can be extracted and calculated: propellant type, camera position, missile length, initial acceleration, missile diameter, engine thrust level, initial trajectory, burn out conditions, peak altitude and velocity, payload, range and also accuracy[24].

A certain tolerance has of course to be added to the results since the dimensions established from the different sources and the pictures contain inaccuracies which cannot be compensated.

Nodong Data and Performance

Obviously, Nodong resembles precisely a large Scud missile scaled in the dimensions by the factor $\sqrt{2}$. Thus the diameter is 1,25 m and the length app. 15,3 m. This volume increase results in a lift off mass, roughly 2,8 times heavier than the original Scud. The lift of thrust is increased by a factor of 2.

The missile internal profile with the tank arrangement and the other components corresponds to that of the Scud missile. The guidance section seems to be rather short.

With the nominal (gross) payload of 1.000 to 1.400 kg a range between 800 and 950 km is achieved. The theoretical maximum distance (without payload) is roughly 1.500 km, which matches exactly the figure stated by Pakistan.

Reconstructed Nodong Data*

System type	Mobile missile with liquid propellants
Propellants	IRFNA/Kerosene
Diameter [m]	1,25
Length [m]	15,3
Mass [t]	15,0
Propellant mass [t]	12,0
Thrust [kN]	263
Spec impulse (sl) [s]	229
Burning time [s]	97
Payload [t]	1,2
Range [km]	900
CEP [km]	10

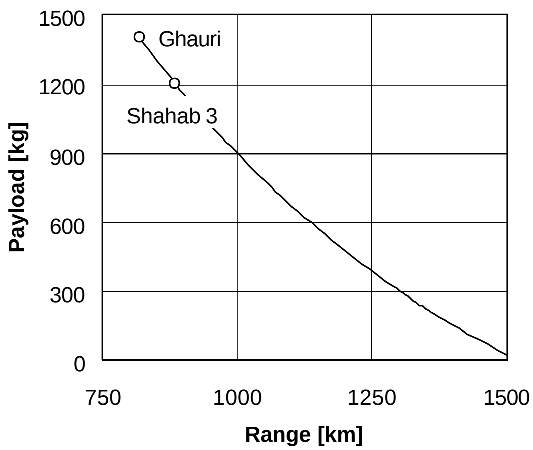
*Due to the uncertainties in photo and data evaluation the listed data should only be used with a certain tolerance figure.

Due to the long burning time, high terminal velocity and final acceleration, the missile's accuracy is rather low and in the order of 10 km.

Approximate Nodong/Ghauri/Shahab 3

[24]While the acceleration, thrust level and dimensions can be established rather accurate, the CEP must be considered as an estimate, mainly based upon engine and Scud characteristics.

Throw Weight Performance



Presumable Nodong History

The rocket's overall design and technology, the identity with the Scud profile, the single engine concept and lack of a vernier system plus the attributed time frame[25] make an independent North Korean scenario unlikely. This rocket was designed and developed in Russia and not North Korea.

Detailed information on the missile activities in Russia of the 60ies are at present not available, especially for those missiles which obviously went not into service. Therefore the events have to be reconstructed leaving significant room for misjudgement and errors.

It seems that this rocket followed the Russian rationale like that for R1, R2 and R3 - extending the range by increasing the dimensions while stretching the available technology.

The objective was a mobile missile for medium range. The design was obviously driven by the idea to make extensive use of the experience, gained during the Scud program, in order to minimise risk and development effort. This required to stick to the Scud geometry as close as possible and to use the proven elements where possible. Thus, no new aerodynamic data had to be established and the guidance scheme for one engine with jet vanes was easily applicable. Obviously at that time a significant change of the guidance was difficult to accomplish.

The dimension driver could have been an existing engine with a suitable thrust level[26]. Probably no major difficulties occurred during the activities, which were initiated by one of the known Russian groups for mobile or other type missiles[27]. It likely started in the period after Scud B deployment which is between 1960 and 1970.

The main bottleneck of this design was the poor accuracy, which resulted from the lack of a vernier system. Therefore, the program for this missile was finally terminated.

It is not unlikely that Russia offered this missile design to various countries and sold complete systems or the main components to North Korea.

Performance Improvement Potential

The performance of this missile with respect to range and accuracy can be improved. This potential makes the missile especially attractive for Iran.

