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TECHNICAL REPORT

Characterizing the North Korean Nuclear Missile Threat

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Supported by the Stanton Foundation

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Preface

North Korea seems to have a relatively sophisticated guided ballistic missile program. As of May 2012, at least nine different guided ballistic missiles are in development or available in North Korea, and some of them are offered for export. In addition, it is commonly accepted that North Korea actively pursues programs for weapons of mass destruction (WMDs). The potential combination of WMD with North Korean missiles,[1] coupled with North Korea's history of proliferation, raises concerns not only within the region but also globally and has a significant impact on related political decisions. Those who study North Korea generally believe that its leadership views missiles as the primary means of nuclear weapon delivery. Therefore, when North Korea is credited with a nuclear arsenal, any assessment of the North Korean missile threat also is an assessment of the North Korean nuclear threat.

The security community generally believes that North Korea has obtained its missiles by producing large numbers of reverse-engineered Soviet ballistic missiles. But the data on North Korean missile tests and missile performance raise questions about this explanation: North Korea tests too few missiles to achieve the level of reliability that its missiles appear to possess. North Korea may have achieved this level of reliability by using missiles supplied directly by Russia or produced as part of a licensed production arrangement. If one of the latter explanations is true, then the size and character of the North Korean threat may be different than is commonly expected.

The objective of this study is to identify the most plausible hypothesis about the nature of the North Korean missile program. To answer this question, I postulate various possible hypotheses, examine the available data, determine the level of confidence in the respective data, and test the hypotheses for their consistency with the data. The lessons learned from this approach might be applied to other countries.

This research should be of interest to a wide audience: policymakers, intelligence analysts, and operational planners who want to get a better understanding of North Korean capabilities; research scholars and students who work on arms control and proliferation issues; and missile experts and defense analysts with good knowledge of missile technology. The research approach might also be of interest for those who are interested in threat scenarios and missile-related issues in regions and countries other than North Korea.

Stanton Nuclear Security Fellows Program

The research reported here was prepared as part of the Stanton Nuclear Security Fellows program at the RAND Corporation. Research was conducted during a one-year fellowship at

[1] Unless stated otherwise, in this document the word *missile* refers only to guided ballistic missiles.

RAND under the guidance and supervision of a RAND mentor. This fellowship is financed by the Stanton Foundation. The author of this report thanks the input of colleagues and reviewers for improvements to the report, but any remaining errors or omissions are the sole responsibility of the author. Comments are welcome and may be addressed to schiller@schmucker.de.

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Summary

The security community generally believes that North Korea acquired Soviet guided ballistic missiles from Egypt, reverse engineered them, and indigenously produced and deployed in North Korea perhaps 1,000 ballistic missiles of various types. Because North Korea is a self-declared nuclear weapon power, there are serious concerns that some of these missiles might be armed with nuclear warheads. North Korea is also believed to have exported perhaps 500 ballistic missiles over the past two decades.

However, upon closer examination, North Korea is not behaving like a developer and producer of large numbers of relatively sophisticated missile systems. Its lack of a realistic missile test program, in particular, raises significant issues about the quality of its products.

This report questions the current common view of the North Korean missile program and seeks to better characterize the North Korean missile threat.[2] North Korea is doing a unique job of hiding its program, such that much of the analysis has to be done indirectly. Nonetheless, the insights that result from this approach are extremely helpful.

Background

For those who study North Korea, ballistic missiles are generally seen as the primary means of nuclear weapon delivery against the territory of the Republic of Korea (ROK) or Japan,[3] thus making operational missile systems a prerequisite for a serious North Korean nuclear threat. In open source literature,[4] North Korea is characterized as a key player in the global missile market, with successful indigenous development, operation, and export of numerous types of capable guided ballistic missile systems that meet the criteria of strategic significance, especially if combined with a nuclear warhead. Since North Korea already claims to be in possession of operational nuclear weapons, U.S. and regional policy and strategy toward North Korea always has to take this threat into account.

However, there are strong indications that North Korea's missiles may not pose such a serious threat. Compared with known missile programs, not only those of the former Soviet Union and the United States but also smaller efforts in Iraq, Egypt, and Libya, the North Korean program has been different. Most notably, from an engineering perspective, the North Korean test program shows several inconsistencies. The low number and low failure rate of

2 Unless stated otherwise, in this document the word *missile* refers only to guided ballistic missiles.

3 North Korean use of combat aircraft to deliver nuclear weapons seems unlikely because of the serious inferiority of those aircraft—they would be unlikely to reach their targets.

4 My survey of the open source literature is documented in the appendix.

its missile flight tests are one obvious aspect. I therefore examine other hypotheses about the North Korean program that might better explain the known evidence than the hypothesis that is commonly accepted in open source literature.

Research Questions

I consider the following research questions:

- What is the most plausible hypothesis to explain the nature of the North Korean missile program?
- What consequences might these findings have for U.S. and ROK policy and strategy toward North Korea?
- What data would be most valuable for better understanding the nature of the North Korean missile program?

Methodology and Approach

In this report, I assess the North Korean missile threat using a broad approach that includes political considerations, engineering aspects, and economic realities. I define five different hypotheses about the origin and status of the North Korean missile program. First is the "Reverse Engineering" hypothesis, which is based on the consensus in the open source literature. Second is a contrasting "Buy" hypothesis that assumes total North Korean dependence on missiles produced by foreign entities. In between the two extremes of North Korean independence and reliance on foreign support are three other scenarios: a "Licensed Production" hypothesis, a hypothesis that assumes reliance on "Mixed Sources" for the missile program, and a "Bluff" hypothesis that assumes that creating the *impression* of a serious missile threat is the main objective of the North Korean program.

To test the hypotheses, I present and evaluate available data that are directly or indirectly related to the missile program. I sort the data into three categories and mark them according to three levels of confidence. Data categories are the *missile* (directly related to the specific delivery systems and their associated warheads), the *program* (generally related to missile development, production, and deployment), and the *country* (related to North Korea in a general way). Confidence levels are *high* (predominantly dealing with technical aspects that are derived from imagery, other firsthand observations, and the laws of nature), *medium* (cannot be verified firsthand but seems plausible and is, for the most part, commonly accepted in open source literature), and *low* (predominantly based on a single source and cannot be verified—weak evidence, but might still be true).

I checked all data points for their consistency with each of the previously defined hypotheses. These results are presented in an evaluation matrix. Inconsistencies or discrepancies with high-confidence data significantly decrease a hypothesis's plausibility. I then rate the hypotheses with an "Inconsistency Score"; the lower the inconsistency score, the more plausible the hypothesis/scenario.

Finally, I present a set of policy suggestions based on these findings.

Assumptions

I assume that the North Korean missile program is subject to engineering realities and limitations in the same way as any other engineering program in the world: Operational program success depends on a lot more aspects than political will alone. This assumption is based on other well-known missile programs—for example, the Iraqi experiences in the 1980s and 1990s, the Iraqi/Argentine/Egyptian Condor joint venture, and Soviet/Russian and U.S. programs from the 1950s up to the present. Knowledge about other defense and space programs also contributed to this assumption. Furthermore, since there is growing consensus in the open source literature, I assume that North Korea possesses nuclear weapons that can now or soon be mated to ballistic missiles for delivery.[5]

Findings

The common view—that North Korea possesses a sophisticated missile program and is capable of indigenous reverse engineering, production, and deployment of numerous missile systems—has the highest inconsistency score and thus is the least supported hypothesis.

My analysis suggests that the North Korean guided missile program was set up in the 1980s and 1990s with significant support from the Soviet Union,[6] though it is uncertain to what extent the Soviet authorities provided or sanctioned this assistance. The extent to which this support is still ongoing is unknown.

The best-supported hypothesis (i.e., the one with the lowest inconsistency score) is the "Bluff" hypothesis. According to this hypothesis, in its testing, North Korea has launched Soviet/Russian-made missiles (that are proven but old designs) to maximize the appearance of performance, but may never have tested missiles from its own production—any such indigenous missiles cannot have noteworthy reliability or accuracy. This hypothesis further supposes that the North Korean government sought to conceal North Korean re-exports of Soviet missiles to other countries. According to the "Bluff" hypothesis, the main purpose of the North Korean missile program is to deter U.S. and ROK action against the North Korean regime and to gain strategic leverage in foreign politics. Domestic policy reasons have probably also played a role: The impression of a successful missile program is useful to bolster the regime's apparent strength. If the "Bluff" hypothesis is true, it remains unknown which members of the North Korean elite are actually aware of the North Korean deception program.

Open source literature frequently claims that North Korea has operationally deployed about 800 to 1,000 missiles.[7] If this number is true, for each of the five hypotheses the missiles would show varying degrees of reliability and accuracy. Figure S.1 shows the degree of reliability and accuracy we would expect to see in North Korea's arsenal under each of the five hypotheses (the figure also shows the inconsistency scores for each of the hypotheses). Even if

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5 North Korea's nuclear weapon capability is not the subject of this study, but it is certainly worth investigating in the future, potentially using the same methodical approach presented in this report.

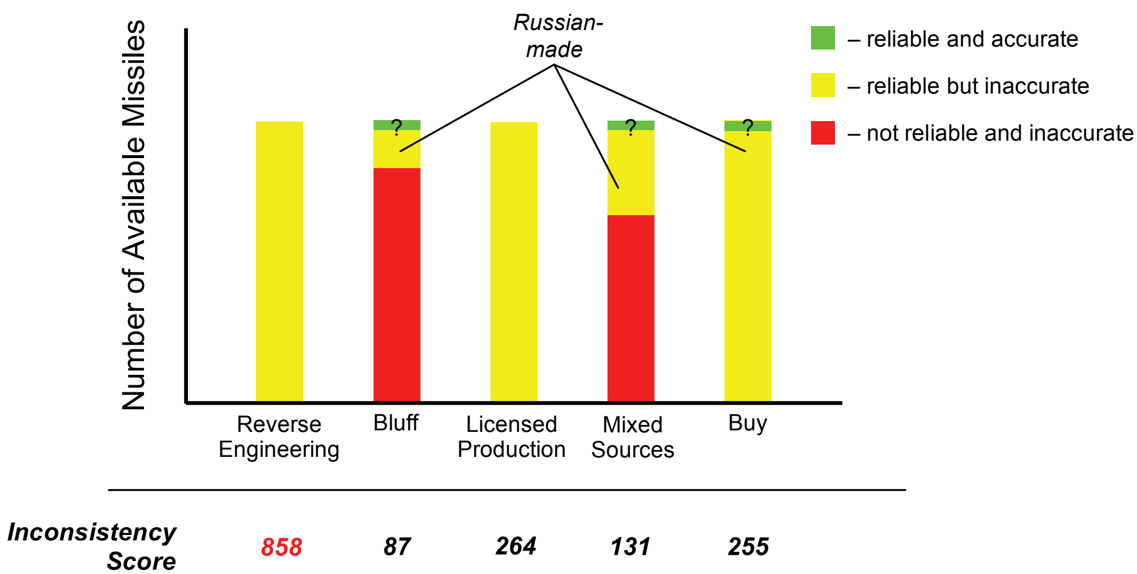
6 See for example SIPRI, 1989, p. 256, according to which 240 Scud B were transferred from the Soviet Union to North Korea in the late 1980s. There is little evidence of later transfers.

7 Again, sources for claims such as this that are made in the open literature are documented in the appendix. I doubt the 800–1,000 estimate; I have been unable to find evidence for it or to determine where or how it first came into being.

North Korea had reverse engineered or bought old Soviet missiles, these missile types are not known for their accuracy, and the majority of North Korean launch crews have never fired a missile. Thus, the missiles might be sufficiently reliable, but not very accurate. In any case, only a few launch crews can be well trained and potentially equipped with reliable and accurate modern missile systems, marked green. Figure S.1 also shows the inconsistency scores for each of the various hypotheses.

It seems likely that the North Korean missile threat is limited to the range of its Nodong missile, which is roughly 1,000 km.[8] Missiles beyond this range seem not to be operationally deployed or sufficiently reliable. North Korea likely purchased a small number of Nodong missiles from the Soviet Union (there is evidence that the Nodong is a Soviet/Russian design). The operational status of North Korea's indigenously produced missiles is questionable due to a very low number of test and training launches. Beyond 1,000 km, the available North Korean missiles are likely of low reliability.[9] The expected number of precise missiles (shown in green in Figure S.1) is very low, if they exist at all,[10] and the launch crews probably lack sufficient training. It cannot be ruled out that North Korea has nuclear warhead designs for its missiles, but without actual testing, the reliability of these warheads has to be assumed to be low.

Figure S.1
North Korean Missile Program Scenarios



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[8] Several references (documented in the appendix) cite longer ranges, but the technical characteristics as I understand them limit the missile's range to roughly 1,000 km, beyond which the missile has not been tested.

[9] Even if rumors of transfers of longer-range SS-N-6 missiles in the 1990s are true, these SS-N-6 missiles would have far outrun their service life and are likely not operational anymore. (Contrary to other Soviet missiles, SS-N-6 missiles were fueled in the factory and sealed, resulting in limited service life.)

[10] Russia has developed tactical ballistic missiles with terminal guidance and may have sold some to North Korea. But North Korea does not appear to have appropriately tested such a capability on its own, having not fired missiles at an instrumented target range where the guidance could be tested (almost all of North Korea's missile tests are fired into the ocean).

Strong indicators for these findings, among others, are as follows:

- North Korea has conducted a very low number of test and training launches.
- The missiles used in these few launches have shown a high level of reliability.
- Launches take place only at politically significant dates and are therefore not dictated by engineering development or training needs.
- Known missile parts of North Korean production are reportedly of poor quality.
- Soviet Scud missiles and the North Korean Scud missiles that have been observed look exactly the same, up to the smallest details.
- Cyrillic lettering has been observed on North Korean Scuds and Nodongs.
- The Nodong engine is an old Soviet design.
- The Scud C is an old Soviet design.

Policy Implications

If the "Bluff" hypothesis is correct, increased nonproliferation pressure on Russia and other countries is essential to keep the North Korean missile threat low and cut any existing proliferation ties.

If these findings about the program's status can be verified, further steps are suggested. First, the policy of the United States and its allies toward North Korea should be reconsidered in the light of a North Korean missile force that is less capable and differently composed than is widely assumed. For example, a lower North Korean missile threat should be incorporated into the defense planning of the United States and the ROK. Specifically, the policy of launch moratoriums should be reconsidered, since a launch moratorium plays into the hands of the North Korean regime—it has only a limited number of Soviet/Russian-made missiles, and every launch depletes this arsenal.

Several bits of information could further strengthen or weaken the "Bluff" hypothesis:

- Details of North Korean Scuds in the United Arab Emirates and those taken from Libya.
- Detailed information about North Korean launches and their trajectories.
- Telemetry data that may have been transmitted as part of these launches. If such data were not transmitted—as appears to be the case—then there cannot be a serious operational development program in North Korea.
- Information on North Korean troop training. If no intensive drills analogous to those of Warsaw Pact countries are observed, the North Korean army is not as capable of using its missiles effectively under wartime conditions.
- Details about old Soviet missile prototypes and how they compare to the North Korean systems. This would involve determining the whereabouts of these prototypes and other decommissioned Soviet missile systems, as well as the status of the old Soviet Scud and SS-N-6 production lines.
- North Korean defectors at key positions might hold valuable information. Their not knowing certain details might be as revealing as their knowing them.

The apparently extensive foreign support for North Korea's missile program also suggests the necessity of strong external support for other countries' missile programs: If North Korea had to rely on Soviet/Russian help and still has no truly reliable indigenous missile program, it is highly unlikely that the current status of other countries' programs is better.

This research approach can be applied to other countries of interest. There are indications, for example, that common hypotheses about the Pakistani and Iranian missile programs might not be the most plausible ones. This research approach can also be extended beyond missiles to other defense-related areas.

Acknowledgments

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Finally, many thanks to Dean Wilkening, Richard Mesic, and Cortez Cooper, who provided valuable and thoughtful comments that strengthened this report. Thanks also to Kimbria McCarty, James Torr, and the whole publications team. All shortcomings obviously remain the author's responsibility.

Abbreviations

APU	auxiliary power unit
CEP	circular error probable
GDP	gross domestic product
Gh1	Ghadr-1 missile
Gha	Ghauri missile
GPS	Global Positioning System
ICBM	intercontinental ballistic missile
IISS	International Institute for Strategic Studies
IRFNA	inhibited red fuming nitric acid
MTCR	Missile Technology Control Regime
NTO	nitrogen tetroxide
PPP	purchasing power parity
RE	reverse engineering
ROK	Republic of Korea (South Korea)
SAM	surface-to-air missile
Sh3	Shahab 3 missile
TEL	transporter erector launcher
UAE	United Arab Emirates
UDMH	unsymmetrical dimethylhydrazine
UNSCOM	United Nations Special Commission
WMD	weapon of mass destruction

CHAPTER ONE

Introduction

The research is intended to improve the understanding of the missile situation in North Korea. In the end, the findings might not only support the decision process for the current policy toward the North Korean missile threat, but also lead to recommendations on how to better counter the global proliferation of missiles and associated warheads.

Since the subject of ballistic missiles is very sensitive, countries tend to conceal their weapon programs and deny outsiders information on these programs, especially if they are related to weapons of mass destruction (WMDs). This is especially true for North Korea. Nonetheless, much information is openly available and can, if collected and combined in the right way, offer valuable insights. To the best of my knowledge, all information used in this report is unclassified and comes from open sources.

I encourage readers with access to classified data to validate the information presented here with available classified sources and to find additional information that could verify (or falsify) my findings. However, it is important to remember that the quality of classified data is not automatically better than that of unclassified data.

The report is divided into nine chapters, including this introduction:

- In Chapter Two, I present basic information about guided ballistic missile systems for the interested reader.
- In Chapter Three, I examine the problem with the current consensus in open source literature on North Korea's missile situation. This discussion serves as a starting point for the research.
- In Chapter Four, I present various hypotheses about the nature of the North Korean missile program: I start with the hypothesis that is commonly accepted in open source literature and then describe four other hypotheses that assume various degrees of foreign assistance as well as different goals of the North Korean missile program.
- In Chapter Five, I present my collected data. Trying to systemize these data, I divide them into the three categories (missile, program, and country) and rate them—according to their origin and the reliability of the respective sources—as being of high, medium, or low confidence. To keep the whole chapter short, only distilled data are presented—details about each data point, including citations for them, can be found in the appendix.
- In Chapter Six, I explain the evaluation method that I used to evaluate the hypotheses for consistency with the data, and I present the results of that evaluation.
- In Chapter Seven, I discuss the findings of the evaluation. This includes how the analyzed data fit into the various hypotheses, what the findings mean for the character of the

North Korean missile threat, and what implications the characterized threat situation has for defense and policy issues.

- In Chapter Eight, I present several questions that, if they can be answered, might further help to verify the research findings or lead to different conclusions.
- In Chapter Nine, I offer a short summary of the findings, their implications, and various recommendations.
- The appendix provides more detail on the data presented in Chapter Five, including citations for the sources in the open literature that are representative of the dominant view in the open literature.

CHAPTER TWO

Missile Basics

For readers not familiar with technical aspects of missiles, the following brief introduction to the basics of missilery will help to increase the understanding of later chapters. Readers more familiar with these topics might skip this chapter and move on to the next one.

Characteristics

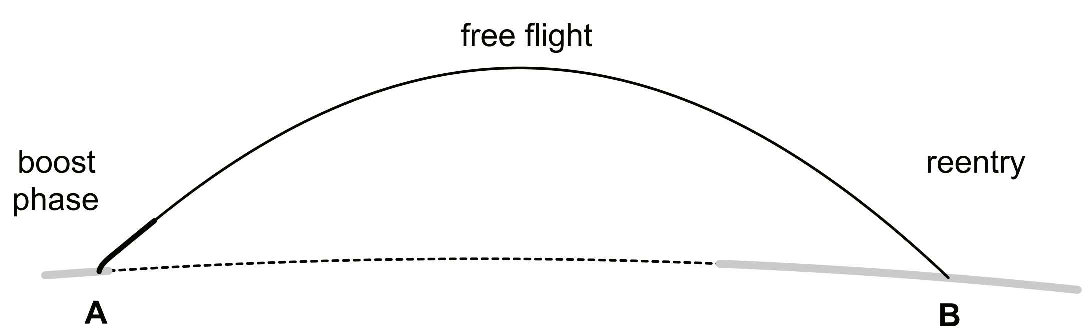
As the name implies, ballistic missiles fly a ballistic trajectory, which means that they are not propelled for the major part of their flight—they are inert, behaving just like a fired bullet or an arrow. Therefore, the launch of a ballistic missile is comparable in some ways to a very long-range artillery gunshot.

A missile's flight can be divided into three phases: the boost phase, free flight, and reentry, as shown in Figure 2.1.

The boost phase is comparatively short. During it, the missile accelerates to the intended speed required to achieve the intended range—the faster the missile travels at engine cutoff, the farther it flies during free flight. The boost phase is also the only phase of flight in which guided missiles use their guidance and control system to stay on the preprogrammed trajectory.[1]

After engine cutoff, the missile travels in free flight on a ballistic trajectory toward its target. Longer-range missiles separate their warhead right after engine cutoff. For physical and

Figure 2.1
Typical 1,000 km Missile Trajectory



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[1] Unguided missiles are aligned to the target and fired, with no further guidance toward the target. Very advanced missiles may feature guidance and control systems for midcourse corrections and/or terminal guidance during reentry, but these are highly complex.

energetic reasons, the maximum altitude of the trajectory of short- and medium-range missiles is roughly one-third of the missile's range, so the free flight phase usually takes place beyond Earth's atmosphere. Any trajectory that deviates from this optimum trajectory reduces the range and usually affects the accuracy of the missile.[2]

Closing in on the target, the missile and/or warhead reenters Earth's atmosphere and finally impacts.

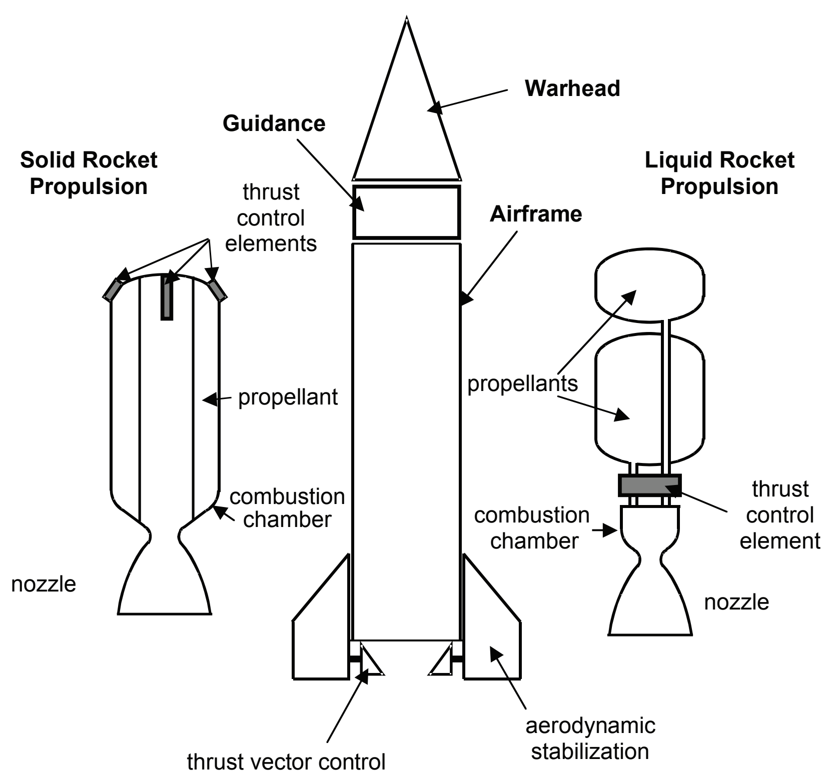
Missile Components

The basic mission of any ballistic missile is the delivery of a warhead to an intended target. For this, a missile requires four basic elements:

- warhead
- airframe
- guidance and control system
- engine.

These are illustrated in Figure 2.2.

Figure 2.2
Missile Elements and Propulsion Systems



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2 The frequently cited "depressed trajectory" significantly reduces the range due to trajectory shape and increased atmospheric drag, and reduces the accuracy due to the lower reentry and impact angle and the increased distance that the missile has to travel through Earth's atmosphere, with all of the atmosphere's negative effects on accuracy.

The warhead contains the actual weapon. It has to withstand the high mechanical and thermal loads that occur during a missile's flight and trigger the weapon effect at the end of the flight, either at impact or at a predetermined altitude.

The airframe, including fuel tanks, is responsible for the integrity of the missile system. The structure itself, unlike the warhead or engine, is basically dead weight that has to be carried, but it is required to accomplish the mission.

The guidance and control system steers the missile on the intended trajectory. It is a highly complex regulation system consisting of various subsystems.

The engine generates the thrust that lifts the missile off the ground and accelerates it to the intended velocity. For missiles, two types of rocket engines are important: liquid fuel engines and solid fuel engines. As the names imply, liquid systems feature liquid propellants that are continuously pumped into a combustion chamber, whereas solid systems feature solid propellants that burn down in place, thus combining tanks and combustion chamber into a single item. In both cases, the combustion products stream out of the nozzle and thus propel the missile.