Range extension is accomplished by a larger propellant loading and, in addition, thrust rise via chamber pressure. By this, up to 1.300 km with a 1.000 kg warhead can be achieved.

The poor accuracy requires a post-boost-system integrated in the warhead. This approach can use a velocity trim equipment, which is based on incremental thrust pulses, pre-set by the guidance, thus avoiding significant missile change.

Taepodong

This missile is the two stage successor to Nodong with significantly increased range[28]. The western view assesses the design with a Nodong as first stage and a Scud as second, but this configuration cannot be properly matched with the available data.

Much information was obtained by the August 31, 1998 launch. Although during this event the missile was used in a three stage version for satellite injection, the basic design consists of two stages. This configuration will be mainly addressed.

Reconstruction Basis

The video of this missiles launch provided a look on the overall design, the initial launch and flight phase. In addition, the impact points for the first two stages and the target orbit are very helpful. Similar to the Nodong evaluation[29] these information are used for assessment of propellant type, initial acceleration, engine thrust levels, stages lengths and diameters and burn out conditions.

The main rationale for the launch had three aspects: demonstration of North Koreas long range missile progress and present capability including the relevant technology for the interested customer, obtaining reliable results for the two-stage

[25]The Scud A engine activities started end of the 40ies and needed more than 5 years for completion. The missile's IOC was achieved in 1956. Hence, Nodong's engine work must have begun in the early 80ies, which cannot be substantiated.

[26]This results from the fact that the engine parameters are not adjusted such that the missile performance is optimised.

[27]Several institutions describe Nodong as a modified version of the Makajev R-13 missile, but a detailed analysis shows significant differences between both systems. This is especially true for the propulsion system - one single engine of app. 270 kN thrust for the Nodong missile versus an arrangement of five motors for the R-13 missile with one main engine of app. 130 kN thrust plus four 25 kN vernier engines.

[28]A small scale version of such a missile type is the Iraq Al Tamous, which consists of a Scud B or Al Hussain as the 1st stage and an Al Samoud as the 2nd.

[29]While the Nodong analysis is rather straightforward and allows to calculate the important data, a two-stage-configuration is more difficult to assess which, with the limited number of information, result in larger uncertainties.

configuration in the full performance range and camouflaging this objective by the three-stage satellite carrier mode. Consequently only the basic, unmodified missile was used during this test so that the results were easily applicable to the military version. The third stage plus satellite was just added in place of a warhead and is therefore of no importance.

Missile Data and Characteristics

Taepodong is based upon a "long tank, high thrust" Nodong - the type described for possible performance increase - as the first stage. The second stage is a suitably modified Soviet missile with the required characteristics, using IRFNA/Tonka for throttling and ignition reliability reasons. It is probably of the SA-5 type[30].

Trajectory control and velocity trim is adjusted by the second stage engine via dual thrust levels and a jet vane thrust vector system. (A vernier configuration with two or four small movable engines would require an independent feed system, resulting in many changes.)

Reconstructed Taepodong Data

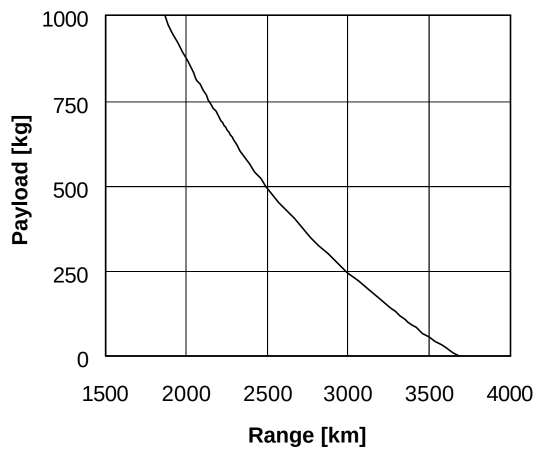
System type	**Two stage missile for fixed launch position**
Overall length [m]	27
Overall mass [t]	22,0
1st stage	
Propellants	IRFNA/Kerosene
Length [m]	14,2
Diameter [m]	1,25
Mass [t]	16,7
Propellant mass [t]	15,1
eff. Thrust [kN]	350
Burning time [s]	95
2nd stage	
Propellants	IRFNA/Tonka
Length [m]	10,3
Diameter [m]	0,8
Mass [t]	4,6
Propellant mass [t]	3,6
eff. Thrust [kN]	110
Burning time [s]	77
Payload [t]	0,8
Range [km]	2.200
CEP [km]	4

In the satellite carrier mode, the burning time of the second stage high thrust phase must be rather short, followed by a long low thrust level period. By this, a free flight trajectory prior to third stage ignition is avoided because otherwise, the third stage would require an additional attitude control system[31].