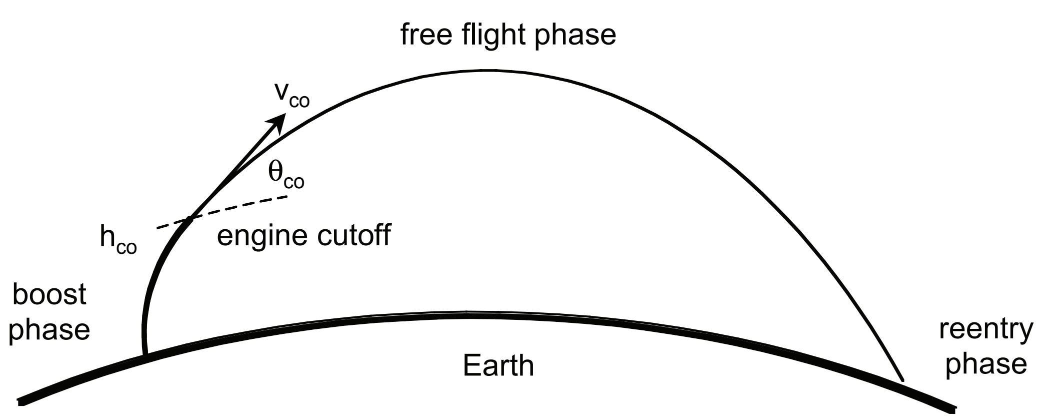
Accuracy and Reliability

Accuracy

As mentioned, most missiles are guided only during the boost phase. This means that, to hit an intended target, the missile has to precisely meet certain criteria at the end of the boost phase, namely at engine cutoff: It has to have a certain speed, v_{co}, at a certain location (at altitude h_{co}) with a certain direction (including the trajectory angle, θ_{co}), as illustrated in Figure 2.3. If these parameters are met, the warhead will—in theory—hit the intended target, like a golf ball flying right into the hole.

These parameters have to be calculated beforehand and programmed into the missile's guidance system, which then guides the missile to the intended cutoff parameters. But in practice, it is not that simple.

Figure 2.3
Missile Flight Parameters



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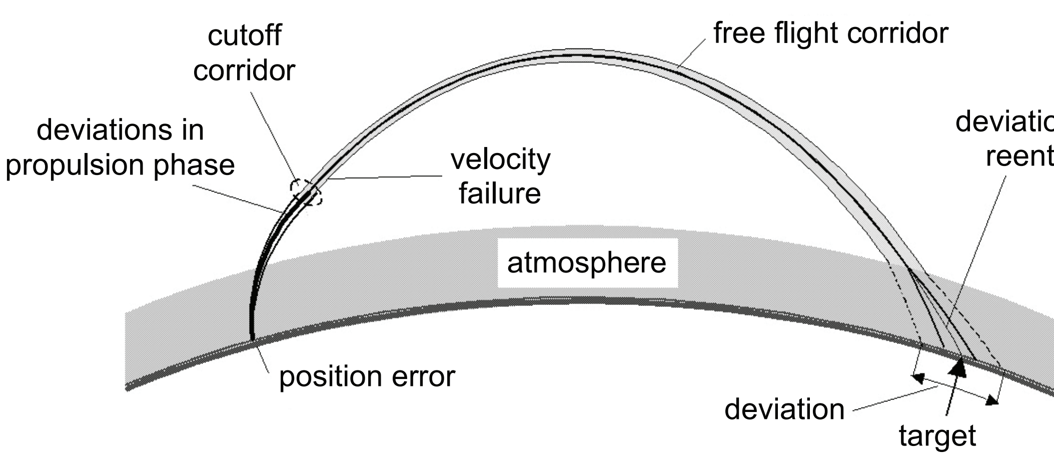
The parameters themselves depend on many factors. The position of both the target and the launch site have to be known exactly to define the distance and direction to the target. Winds and other meteorological phenomena might have an effect on the boost phase trajectory, so these have to be taken into account. Air pressure, air density, and temperature have a significant effect on engine performance. The engine itself has to be calibrated, since its thrust and performance have to precisely meet nominal specifications. These elements are depicted in Figure 2.4.

Figure 2.5 shows that additional factors add to the uncertainty. Weather conditions at the target area, for example strong crosswinds at high altitudes, affect the warhead reentry and its accuracy. Differences in the local gravitational field can significantly affect the ballistic trajectory, especially at longer ranges.

The engine cutoff itself is another source of inaccuracies. Just before cutoff, the missile's propellants are almost used up, the tanks are almost empty, and the missile is therefore very light. However, the engine's thrust is the same as during launch, resulting in a very high acceleration just before engine cutoff.[3] This has simple consequences: If the engine cutoff is done only milliseconds later than intended, the missile still accelerates for these few milliseconds and ends up faster than intended. During the whole free flight phase, it travels faster and therefore farther. To give an idea of the precision involved in engine cutoff: For a 1,000 km missile, a 5-millisecond cutoff error can lead to a longitudinal (that is, range) error of more than 200 m.

There are many more factors that have an effect on missile accuracy. Many can be calculated in advance and taken into account, but others are unpredictable. Therefore, missile accuracy is seriously limited without mid-course and/or terminal correction; the majority of accuracy statements in the open literature are significantly exaggerated. (These statements are detailed in the appendix.)

Figure 2.4
Missile Deviation from Target



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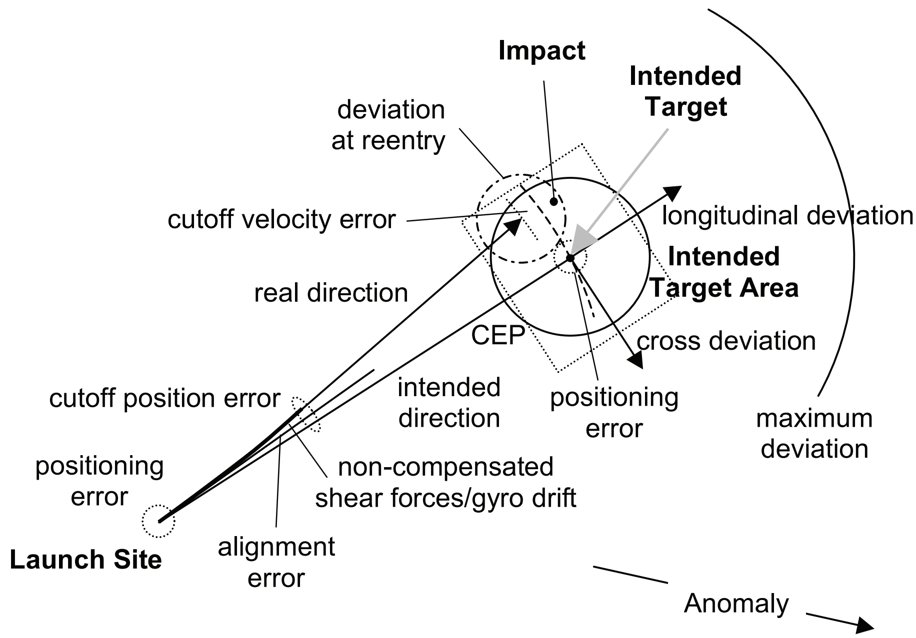
3 To be precise, the thrust is even higher than at launch due to the lower outside air pressure at high altitudes.

Figure 2.5
Various Effects on Missile Accuracy



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Reliability

There is no commonly agreed definition of failure criteria for a missile flight. Therefore, accuracy and reliability are closely linked. To clarify this: It is obvious that an impact with very high inaccuracy has to be regarded as a failure, and thus as a reliability issue, while a deviation of a few hundred meters is usually regarded as an accuracy issue. But there is no clear line separating the two.

It is almost impossible to judge whether a missile has hit its intended target if the target is not known to the observer. Any statements about successful missile tests, especially those launched into the sea, therefore must be taken with a grain of salt.

But there also are obvious malfunctions during missile flight, including explosions at boost phase, failed stage separation, and other anomalies. Evaluation of available data suggests that operational ballistic missiles have an average reliability of between 75 and 90 percent, but higher or considerably lower reliability might be possible, too. The real values are probably much lower because of the mentioned accuracy issues, launch conditions that are not perfect (nighttime, weather, etc.), and the increased probability of human error in wartime conditions.

Basic Facts

A few basic facts about ballistic missiles might further help comprehension of several aspects of the later analysis.

Missile Size

A missile's range is physically limited by its size. To increase missile range—to throw a certain warhead mass over a longer distance—the warhead has to be accelerated to a higher velocity. This means that the engine has to burn for a longer time, which in turn requires more propellant. These propellants have a mass of their own, as do the larger tanks needed to contain them. These additional masses might be high enough to require a higher engine thrust. Bigger engines have to be used or additional engines added. This, again, adds mass and might require longer burn time and more propellants. The missile's size grows.

Consequently, a missile's size roughly indicates the missile's range. Small missiles cannot fly very far; big missiles can but do not necessarily have to.

Missile Weapon System

An operational missile weapon system consists of much more than the missile and a launch vehicle. For example, Figure 2.6 shows the vehicles required for one Indian Prithvi system.

A typical Scud B launch battery in the East German army consisted of two launch vehicles (transporter-erector-launchers [TELs]) with seven support vehicles and a crew of 45 soldiers (at wartime strength). Operations required an additional technical battery with units for rocket propellant loading, meteorological services, maintenance and support, communications, logistics, and security forces. A rocket battalion with four TELs had a strength of 204 soldiers during peacetime, with a corresponding number of vehicles and support infrastructure.[4]

Figure 2.6
The Indian Prithvi Missile System

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4 See statements of former East German armed forces personnel in the section about missile troops in NVA Forum, 2011.

This need for support systems and staff is similar for every operational missile system, and especially for systems based on the mentioned Scud technology.[5]

Development and Production

Production, not development, is the most challenging part of a missile program. The theoretical development activities are difficult enough, but to transfer these theoretical considerations into operational hardware is even harder. This is true for all high-technology machinery.[6]

Contrary to common belief, the transfer of a secret technology, certain drawings, or a few knowledgeable scientists is not the key to success. In April 2010, the lead engineer of the new Russian Bulava missile said about the missile's flight test failure series (only five official successes in 12 launches): "I can say in earnest that none of the design solutions have been changed as a result of the tests. The problems occur in the links of the design-technology-production chain."[7] Production, not design, is the real challenge.

Testing

As with every other type of machinery, extensive testing is required to guarantee operational capability of a missile system. In comparison, civil and military aircraft are thoroughly tested prior to deployment, as are cars, for example.[8] Space transportation systems are a notable exception: They are produced in very low numbers and remain in prototype status throughout their life cycle.[9]

Missile tests are done to identify unforeseen failure sources. These failure sources can be determined only by an actual failure of the launched missile and subsequent reconstruction of the failure mode, or sometimes by telemetry analysis of a basically successful test launch. Design and/or production are then modified accordingly to neutralize the discovered potential failure source. If this is not done, all subsequently produced missiles will have the same inherent failure potentials as the first production lot. The records show that early missile production lots can suffer very high failure rates.[10]

Other Countries' Missile Program Experiences

Much can be learned by analyzing missile programs in other countries. The now well-known early programs of Germany, the United States, and the Soviet Union in the 1940s and 1950s

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5 The term "Scud technology" is common in open literature for the characteristic technology and design approach that was first used for the Soviet R-17/Scud B missile.

6 This was confirmed to me in personal conversations with numerous program managers and engineers with firsthand experience. These included experts in rocket and missile programs (Robert H. Schmucker, Harry O. Ruppe, and others) and other industrial sectors (automotive, aircraft, satellite production, and other areas).

7 Space Travel, 2010.

8 As of August 24, 2011, the Boeing 787 test program has already logged almost 5,000 hours of flight testing (see Boeing, 2011). Military aircraft usually also require several thousand hours of flight testing before initial operational capability is declared.

9 This means no serial production, very long preparation time, large numbers of highly skilled personnel, endless testing routines prior to launch, regular launch delays, and launch only under perfect conditions.

10 A recent example is the new Russian RSM-56 Bulava missile, which was tested 12 times between 2005 and 2009. Seven of these tests were clear failures, and three others suffered significant problems. Only two were full successes, thus resulting in an early failure rate of 83 percent (Isby and Richardson, 2010).

might be seen as hardly comparable more than half a century later, but the technical realities and physical constraints remain the same, and much *can* actually be learned by studying them.

Much insight can also be gained by looking at Iraq's missile program of the 1980s and 1990s. Though considerable effort was put into this program, Iraq was not capable of producing operational replicas of Soviet engines or guidance systems.

Other reference examples are the Egyptian satellite launcher program in the 1960s and the German OTRAG adventure in the 1970s and 1980s, both without any serious results.[11] The same is true for the Condor/Badr 2000/Vector program, a cooperation between Argentina, Egypt, and Iraq, initiated in 1979. It was canceled in 1989 having achieved no more than a few static engine tests; but by then, the three countries had already spent a total of $3 billion on the program.

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[11] OTRAG stands for Orbital Transport und Raketen AG, or Orbital Transport and Rockets, Inc. It was the name of a German company that tried to develop an inexpensive alternative to existing launch systems.

CHAPTER THREE

The Problem

As of May 2012, at least nine different missile types have been observed in North Korea. These are listed in Table 3.1. Technically, these missiles could be armed with WMDs, including nuclear warheads. It is generally agreed that, aside from terror attacks, missiles are the only plausible means for North Korea to deliver nuclear warheads.[1]

According to the dominant view in the literature, North Korea developed and produced these missile systems with the know-how that was initially gained from successfully reverse engineering Soviet R-17/Scud B missiles that North Korea received from Egypt in the 1980s.

However, there are several indications that this view might be wrong.

Known Inconsistencies

The most obvious indication is a lack of testing. As illustrated in Figure 3.1, compared with other known missile programs, the North Korean programs have experienced a very small number of test launches before the missiles were apparently declared operational and deployed

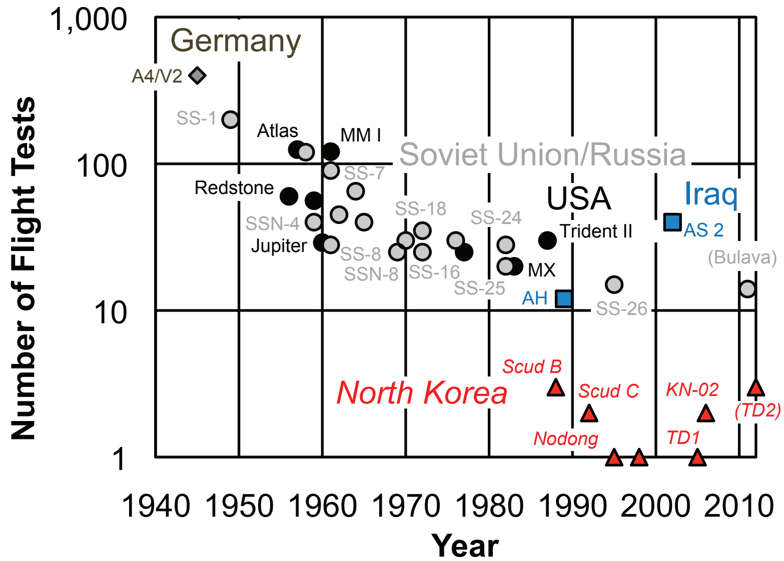
Table 3.1
North Korean Guided Ballistic Missiles and Rockets

Missile	Alternative Designations	Stages	Range [km]
KN-02	Toksa	1	~100
Scud B	Hwasong 5	1	300
Scud C	Hwasong 6	1	500
Scud D	Hwasong 7/Scud ER	1	700+
Nodong	Nodong 1/Nodong-A	1	~1,000
Taepodong I	Paektusan-1	2/3	1,600+
Musudan	BM-25/Nodong-B	1	2,500+
Taepodong II	Unha-2/Paektusan-2/Unha-3	2/3	5,500+
KN-08	–	3	5,000+/9,000+

NOTE: The Taepodong rockets had three stages, but are frequently credited with a two-stage configuration in a potential missile role.

[1] North Korean use of combat aircraft to deliver nuclear weapons seems unlikely because of the serious inferiority of those aircraft—they would be unlikely to reach their targets.

Figure 3.1
Missile Development Test Flights



SOURCES: Numbers for Germany, Iraq, the United States, and the Soviet Union according to Robert H. Schmucker, Technical University Munich. The basis for the numbers for North Korea is presented in the appendix. Numbers for China are less certain, but there are indications that Chinese test numbers are similar to U.S. and Soviet numbers.

NOTE: Each data point represents the number of development test flights for a single missile program at the declared end of development or at the most recent launch, and not the total number of flight tests.

RAND *TR1268-3.1*

with the armed forces or exported to other countries. A new North Korean missile, the Musudan, was never launched at all but is attributed as already being deployed with the North Korean armed forces.[2] The KN-08, presented in 2012, was never launched either.

In addition to a low number of tests, the failure rate of North Korean missiles is noticeably low. The North Korean Scud missiles that were launched by Iran against Iraq in the late 1980s, for example, had a reliability of 90 percent or more,[3] and no failures of the tests of the Nodong, Scud C, or Scud D in North Korea are known.

Some simple calculations might help illustrate the reliability problem. Reliability for the missile P_{mis} is the product of the reliabilities P_i of each of the n missile parts that, in case of failure, might lead to total failure:

$$P_{mis} = \prod_{i=1}^{n} P_i \, .$$

Assuming that each missile consists of a warhead, airframe, guidance and control system, and engine, there are three potential failure sources (the warhead will not affect a flight test):

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2 See for example Bermudez, 2004, or Jane's, 2010g.

3 See the "Scud B—M1" section of the appendix for details.

$$P_{mis} = P_{af} \times P_{G\&C} \times P_{en} .$$

Assuming that each of the three elements in turn consists of only 10 subsystems that might lead to total failure, even high reliability numbers lead to low total reliabilities: If each subsystem has a reliability of 95 percent, total reliability of the missile is 21 percent—statistically, four out of five missiles fail.

Assuming that North Korea purchased two of the three elements with a combined high reliability of 98 percent, and completed indigenous development and production of the third element with a 95 percent *subsystem* reliability for each of the ten subsystems, total missile reliability is only 59 percent.

For newly developed missiles, the reliability increases only by rigorous testing to gain experience for developers and factory floor workers—a typical learning curve. This effect of increasing reliability was never observed with the known North Korean missile launches, even including later launches in Pakistan or Iran.

There are other indications that make the commonly accepted hypothesis about indigenous North Korean missile development look increasingly suspect. Among them are Cyrillic (Russian) markings on the observed missiles and the existence of analog Soviet missiles for at least four (possibly seven) of the nine observed North Korean missile types. These other indications are presented in Chapter Five.

Research Question

Since the dominant hypothesis in open source literature is suspect, the following research question is postulated:

- What is the most plausible hypothesis to explain the nature of the North Korean missile program?

The currently accepted view of North Korea's missile capabilities dictates a certain set of policies. In this view, North Korea has deployed a large number of reliable short- and medium-range missiles that may be armed with WMDs. The whole Korean peninsula, Japan, and U.S. bases out to Guam are in range of this threat.[4] And the deployment of an operational intercontinental ballistic missile (ICBM) able to reach the continental United States seems only a question of time.[5] This threat situation hovers above all decisions made about policies toward North Korea, and defense planning by the United States and its allies also has to take this massive missile threat into account. The threat of nuclear-armed North Korean ICBMs has been one of the pacemakers of U.S. foreign and defense policy since the late 1990s and continues to affect decisionmaking.

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[4] See for example Wikipedia articles (that might be seen as indicators for public views) on North Korea and North Korea and weapons of mass destruction, various articles on the GlobalSecurity.org website, or numerous news reports over the past years.

[5] North Korean activities in this direction were indicated as early as January 2011 by remarks of U.S. Secretary of Defense Robert Gates about the North Korean missile threat (Reuters, 2011). Mock-ups of a road-mobile ICBM were finally presented to the public at a parade in Pyongyang on April 15, 2012.

A different explanation for the currently observed missile situation in North Korea leads to a different threat assessment, and that in turn suggests a different set of policies toward North Korea, as well as different decisions in future defense planning.

Therefore, I postulate two additional research questions that complement the main one:

- What consequences might these findings have for U.S. (and Republic of Korea [ROK]) policy and strategy toward North Korea?
- What data would be most valuable for better understanding the nature of the North Korean missile program?

CHAPTER FOUR

Defining Five Hypotheses About the North Korean Program

Aside from the reverse engineering consensus in the open source literature, the North Korean missile program could have been developed in several other ways. In this chapter, I describe the "Reverse Engineering" hypothesis as well as four other possible scenarios.

The second hypothesis is quite contrary to the "Reverse Engineering" hypothesis: It assumes total North Korean reliance on missile purchases from other countries, and is therefore designated the "Buy" hypothesis.

I consider three more variations that lie in between the two extremes of North Korean total self-reliance and total dependency on others:

- The "Bluff" hypothesis assumes that North Korea's missile program is primarily intended not for operational missile capability, but for political effect and strategic leverage.
- The "Licensed Production" hypothesis assumes that North Korea received foreign support in early phases of its program (including the provision of designs and perhaps production lines), but is now widely independent.
- The "Mixed Sources" hypothesis assumes ongoing foreign support of North Korean missile development and production, with a mix of imported and indigenously produced missiles available in North Korea, as well as North Korean assembly of hybrid missiles consisting of imported and indigenously produced components.

I recognize that it is unlikely that one of the hypotheses perfectly characterizes the North Korean program; my objective is to identify the direction in which the truth might lie. The hypothesis that emerges as being the most consistent and plausible should be seen as a starting point that has to be continuously refined, to keep it up to date with new data and future revelations and developments.

The "Reverse Engineering" Hypothesis

According to most open source literature, North Korea developed its missile and warhead program through reverse engineering.

Hypothesis

Since the Soviet Union refused to provide North Korea with guided ballistic missiles, North Korea obtained several Soviet-made Scud B missiles from Egypt during the late 1970s or early

1980s.[1] These missiles were then reverse engineered by North Korean experts, and the resulting North Korean missiles were named Hwasong 5.[2] Test flights occurred in 1984, and serial production started in 1987.[3]

From 1987 on, North Korea assisted in establishing a missile facility in Iran and delivered 90 to 100 Hwasong 5s to Iran, with approximately 77 of them being successfully fired at Iraqi cities.[4]

In 1990, and again in 1991, North Korea tested a Scud version with an identical outer appearance to the Hwasong 5 but with significantly improved range (about 500 km instead of 300 km). This missile was designated the Hwasong 6 or Scud C. It entered serial production in 1992 and was quickly deployed. The design approach was superior to that of Iraqi ballistic missiles (Iraq also had tried to extend the range of its Scud missiles), which is generally attributed to the experience that North Korea gained in successfully reverse engineering the Scud B. The Scud C was then exported to several countries.[5]

Also in the late 1980s, North Korea reportedly began development on an up-scaled version of the Scud B, widely designated the Nodong, with a commonly estimated range of up to 1,300 km. The majority of the open source literature states that the Nodong was developed by North Korea alone, though some assume that North Korea received at least some outside help. Small-scale production started in 1991, even before the first attributed flight test in 1993. Nodong missiles were sold to Iran and Pakistan, together with assistance in setting up production lines there. The Nodong has been deployed in North Korea since 1995.[6]

In the early 1990s, North Korea started development of a larger, multistage rocket, later named Taepodong I. The first stage was based on the Nodong, the second stage on the Scud C, and the third stage was a new development. Assembly and tests were done in underground facilities, and the only known launch occurred in 1998. The objective—to place a satellite into orbit—failed in the last seconds of flight due to a malfunction of the third stage. In missile configuration, the Taepodong I is commonly attributed with a range of up to 5,000 km.[7]

North Korea also developed a Scud version for Syria, commonly named the Scud D. It has a range of 700 km and was first tested in 2000 in Syria. Two more tests occurred in Syria in May 2005, with one of the missiles disintegrating in Turkish airspace and debris raining down on Turkish territory.[8] Scud Ds were reportedly launched in North Korea at the two launch campaigns in 2006 and 2009.

The largest missile in the North Korean inventory is the three-stage Taepodong II or Unha-2/-3. Development started with the Taepodong I in the early 1990s, and the same underground facilities were used for assembly and tests. The first launch in 2006 was a failure, as was the second launch, which was done in satellite launcher configuration (it failed late in the

1 Pinkston, 2008, p. 15.

2 Bermudez, 1999, p. 10.

3 Pinkston, 2008, p. 16.

4 Bermudez, 1999, p. 12.

5 *Jane's*, 2010a.

6 Pinkston, 2008, pp. 18–20.

7 *Jane's*, 2010b.

8 GlobalSecurity.org, 2011a.

separation of the third stage). The third launch attempt in April 2012 also failed, around two minutes into flight. Maximum range is believed to be up to 8,000 km, and several reports suggest that the missile has been deployed since 2009. The most likely warhead configuration is nuclear.[9]

In the 1990s, North Korea also received samples of the Soviet SS-21 Tochka for reverse engineering. With assistance from Syria, and probably Iran and Pakistan, North Korea succeeded in reverse engineering the Tochka, and the resulting KN-02 missile was first displayed in 2007. Unlike the other North Korean missiles, it uses solid propellants. It is easily storable and, though the range is only 120 km, it is much more accurate than the Hwasong missiles.[10]

Since 2003, there have been open source reports (detailed in the appendix) that North Korea also reverse engineered and improved the Soviet R-27/SS-N-6 submarine-launched missile. In October 2010, this missile, commonly referred to as the Musudan, was finally publicly displayed at a parade in North Korea, verifying the assumed configuration and dimensions and thus the previously attributed range estimate of about 3,200 km.[11]

Rumors about a North Korean road-mobile ICBM program were confirmed by the public display of a road-mobile ICBM design in April 2012. Like the Musudan missile, the three-stage ICBM is widely believed to be based on the Soviet SS-N-6 technology.