The diameter of the second stage is small: 0,8 m. With the usual geometric configuration of a warhead for the long range application - nose radius, cone angle -, the weight is probably in the order of 500 - 700 kg. This means that Taepodong is not intended for a conventional device.

The accuracy of the system for this range should be in the order of 4 km.

Approximate Throw Weight Performance of Taepodong



With a warhead of such dimensions and weight, a range of approximately 2.200 - 2.500 km can be covered.

Missile History

The few reconstructed data on Taepodong indicate again that all major components stem from Russia or are of Russian design[32]. But an answer beyond this statement about design responsibility, origin of this missile's concept and North Korean contribution to the various components is not possible. No Russian space launcher of this configuration exists, nor represents Taepodong in the tested version an attractive concept for this purpose. Obviously Taepodong is a sensible MRBM design for countries like North Korea or Iran, but of course not for Russia.

The conclusion to be drawn is that Taepodong must be a more recent project from North Korea, proceeded with Russian help.

The first stage results probably from past Russian work for a "long tank, high thrust" Nodong to increase the range of Nodong. It is completely unlikely that North Korea was solely responsible for this effort or performed it without any foreign help keeping in mind that up to now, not any full performance North Korean test flight proofed the original Nodong design.

The second stage with the properly adapted SA-5 propulsion section plus modified Scud jet vane thrust vector control system may incorporate significant indigenous North Korean activities.

The other components should be modified Scud or other suitable elements.

[30] The thrust level results from the satellite mode.
[31] Such a system was used for the US Juno I and II.
[32] This assessment is especially supported by the evaluation of the Taepodong satellite launcher version.

A little substantiated guess places the begin of Taepodong in the years 1989/1990, nearly in parallel to Nodong itself. The performance of Nodong in its present version is too small to be attractive for countries like Iran for their special purposes. Therefore, already in the beginning of these activities, a two stage version must have been considered in order to extend range and improve accuracy. The three tests in 1993, often interpreted as Scud B or Scud C flights with significantly reduced range, might have been flight tests with this second stage - a modified SA-5 missile.

The reason for the 5 year interruption between these 1993 activities and the 1998 satellite launch attempt is unknown. But this may relate to the overall concept of the satellite launcher configuration, the provision for the third stage, the adaptation of the guidance for this purposes and stage connecting adapters and separation devices[33].

Taepodong's Satellite Launcher Configuration

Taepodong was tested in a three stage configuration to launch a small satellite, but obviously, this attempt failed. The published information provided many detailed data that a rather reliable reconstruction of the system should be possible.

The test objective was probably the demonstration of the missile performance while avoiding the typical characteristics of an "aggressive" missile trajectory. Thus, all adaptations had to be consistent with the basic Taepodong design.

North Korean Satellite Launcher

System description		
1st stage	"Lg tank" Nodong	
2nd stage	SA-5 stage	
3rd stage	SS-21 motor	
Overall mass [t]	23	
Overall length [m]	29	
Orbit [km]	220 x 220	
Payload [kg]	20 - 30 kg	
Trajectory parameters	**avail**	**reconst**
1st stage impact [km]	375	380
2nd stage impact [km]	1.522	1.520
Thrust level switch [s]	140	138
Thrust vector inflect [s]	260	265
NK mid trajectory point	good agreement	
2nd stage max speed [km/s]	-	3,4
3rd stage initial accel. [g]	-	10
3rd stage burning time [s]	-	20,5

The required velocity increment between 2nd stage burn out and final orbit velocity must be provided by the 3rd stage. In 1996 North Korea had received a number of SS-21 missiles from Syria, which motor meets exactly the required performance for a small low earth orbit satellite. Though this motor is rather long, it can easily be installed at the top end of Taepodong.