In 2006, North Korea tested its first nuclear weapon. The comparatively small yield is attributed either to a sophisticated design or to problems that resulted in a fizzled explosion.

Another nuclear weapon test occurred in 2009, with a somewhat higher yield than the first one. This test is widely acknowledged as an important step toward an operational nuclear weapon, or as a test of a functional nuclear weapon or warhead.

In summary, North Korea indigenously develops and produces its own missiles and warheads, and it does this in significant quantities.

Implications

There also is a consensus in open source literature regarding the consequences of the depicted situation. All missiles are commonly seen as operationally deployed. North Korea is viewed as capable of arming its ballistic missiles with chemical, biological, and nuclear warheads, or at least very close to doing so.

Therefore, the ROK and its allies, foremost the United States, see themselves confronted with a significant North Korean missile threat, including nuclear armed missiles. Common estimates of the number of operationally deployed missiles are 600 Scud type (B, C, and D), 200 to 300 Nodong (with 50 TELs), up to 50 TELs for Musudan missiles, possibly 20 to 30 Taepodong I missiles, and 5 to ten Taepodong II, with a possible nuclear capability for all missiles except for the Scuds.[12] Common estimates for the North Korean nuclear weapon stockpile range between five to perhaps 20 weapons. Because of the quick and successful pace of the North Korean missile and nuclear programs in the past, it is generally assumed that an

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[9] *Jane's*, 2010c.

[10] Pinkston, 2008, pp. 36–37.

[11] The Missile Defense Agency (MDA) is reported to have stated this range estimate. See for example Pollack, 2010.

[12] Numbers and nuclear capability statement from *Jane's*, 2011.

operational nuclear-armed ICBM capable of striking most major U.S. cities may be only a few years away.[13]

North Korea's resulting ability to project unconventional threats not only within the region, but eventually extending to U.S. territory, certainly has an effect on the political agenda of the United States and its allies, especially the ROK. Worried about a worst-case scenario in which North Korea launches nuclear missile strikes against ROK and U.S. territory, policymakers might feel inclined to avoid acting in a way that provokes North Korea and might ultimately lead to a nuclear disaster.

This also has significant effects on the force structure of the ROK and its allies, including the United States. The United States perceives an urgent need for highly capable layered missile defense, able to fend off intercontinental attacks against the United States as well as a large number of short-range strikes within the Korean region. The ROK armed forces and their allies should be capable of sustaining operations despite North Korea launching nuclear, biological, and chemical strikes by theater ballistic missiles. The ROK and the United States would require many special forces units and substantial airstrike capability to quickly disrupt North Korean missile launches.[14]

The "Buy" Hypothesis

Several indications allow for an alternative hypothesis about the North Korean missile program: It relies solely on imported Russian missiles.[15]

Hypothesis

In the 1980s, the widely deployed R-17/Scud B was phased out of Soviet arsenals. The production lines in Votkinsk and Zlatoust were closed down in 1984 or later. Large amounts of decommissioned and mothballed Scuds were readily available in the Soviet Union.[16] According to this hypothesis, North Korea may have failed to reverse engineer the Scud B, as did every other country before and after that tried to reverse engineer Soviet missile technology,[17] but North Korea still wanted to enhance its deterrence. Soviet institutions saw a chance to export missiles to North Korea and also use it as a vendor to export missiles to other countries (for example to Iran), thus concealing the Soviet involvement.

The North Korean Scud B program therefore had no necessity of flight testing. Soviet Scuds were transferred to North Korea and then to Iran and other countries, thus explaining the low failure rate of North Korean Scuds in the war against Iraq and their performance

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13 See for example Maxon, 2011.

14 The 2010 ROK Presidential National Security Review Commission appears to be adopting a concept referred to as "active deterrence," which would involve conventional counterforce strikes against North Korean weapons of mass destruction and delivery means. This concept involves strikes executed on warning of war, resembling the preventive/preemptive counterforce approach that was a key element of President Bush's 2002 *National Security Strategy*.

15 This hypothesis was first introduced in Schmucker, 1999.

16 Military Russia, 2011a.

17 See for example Fitzpatrick, 2010, or Schmucker, 2009.

(thrust, launch acceleration, etc.) that mirrored that of Soviet Scuds,[18] as well as Cyrillic lettering and characteristic Soviet serial numbers found on North Korean Scuds en route to Yemen.[19]

There were various Soviet efforts to increase the Scud B's range, and it seems that a version with a 500 km range was used during the Soviet invasion of Afghanistan, where the Soviets, later in cooperation with Afghan forces, reportedly launched up to 2,000 Scud-type missiles. In this hypothesis, the same thing happened with this advanced Scud C as had happened before with the Scud B—it was purchased by North Korea, designated a North Korean product, and was deployed, as well as exported, with only a few flight tests.

But there also was a demand for missiles of longer range, and exports might have become easier with the collapse of the Soviet Union. First reports about the Nodong missile surfaced in the open literature in the early 1990s, but its existence was confirmed only simultaneously with that of the Iranian Shahab 3 and the Pakistani Ghauri in the late 1990s. According to this hypothesis, these two missiles are not derived from the Nodong, but they are identical—Nodongs were simply transferred to Iran and Pakistan. There are numerous indications that the missile was developed in the late 1950s by the same Soviet design bureau that was responsible for the R-17/Scud B, and later for the R-27/SS-N-6.[20] As with many other Soviet missile programs, this program was stopped late in development but before deployment, and the drawings, production equipment, and produced prototypes remained in storage. These were later transferred to other countries. The program's status at cancellation remains to be identified, possibly ranging from functional proof of single prototypes to the first serial lot production, with firing table[21] and operational deployment procedures already created, which would affect the operational status of the Nodong missiles.[22]

The single Taepodong I prototype was probably tailor-made for North Korea by the same Russian institutions that transferred Scuds and Nodongs, since the Taepodong I was made of various Soviet/Russian missile components.[23]

This might also be the case for the Taepodong II/Unha-2/-3,[24] though Chinese institutions might have been involved here as well.

For this hypothesis, the same pattern as for the Scuds can be applied to the KN-02, which appears to be the Soviet SS-21/Tochka. Therefore, it has to be assumed that the cooperation still continued on a certain level well into the 2000s, and that these missiles were actually imported from Russia.

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18 Schmucker and Schiller, 2008.

19 These missiles were found on a North Korean freighter that was boarded by the Spanish navy in 2002. See also the "Missile/Scud B/High-Confidence Data Points/H2" section of the appendix.

20 See the appendix.

21 To determine how much boost to apply to achieve any given range, a series of test launches is required to create firing tables. Available firing tables can be applied to new production lines only if the licensor fully oversees the licensed production (material and quality standards, …).

22 To clarify this: Prototypes might fail at special conditions (for example, low temperatures in winter), whereas fully developed missiles have proven operational readiness in the required temperature ranges. Other affected areas include fueling procedures, range settings, crosswind limitations, and much more.

23 See for example Postol, 2009, pp. 25–32.

24 See Postol, 2009, pp. 33–55, and Wright, 2009.

The Musudan missile apparently was initially observed in North Korea in 2003,[25] and it was openly displayed in the 2010 military parade.[26] The Musudan is seen as being a derivative of the Soviet SS-N-6/R-27 missile, longer than the standard R-27 by roughly 2 m. There were several versions of R-27 developed and deployed in the Soviet Union, and it is not clear whether the North Korean version is indeed a new development[27] or whether this very version already existed in the Soviet Union. The Musudan might also be assembled from imported R-27 components, but since the missile has never been launched by North Korea, it may well be that there are no functional Musudans.

Under this hypothesis, the KN-08 missiles in the April 2012 parade were mock-ups that were presented to create the impression of an advancing North Korean ICBM program. If a KN-08 is actually tested one day, it would have to be a procured missile.

Implications

If this alternative hypothesis is true, North Korea still lacks the know-how of indigenous missile development and production. This is possibly also true for the associated warheads. Indigenous weapon developments cannot simply be incorporated into existing warhead designs to create a "proven warhead." Therefore, the availability of a proven nuclear, chemical, or biological warhead also seems very unlikely. The alternative option—that Russia delivered functional, complete nuclear, biological, or chemical warheads—is very unlikely. North Korean missile attacks with WMDs are therefore seen as possible but very unlikely, and unlikely to perform well. There is also the obvious problem of lacking troop training launches in North Korea, with negative effects on the operational quality of the missile forces.

The "Buy" hypothesis therefore implies that the actual strategic threat from North Korea is considerably lower than generally assumed by open source literature. The country's political blackmailing efforts could be dismissed more easily, because there is no way for North Korea to make pronounced threats come true; the force structure of the ROK and its allies should focus on other, more conventional North Korean threats.

Hypotheses Between the Two Extremes

Between the two extremes of total North Korean independence and total dependence on Russian production, other options are also possible.

The "Bluff" Hypothesis

According to this hypothesis, North Korea produces and presents a variety of missiles not for operational-tactical reasons, but for strategic ones. The main objective of the North Korean missile program is to create the illusion of a sophisticated threat for domestic and foreign policy reasons, with the actual operational status and capability of North Korea's missile force being of secondary importance or none at all.

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[25] IISS, 2004.

[26] The missiles shown in the parade were most likely mock-ups (see Figure 5.13 in Chapter Five).

[27] Consensus in open source literature and news media.

This program intent cannot be observed directly. But a missile program that is set up for this reason would show several characteristics that could be observed from outside.

Under this hypothesis, the North Korean regime is mainly concerned about convincing its elites, and especially its military, that it is creating a powerful state, which seems to be essential for North Korean regime survival. A powerful missile force is supportive of this. The regime is also interested in the deterrence potential and the strategic leverage resulting from this missile force, parts of which might also be used as a token in negotiations. As long as these strategic objectives are achieved, actual test flights and training launches are of low priority. Test flights with obvious failures might discredit the missile threat (as has happened with the failures of their declared Taepodong space launches) and would therefore be avoided. Moreover, a missile test moratorium has great value for North Korea if it provides the regime leverage in international negotiations—the regime might be "generously" willing to accept a moratorium on certain conditions, such as crude oil deliveries or food aid. The North Korean regime would still prefer a missile force with combat potential, but it is prepared to sacrifice a significant level of missile performance to achieve its strategic objectives. And, as a welcome side effect, upholding the illusion of a program is certainly cheaper than creating a real program.

In this hypothesis, decommissioned Scuds and other old Soviet missile prototypes have been imported from Russia in the late 1980s and 1990s. At the few North Korean test launches, it is these Russian missiles that have been launched, thus explaining the low failure rate. Nonetheless, there are production efforts in North Korea, not only to create the illusion of indigenous serial production, but also in hopes to achieve success in reverse engineering one day. This is analogous to the Iraqi missile program, in which intense production efforts also took place. The Iraqi efforts to copy the Scud B missiles and the Soviet SA-2 engines were never successful, though.

If this hypothesis is true, the North Korean missile threat is lower than anticipated.

The fact that North Korea exports missiles is not a contradiction to the "Bluff" hypothesis. If missiles of North Korean production have a low reliability and accuracy, or do not function at all, North Korea should have difficulty selling them. But if other governments are also primarily concerned about the strategic effects of their missile programs, they may be ready to purchase, at a relatively low cost, missiles intended for strategic leverage instead of improving their warfighting capability. And there also is the chance that the exported missiles actually are of Soviet/Russian production, even though they are labeled as "made in North Korea."

The "Licensed Production" Hypothesis

In this hypothesis, North Korea received old Soviet production lines, drawings, and documentations to establish indigenous missile production, effectively licensed from Russia. This would have required experienced Russian personnel instructing North Korean workers, which is consistent with reports that in the 1990s, Russian scientists and personnel from the Russian Makeev missile design bureau were present in North Korea, and dozens were detained by Russian authorities as they tried to travel to North Korea.[28]

In the case of licensed production, the missile production lines should be self-sufficient by now, but establishing new lines for new missile types would still require support. That support

[28] Pinkston, 2008, pp. 19–20.

may still be in North Korea, with many former Soviet rocket personnel having moved there in the early 1990s when they were put out of work.

This scenario has some obvious weaknesses: It cannot explain the lack of lot acceptance tests and firing table creation launches, though the North Koreans might be using Soviet firing tables. It also seems unlikely that North Korea succeeded in licensed production of Soviet/Russian engine technology, when even the United States tried and could not,[29] unless actual production facilities were sent from the Soviet Union to North Korea.

The "Mixed Sources" Hypothesis

This scenario involves a mix of licensed production, procured components, and procured Russian missiles. Possible variations may be, for example, that North Korea tried to set up a licensed production of the Scud B, but with poor results; the Soviet Union then provided Soviet Scud B missiles to North Korea for transfer to Iran. Later, airframe production was established in North Korea, and key components (guidance and engine) are still procured from Russia. Later missile types may be acquired under similar circumstances, with airframe production in North Korea and procurement of key components from other countries.