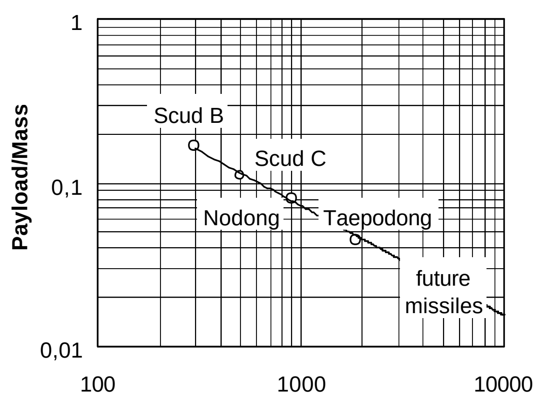
A comparison of the reconstructed trajectory data with the available information of this test shows that both figures match perfectly, indicating that the evaluated data for Nodong and Taepodong should agree rather well with the real data of the systems.

Future Missiles

The maximum range of the North Korean missiles is approximately 2.000 - 2.500 km. This performance seems to be sufficient for most of North Korea's customers.

For a significant range increase beyond this value larger missiles are required, extending the present sequence to bigger systems. Facilitated by Russia, various rocket engine types, suitable guidance systems and control equipment are available which allow with the staging experience to construct a family of heavier missiles with substantially increased performance. Details of these designs cannot be given, since the variability is significant, but not really important.

Normalized Payload of Selected North Korean Missiles



By engine clustering, staging, strap-on-boosters and post-boost systems a launch mass two to three times of that of Taepodong is within North Korea's reach. There is no need for additional rocket engines like RD-214[34]. Guidance improvements for better accuracy are obviously desirable, but certainly no necessity. The airframe design should not represent a major obstacle so that a number of configurations are possible.

The performance of these systems will likely correspond to that of the early Soviet missiles, so that a clear picture about the to be expected performance can be given. The only question for this outlook consists in the size of the next steps towards larger missiles, time frame, foreign support

[33]A full range Taepodong test in the weapon mode requires a functioning re-entry vehicle which may not be available for North Korea at present.

[34]The booster rocket engine for the Burya cruise missile consisted of a four engine cluster with Scud-type rocket motors of together 670 kN thrust, which corresponds to the RD-214 thrust level of 630 kN.

and, most important, customer with the necessary financial capability.

The present (supported) environment places no unclimbable obstacles in front of North Korea to proceed to missiles with several 1.000 km range. The time required will certainly be long - following the observed path and progress more than 10 years. The only benefiting aspect of this depressing perspective consists in the dependence on foreign support, which brings proliferation into the focus.

Proliferation Aspects

All indications point to the fact that North Korea's missile programs depend heavily on Russia's involvement - either Russian experts for design and manufacturing in North Korea or direct missile and component delivery from Russian companies. A government involvement is highly unlikely and must be excluded. Without this support, North Koreas missile activities would quickly collapse.

It is this Russia-North Korea connection which presently represents the key aspect for missile and technology proliferation in the 3rd world. Which role China plays in this business is difficult to establish, but seems to be limited to the sale of complete missiles and production line installation at best. All other aspects in missile production are of minor importance and can be neglected at the moment.

Consequently, this flow of information, technology and hardware must be controlled and finally interrupted to terminate North Koreas missile activities. By this, countries like Pakistan, Iran, ... , which heavily depend on North Korea will either have to terminate their programs or turn directly to Russia for help.

It looks as if Iran is already proceeding in this direction. This not only supports this view on the Russian involvement, but also underlines that Russia has to be integral and supportive partner in the MTCR. Otherwise, all ventures to limit the missile technology spread are to be useless and certainly without any success.

Conclusion

The general view allocates to North Korea an important and decisive role in guided long range missiles with liquid propellants, which can be seen by the export of Scud missiles and the development of longer range systems like Nodong and Taepodong.

But an assessment of North Korea's activities with the observed flight testing and the types of rockets developed must call this view into question, especially when the efforts and experiences in other countries are used as reference. Here especially Iraq, but also the former Soviet Union and China must be mentioned.

Without any doubt, North Korea bases it's success upon help and support from Russia, making own indigenous work for reverse engineering and development unlikely and, more important, completely unnecessary. Russia provides the required instruction, equipment and hardware so that North Korea's own contribution is rather limited. This holds not only for Scud B and Scud C, but also Nodong and, to a lesser extent, for Taepodong too.

The performance of the latter missiles seems to be sufficient for North Koreas customers. But with Russian support, these capability can easily be extended. The time required will certainly be long, but there are not any technical obstacles to prevent such a path.

The future of North Korea's work and success depends completely on the Russian involvement. It is therefore imperative that the Russian government terminates these in-country activities in order to make the MTCR effective and successful.