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[29] In cooperation with the appropriate Russian companies, Pratt and Whitney reportedly tried to establish licensed production of the RD-180 engine for the first stage of the Atlas V space transportation system (RD-180 is derived from the Soviet RD-170 engine; RD-170 development started in the early 1970s, with its first flight in 1987). After a decade of cooperation, the United States still procures these engines from Russia.

CHAPTER FIVE

What We Know

Due to its nature, not much firsthand information on the North Korean missile and WMD programs is publicly available. Much of the open source literature is based on hearsay and relies on primary sources of unknown quality. To clarify uncertainties in the subsequent presentation, I therefore distinguish information as being of high, medium, or low confidence.

- *High-confidence* information predominantly deals with technical aspects that are derived from imagery, other firsthand observations, and the laws of nature.
- *Medium-confidence* data are hard to verify firsthand, but seem plausible and are, for the most part, commonly accepted in open source literature.
- *Low-confidence* information is predominantly based on a single source and cannot be verified—it is dubious, but might still be true.

I use an abbreviation system to label the data: Each data point within the text is labeled with its confidence level and a consecutive number. For example, "H1" means the first data point for a given subject for which there is high confidence in the data; "H2" would be the second point of high-confidence data. "M1" is the first data point of medium confidence, and "L1" is the first data point of low confidence.

I also arrange the data into three categories:

- *Missile* data cover all characteristics directly related to the specific delivery systems and their associated warheads.
- *Program* data include all information that is generally related to missile development, production, and deployment.
- *Country* data cover aspects that are related to North Korea in a general way but might be relevant for its missile program.

Some data statements may seem irrelevant or out of context, but they are required for later analysis. In several cases, the data presentation may have an unstructured appearance, or to be somewhat repetitive; this is an artifact of the separation of related points into the three categories described above. That is, separating information on the North Korean missile program into discreet data points is necessary for the analysis presented in Chapter Six, but it results in a less holistic presentation of the information in this chapter and in the appendix.

I present the data in this chapter in a very condensed way to minimize its length. The corresponding details and sources for each data point can be found in the appendix. Experts on the subject are hereby urged to read through the subsequent data points and the appendix in parallel.

Missile

Nine different missiles are of interest: the Scud B, Scud C, Scud D, Nodong, Taepodong I, Taepodong II/Unha-2/-3, KN-02, Musudan, and KN-08.[1] They are arranged chronologically in their sequence of public appearance.

Scud B

The Scud B is also called the Hwasong 5. It is related to the Soviet R-17/8K14/SS-1c/Scud B.

North Korea apparently has a missile available that closely resembles the Soviet R-17/ Scud B (H1).

The North Korean Scud B looks exactly like the Soviet model (see Figure 5.1), up to small and irrelevant details, markings, and the same Cyrillic lettering at the same locations on the missile body (H2).

It seems that the North Korean Scud B also shows exactly the same performance as the Soviet one (H3): 300 km nominal range with a 1 ton warhead (H4). The missile has a diameter of 0.88 m, sometimes claimed to be 0.884 m (H5). North Korea presents its Scud missiles on a TEL that looks very close to the Russian TEL, which is based on the Belarusian MAZ 543 truck, as shown in Figure 5.2 (H6).

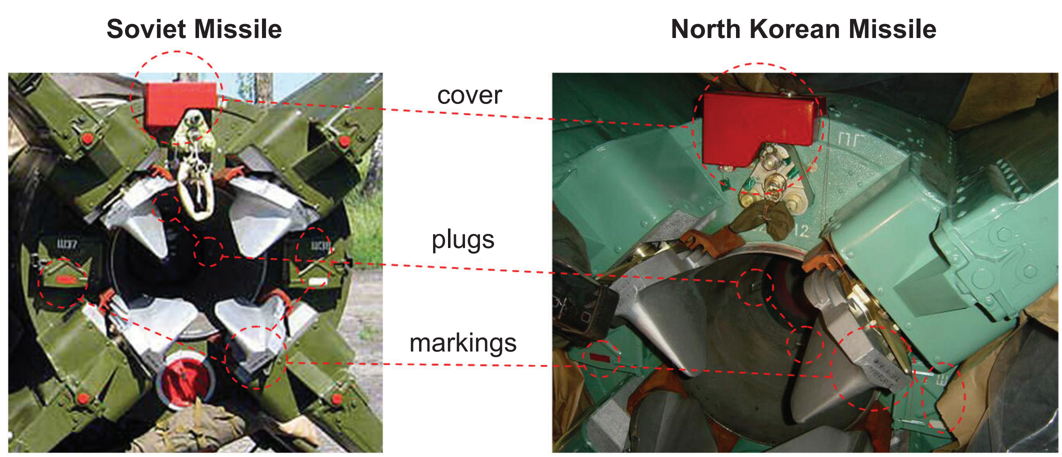
The Scud B was originally designed around 1960 by the Soviet Makeev design bureau (H7), with an engine from the Soviet Isaev design bureau (H8).

North Korean Scud Bs were launched in great numbers by Iran against Iraq in the late 1980s, with an exceptionally low failure rate (M1).

Even though Scud B was phased out of Russian arsenals, Makeev conducted research on a service life extension in 2005 on behalf of the Russian defense export agency (M2).

The North Korean Scud B looks like the Soviet Scud B because it is a perfect clone created by reverse engineering (L1). North Korea improved the range to 320 km (L2), increased the diameter to 0.884 mm (L3), and switched to a new rocket fuel (L4).

Figure 5.1
Soviet R-17 and North Korean Missile



SOURCE: (image on right) Spanish Defense Ministry and U.S. Navy.
RAND *TR1268-5.1*

[1] Designators in open source literature vary. See the respective paragraphs for details.

Figure 5.2
TELs for Scud Class Missiles (Hwasong 5, R-17, DF-11)

RAND *TR1268-5.2*

Scud C

The Scud C is also called the Hwasong 6, sometimes also Scud-PIP. It is seen as an improved version of the Scud B.

The configuration of the Scud C is known, and respective missile parts were discovered on a North Korean freighter in 1999 (H1), as shown in Figure 5.3. Available photos of the Iranian Shahab 2 missile are consistent with this configuration (H2).

The same size as the Scud B, the Scud C has a range of 500 km with a smaller payload of perhaps 700 kg (M1). This is achieved through a lighter airframe and other modifications, though the engine is most likely the same as that of the Scud B (M2).

The Iranian Shahab 2 is the same missile as the North Korean Scud C (M3).

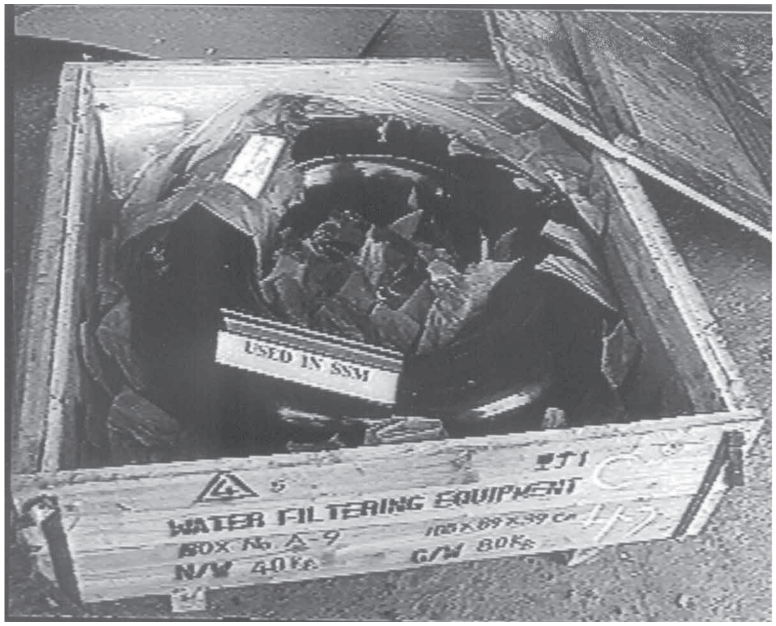
The Soviet Makeev bureau developed and tested an advanced Scud B version in the 1960s, designated R-17M/9M77, with the same performance as Scud C; it was produced in Votkinsk (M4). During the 1980s, Western sources reported a missile designated Scud C being deployed with Soviet forces since 1965, with similar performance data as the North Korean Scud C (M5).

Nodong

The Nodong is seen as similar or identical to the Iranian Shahab 3 and the Pakistani Ghauri/Hatf 5.

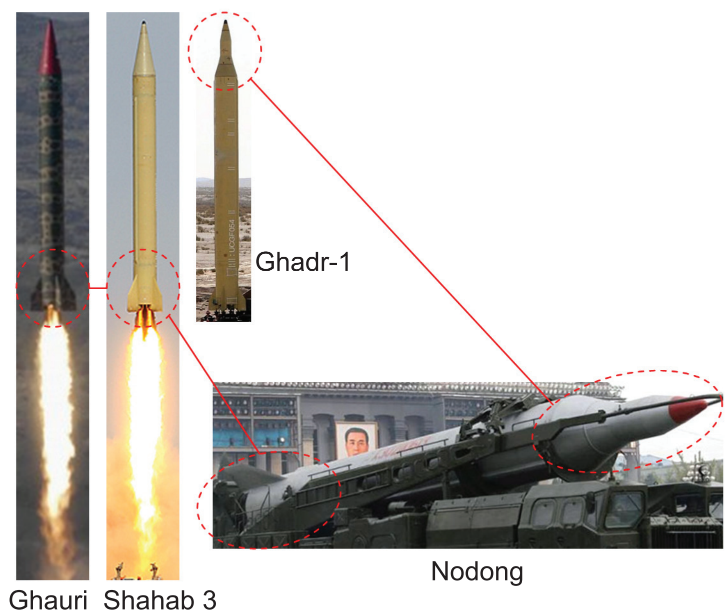
The "Nodongs" that were presented at the October 2010 parade in Pyongyang look slightly different than the basic version of the Pakistani Ghauri and the Iranian Shahab 3, with elements similar to the Iranian Ghadr-1 (H1), as shown in Figure 5.4. However, these "Nodongs" obviously were mock-ups, and not real missiles, as noted in Figure 5.5; the real North Korean Nodong configuration is therefore still unknown to the public, and reliable technical state-

Figure 5.3
Torus Tank Aboard North Korean Freighter



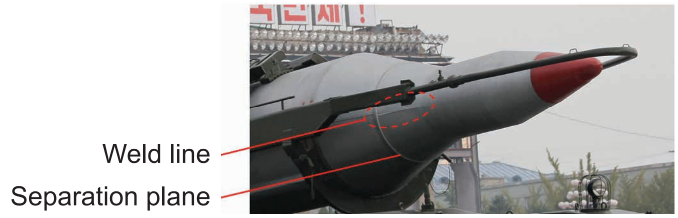
SOURCE: Schmucker Technologie. Used with permission.
RAND *TR1268-5.3*

Figure 5.4
Ghauri, Shahab 3, Ghadr-1, and Presented Nodong



RAND *TR1268-5.4*

Figure 5.5
Nodong Mock-Up



RAND *TR1268-5.5*

ments can only be made about the well-known configuration of Shahab 3/Ghauri, further referred to as Sh3/Gha (H2).

Unexpectedly, the Sh3/Gha configuration is analogous to the Scud B and does not feature the advanced design of the Scud C (H3). The Sh3/Gha looks like a Scud B that was enlarged by the factor of $\sqrt{2}$, resulting in a 1.25 m diameter (H4). The Sh3/Gha's outer appearance is not based on that of the conventional Scud B, but rather on that of the Soviet nuclear version (see Table 5.1), which was never available to North Korea (H5).

The guidance compartment is extraordinarily large, with a size that might have been required for guidance systems of the 1950s or 1960s, but not for modern ones (H6). The aerodynamic layout is also characteristic of old missiles but is not required for new missiles with modern guidance systems (H7). The Sh3/Gha uses the same propellant combination as the Soviet Scud B, one that was typical and unique for old Soviet systems of the 1950s and 1960s (H8). Unlike other liquid missiles of this size since the late 1950s, the Sh3/Gha can be filled and drained only when it is in a vertical position (H9).

The engine design shows typical characteristics of old Soviet engines from the Isaev design bureau (H10), as shown in Figure 5.6. Launch acceleration of the Sh3/Gha is 1.8 g, a typical value for old Soviet missiles (H11). In a Russian textbook for a course on missile production held in Iran in the 1990s, manufacturing of an engine that perfectly matches the Sh3/Gha engine is explained (see Figure 5.7) (H12). One of the book's authors admitted that the engine in the book is a very old design from the Soviet Isaev bureau, developed for the Soviet Makeev bureau, and that it is the engine for the Shahab 3 (H13).

There is an analogy between the old postwar Soviet R-1 missile and the Sh3/Gha and Scud B: With the Scud technology, the Scud B offers the same performance as the R-1 with a

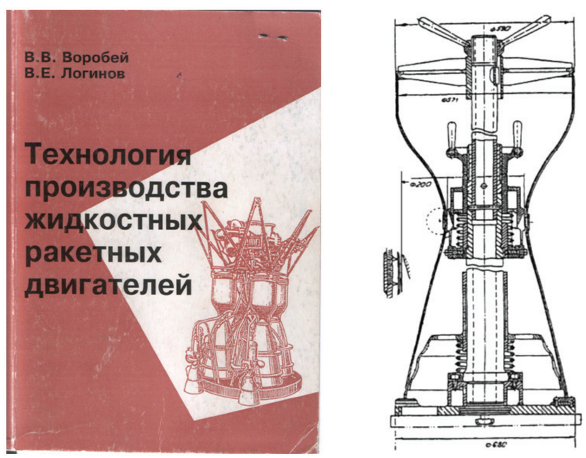
Table 5.1
Geometrical Parallels of Sh3/Gha and R-17

	R-17/Scud B Conventional	R-17/Scud B Nuclear	Sh3/Gha (Nodong)
Total Length (m)	10.944	11.164	15.6
Warhead Cone Length (m)	2.285	2.285	3.05
Rest of the Missile (m)	8.659	8.879	12.55
Scaled up by $\sqrt{2}$	12.246	12.557	

Figure 5.6
Scud B and Shahab 3 Engines (roughly in scale)

RAND *TR1268-5.6*

Figure 5.7
Russian Textbook with Manufacturing Device for a Nodong-Size Engine



RAND *TR1268-5.7*

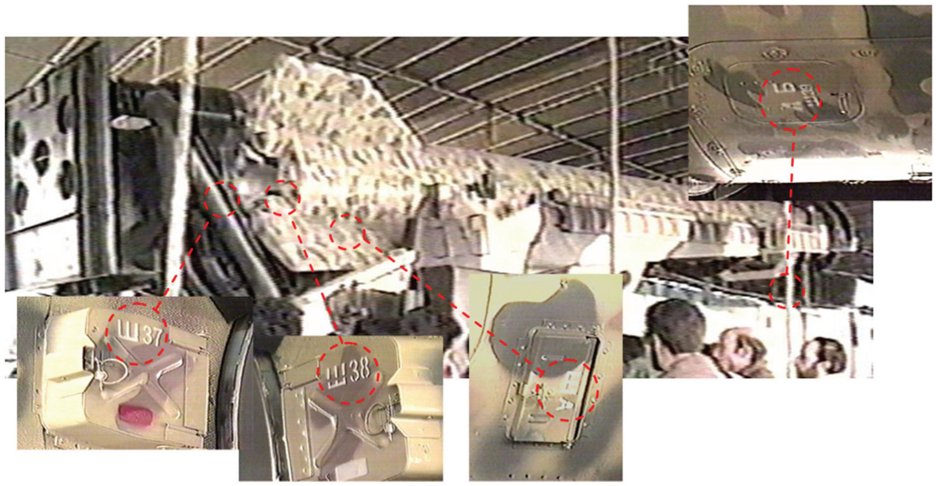
much smaller size, while the Sh3/Gha offers a much better performance at the same size as the R-1 (H14).

A photograph of a Burmese delegation from a claimed Scud factory visit shows a missile body (or mock-up) that is most likely a Nodong (H15).

At its presentation in Iran in 1998, all markings on the Shahab 3 missile body were in Cyrillic letters, and they were analogue to those of the Soviet Scud B (H16), as shown in Figure 5.8.

At the October 2010 parade, the North Korean Nodong mock-ups were presented on TELs that looked very similar to Russian Scud TELs (Figure 5.9), which are based on a Belarusian truck and not on a similar Chinese five-axle TEL (H17).

Figure 5.8
Cyrillic Markings on the Shahab 3



SOURCE: Schmucker Technologie. Used with permission.
RAND *TR1268-5.8*

Figure 5.9
North Korean and Chinese Five-Axle TELs, Soviet Four-Axle TEL

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Scud D

The Scud D is also called the Hwasong 7 and Scud-ER. It is seen as an improved version of the Scud B.

A drawing found on a North Korean freighter in 1999 (Figure 5.10) shows an enlarged Scud that complies with common reconstructions of the Scud D (H1). The missile is longer than the Scud B and C (H2).

Offering a longer range than Scud C, the Scud D has been available in North Korea since 2000 (M1). This missile might be the same as the Syrian Scud D (M2). It offers a range of roughly 700 km, which is the maximum for conventional Scud modifications (M3). As with the Nodong/Shahab 3/Ghauri, the warhead is separable (M4). The engine is the same as for Scud B and C (M5). Others claim the use of a highly modified Scud engine (L1).

Taepodong I

The Taepodong I is also called the Paektusan-1.

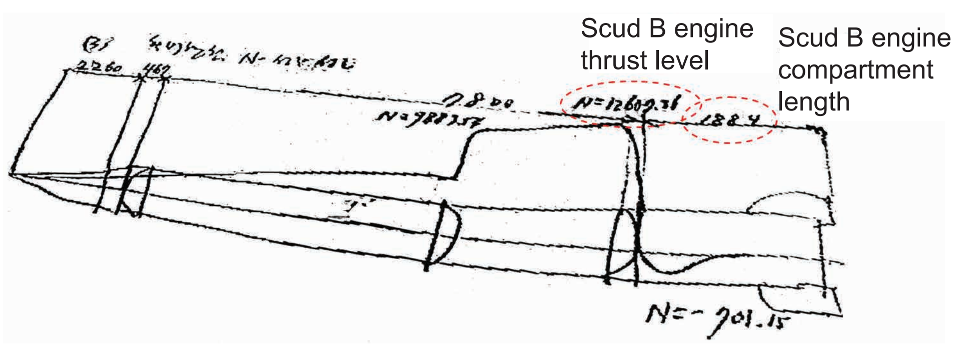
This rocket features three stages (H1). The first stage is a basic Nodong/Shahab 3/Ghauri missile (H2). The second stage diameter is around the same diameter as that of the Scud (H3).

The Taepodong I's only launch, in 1998, failed due to a late failure of the third stage (M1). The complicated separation events of the first and second stage, a first for North Korean missiles, were both flawless (M2). Available data on the trajectory are contradictory (M3). However, all data imply the use of an engine different than a Scud engine for the second stage (M4). In any case, it is commonly agreed that Soviet/Russian missile elements were utilized for the second and third stage (M5). The publicly available launch video seems to have been modified to imply a higher launch acceleration (M6).

The Soviet design concept R-55 of the 1950s or 1960s, linked to Makeev, shows similarities to the Taepodong I configuration (L1).

Another source indicates that the second stage of the Taepodong I is a Scud, and the third stage is not an SS-21 (L2).

Figure 5.10
Kuwolsan Drawing of Long Scud Version



SOURCE: Schmucker Technologie. Used with permission.

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Taepodong II/Unha-2/Unha-3

The Taepodong II/Unha-2/Unha-3 is also called the Paektusan-2.

There is basically no imagery of the first Taepodong II launch publicly available (H1). Imagery of the Unha-2 is available from 2009, showing a three-stage rocket (H2). The 2012 Unha-3 looks like the Unha-2, perhaps with a slightly different third stage (H3). The design approach is totally different from that of the previously known North Korean missiles (H4). It is not clear whether the Unha-2 of 2009 and the Taepodong II of 2006 are the same type of rocket (H5). The Unha-3's second stage uses the same propellants as the Nodong and the Scud and is therefore not based on the more advanced R-27/SS-N-6 missile (H6).

The rocket exhaust and the first stage configuration indicate the use of four Nodong engines in the first stage (M1).

KN-02

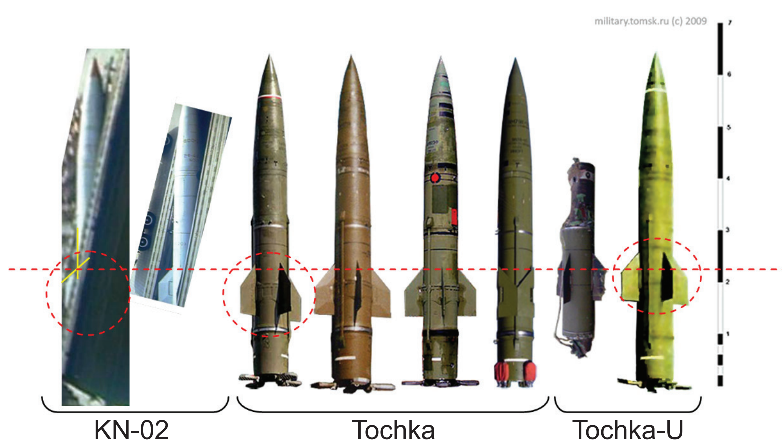
The KN-02 is also called the Toksa. It is related to the Soviet/Russian OTR-21/9M79/SS-21/Scarab/Tochka or its advanced version 9M79-1/Tochka-U.

In 2007 and 2010, North Korea presented a missile that looks very similar to the original Russian SS-21/Tochka (H1), as shown in Figure 5.11. The Tochka has a maximum range of 70 km with a 482 kg warhead (H2), while the Tochka-U offers a range of up to 120 km with the same warhead (H3).

The SS-21 technology is totally different than the Scud technology or that of the SS-N-6, ranging from the fuel and engine type to the airframe and the guidance system (H4). The SS-21 is also quite different from the FROG missile and therefore not familiar to North Korean engineers (H5). Several warheads were developed for the SS-21, including nuclear ones, but no chemical and biological warheads (H6).

The North Korean KN-02 was presented on a different TEL than the Russian SS-21 TEL, but like all other North Korean TELs, the one for the KN-02 is also based on a truck that is produced by the Belarusian MAZ company (H7), as shown in Figure 5.12.

Figure 5.11
Presented KN-02 and Soviet/Russian Tochka and Tochka-U



SOURCE: (Tochka and Tochka-U images) DIMMI (blog contributor), 2012.
RAND *TR1268-5.11*

Figure 5.12
North Korean and Soviet Three-Axle TELs

SOURCE: (top image) Tourbillon, via Wikimedia Commons.
RAND *TR1268-5.12*

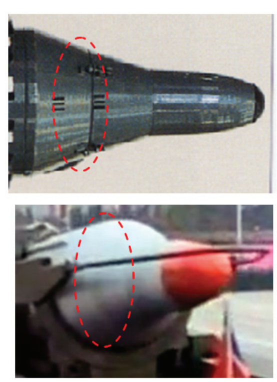
Musudan

The Musudan is also called the BM-25, or the North Korean R-27 derivative. It is related to the Soviet R-27/RSM-25/4K10/SS-N-6/Serb.

Before it was finally presented to the public in October 2010, there were various descriptions available of the Musudan missile, which resembles an elongated Soviet SS-N-6/R-27 submarine missile (H1). The presented Musudans were clearly mock-ups, meaning that there are still no photos of real Musudan missiles or any other evidence of their existence available in open sources (H2).

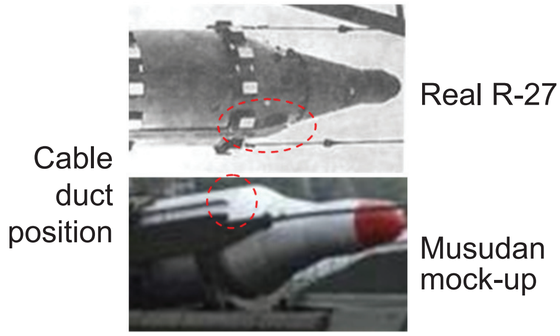
The presented mock-ups look very similar to the Soviet SS-N-6 (H3). Besides the slightly increased length, there are other minor differences, as illustrated in Figures 5.13 and 5.14 (H4).

Figure 5.13
Musudan/BM-25 Mock-Up



RAND *TR1268-5.13*

Figure 5.14
Different Cable Duct Positions of R-27 and Musudan/BM-25



RAND *TR1268-5.14*

The Soviet SS-N-6 was designed in the 1960s by the Makeev bureau (H5), with an engine from the Isaev bureau (H6). Several rocket parts that look like SS-N-6 components were observed in Iran as part of their Safir satellite launcher (H7).

The SS-N-6 was designed as a submarine missile and not as a land-based missile, resulting in various special characteristics that are problematic for mobile land-based deployment (H8). The SS-N-6 was fueled and sealed in the factory and then deployed aboard the submarines (H9). Its airframe is very fragile and easily ruptured (H10). The propellants react violently when they come into contact, and they are very temperature-sensitive (H11). The technology that was used for the missile and the engine is totally different than the Scud technology (H12). Though being an almost 50-year-old design, the missile's technology is still close to the technical limits, and its performance is state-of-the-art (H13).

A missile with the presented mock-up configuration can reach more than 3,000 km with a payload of more than 500 kg (H14).

The Musudan missile and its deployment mode were predicted as early as 2004, and the observed mock-ups and deployment mode of October 2010 perfectly match the open source predictions (H15).

The North Korean TEL, shown in Figure 5.15, looks like the Soviet TEL for the SS-20 missile, which was based on a Belarusian MAZ truck (H16). This TEL is oversized for the Musudan missile (H17).

The Makeev bureau also developed an elongated version of the SS-N-6/R-27 in the 1960s, named R-27M, Index 3M30 or 4K10M (M1).

The Musudan might also be related to the Unha-2/-3 second stage, which seems to be based on the Nodong and not on the SS-N-6 (M2).

North Korea indigenously developed two versions of the Musudan: a land-based and a sea-based system (L1).

KN-08

The KN-08 is also referred to as the North Korean road-mobile ICBM.

Following several rumors about a road-mobile ICBM in North Korea, the KN-08 was finally presented in April 2012 at the parade in honor of Kim Il Sung's 100th birthday (H1). The presented KN-08s were clearly mock-ups, meaning that there are still no photos of real KN-08 missiles or any other evidence of their existence available in open sources (H2).

Figure 5.15
North Korean and Soviet Six-Axle TELs

RAND *TR1268-5.15*

The North Korean TEL is based on a Chinese truck (H3). This TEL is oversized for the KN-08 missile (H4).

From an engineer's perspective, the presented design is puzzling (H5).

A KN-08 with SS-N-6 technology could offer intercontinental range, while the use of Nodong technology limits range to around 5,000 km (M1).

Program

The following information is related to missile development, production, and deployment. Available facts are limited. Reports of medium and low confidence are the major sources for statements about the program.

Tests and Training

Testing and training are important for any effective operational weapon system.

In general, weapon systems are only deployed when they are tested, when procedures for operations are verified, and when their reliability under any circumstances is sufficiently proven (H1). Exceptions are observed for weapons with primarily strategic and political meaning (H2).

Only three tests of North Korean missiles—the Taepodong I, Unha-2, and Unha-3—can be verified with available open source imagery; no imagery of other tests is available (H3). Even though available data about other tests are inconsistent, all sources agree on very low numbers (H4). These numbers are lower by roughly an order of magnitude than those required by the United States or the Soviet Union/Russia (H5).

Table 5.2 provides the numbers of flight tests from various sources. The exact numbers may vary from source to source, but the order of magnitude shown here is correct. Blanks reflect a lack of available data.

Test flights in the United States and Russia decreased over time, as can be seen in Figure 5.16. The test flight numbers in North Korea are consistently low.

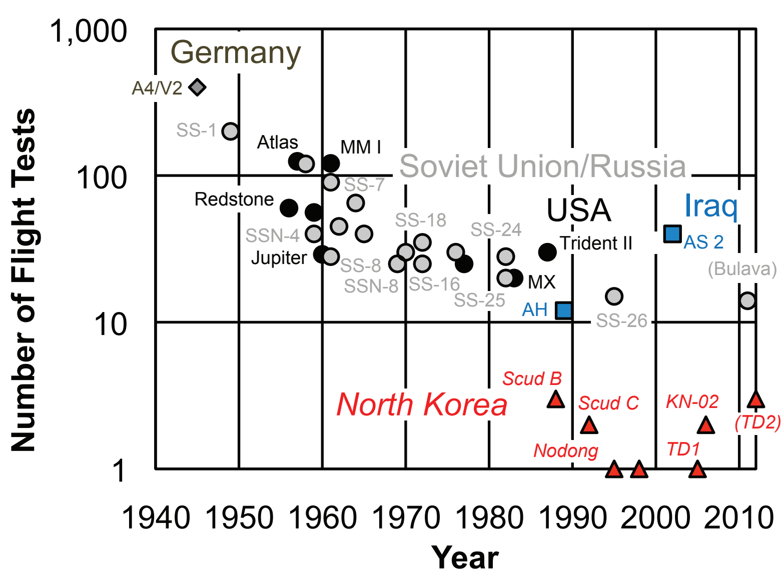
Table 5.2
Various Missile Development and Life Cycle Launch Numbers

				Test Flights	
Time	Country	Missile	Generation	Development	Life Cycle
1940s	Germany	A4/V2	1st (5th)[a]	400	
	Soviet Union	R-1	(1st)	200	
1950s	USA	Redstone	2nd (6th)[a]	37 (60?)	
	Soviet Union	R-17	nth	50+	Hundreds
	USA	Atlas	(1st)	125	
1960s	Soviet Union	R-16	nth	90	
	Soviet Union	R-27	nth		~500
1970s	Soviet Union	SS-18	nth	35	
1980s	Iraq	Al-Hussein	modification	12	
	USA	Trident II	nth	30	130
1990s	Russia	SS-26	nth	15+12	20
2000s	Iran	Ghadr-1	modification	4	2
	Russia	Bulava	nth	13	In development

SOURCES: The table draws on numerous articles from the Internet resources SpaceDaily.com and Astronautix.com, personal conversation with Robert H. Schmucker, United Nations Special Commission report information, and others. Numbers are easy to find for the interested.

[a] Including the preparatory missile programs A1, A2, A3, and A5.

Figure 5.16
Missile Program Developmental Test Flights



SOURCES: Numbers for Germany, Iraq, the United States, and the Soviet Union according to Robert H. Schmucker, Technical University Munich. For numbers for North Korea, see later paragraphs with medium confidence.

NOTE: Each data point represents the number of developmental test flights for a single missile program at the declared end of development.

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Compiling data from available sources, the following numbers seem likely:

- The North Korean Scud B was probably launched not more than three times before it was transferred to Iran and successfully launched in significant numbers. Since then, it has been launched perhaps three more times in North Korea, seemingly without failures (M1).
- The Scud C was launched twice before being deployed, and perhaps four more times since then, with all launches being successful (M2).
- There was only one Nodong launch before the missile was deployed and transferred to Iran and Pakistan, with perhaps five more launches in North Korea since 2006; all launches seem to have been successes. From 1998 on, several Ghauri and Shahab 3 launches were observed in Pakistan and Iran (M3).
- The Scud D was launched once in Syria prior to deployment in North Korea, and perhaps three times after that in North Korea, with two more launches in Syria; only one of the two last Syrian launches seems to have failed (M4).
- The Taepodong I was only launched once, in 1998, with a third-stage failure (M5).
- Taepodong II/Unha-2/Unha-3 was launched once in 2006 with a first-stage failure, once in 2009 with a third-stage separation failure, and once in 2012, probably with a second-stage separation failure (M6).
- The KN-02 was launched perhaps twice before North Korea's claim of initial operational capability, and perhaps eight more times since then, with only one failure that occurred at one of the first two launches (M7).
- As of May 2012, the Musudan has not been launched at all (M8). The same is true for the KN-08 (M9).

There are two interesting aspects about the Nodong tests: In North Korea, the Nodong was never launched over its full range (M10), and no telemetry was detected at the Nodong's first and only development flight in 1993, which is very unusual. No telemetry was detected at the 1993 Scud launches, either, and it is not known if telemetry was detected at other tests (M11).

There are reports of intense North Korean training activities, but these are conducted without actual launches (L1).

Personnel

Demanding high-technology programs require appropriate personnel. For missile programs, this includes the need for excellent scientists, managers, and engineers, but even more important, for skilled factory floor workers, including administrative staff, security staff, and other personnel. Along with subcontractors and staff at other related production sites, numbers quickly end up in the ten thousands (H1).

Russian personnel, including experts from the Makeev design bureau, were present in North Korea in the 1990s (M1). At the same time, North Korean missile experts were in Iran, where they displayed knowledge and skills that were "very unimpressive" (M2). Russian government sources are said to have admitted that Russian nuclear scientists and missile experts provided support to North Korea but returned to Russia by 1998 (M3).

To get an idea of the personnel requirements of nuclear and missile programs, note that the Manhattan project during World War II required about 130,000 people (M4), and for the

Soviet nuclear weapon research program alone, at least ten closed cities were created just for the involved personnel (M5).

In contrast, about 3,000 people reportedly work on the North Korean nuclear program, including some 200 scientists and key researchers (M6).

The numbers of personnel for the North Korean missile program are not known to the author, but an estimated 80,000 people have worked on the early U.S. ICBM development in the 1950s, with extensive industrial participation (M7).

Infrastructure and Facilities

A missile program requires sufficient infrastructure and facilities to support research, development, production, testing, and training.

For the past few decades, the Musudan-ri launch facility on North Korea's east coast was used for rocket launches; it is small and looks improvised, with dirt roads connecting the few buildings (H1). A new second facility on the west coast is much larger, but construction progress was slow, and only concrete and steel structures are visible, even though the Unha-3 was launched there in April 2012 (H2).

The Nodong was also launched from Musudan-ri, but other Nodongs and all smaller missiles are launched from other, mobile sites (M1). As of May 2012, only the Unha-3 was launched from the new facility in the west (M2).

Several other facilities are also involved in the missile program, including academic sites and factories (M3). Many facilities are located underground (M4). There is one photograph available that was reportedly made in a missile factory (see also H15 in the Nodong section), but no production equipment is visible (M5).

Development and Production

Any development and production program shows certain characteristics.

There is no such thing as perfect reverse engineering: Products of reverse engineering programs always show slight differences in design and performance, and, if not, they use parts from the original production (H1).

This is also true for North Korean missile parts that were confiscated in Zurich: Electronic components showed Cyrillic lettering, and the machined metal parts were of poor quality (H2). North Korean missile parts were also observed in Iran, their quality reportedly being "very poor" (M1).

Nonetheless, North Korea is attributed with having reverse engineered the Soviet Scud B within perhaps three years, with serial production running within another three years (M2). Development of the advanced Scud C took the North Koreans three to seven years (M3), and that of the Nodong took between five and ten years (M4). For the Taepodong I, North Korea needed eight years of development (M5), for the Taepodong II/Unha-2 it was 16 years (M6), and seven to nine years for the KN-02 (M7). The Musudan missile was developed in only three to five years (M8).

North Korea is also said to have remanufactured earlier Scuds to Scud C and D configuration (L1).

Numbers and Deployments

There are many reports about North Korean missile deployments and production numbers, many of them contradictory. Numbers for other countries are better known and can give an idea of common deployment and production numbers.

Peak deployment of the Scud B in East Germany—the frontline Warsaw Pact country in Europe—was 20 TELs with 100 missiles (H1).

In North Korea, several hundred Scuds of B and C configuration are deployed (M1). Some sources claim operational biological, chemical, and even nuclear warheads for these missiles (M2).

According to a frequently cited source, 600 Scud missiles were deployed in 2006 (M3), and 300 Scud B missiles were produced in North Korea, with only 100 to 150 deployed and the rest exported (M4). The same source claims that 200 Scud Cs are in service, with 50 TELs or fixed launch sites (M5); that perhaps 300 Nodong missiles with 50 TELs are in service (M6); that five to ten Taepodong II missiles are deployed (M7); that up to 50 Musudan missiles are deployed, with 50 TELs available for the Musudan (M8); and that the KN-02 missile is already in service (M9).

Twenty to 30 Taepodong I missiles are said to be in storage in North Korea (L2).

Perhaps related to the North Korean Scud C, there are indications that a missile designated as a Scud C was in service with the Soviet forces in Afghanistan in the late 1980s (L1).

Exports

North Korea is commonly regarded as one of the most active proliferators of missiles and related technology.

In 1999, missile components and other related cargo were discovered aboard the North Korean freighter *Kuwolsan* en route to Libya (H1). Another freighter, the *Sosan*, transported complete Scud missiles to Yemen in 2002 (H2).

In 1987 and 1988, North Korea transferred between 100 and 400 Scud B missiles to Iran (M1). North Korea also transferred between 25 and 40 Scud B missiles to the United Arab Emirates in 1989 (M2). North Korea provided technical assistance in Scud production to Iran and Libya, who also received an unknown number of Scud B missiles (M3).

North Korea provided technical assistance for Scud C production to Libya and Egypt, and North Korea exported Scud C missiles to Libya, Syria, Iran, and Yemen (M4).

North Korea probably provided technical assistance for Nodong production to Iran, and it exported Nodong missiles to Iran and Pakistan (M5).

In 2005, North Korea transferred 18 Musudan/BM-25 missiles to Iran (M6).

Until 2009, North Korea had exported an estimated number of 510 ballistic missiles, with more than 80 percent of the total units delivered between 1987 and 1993 (M7).

North Korea also delivered Scud B missiles to Vietnam, Ethiopia, Congo, and Burma (L1) and Nodong missiles to Syria, Libya, Egypt, and Iraq (L2).

Imports

There also are many reports about imports of missiles and related technology into North Korea.

North Korea has received Soviet FROG unguided missiles since the 1960s (M1). Around 1980, it received several Soviet Scud B missiles from Egypt, because the Soviet Union refused to provide Scuds to North Korea (M2). During the 1980s and 1990s, North Korea received various surface-to-air missiles and anti-ship missiles from the Soviet Union/Russia (M3). During the same time, North Korea also imported various surface-to-air missiles and anti-ship missiles from China (M4).

North Korea also repeatedly imported or tried to import materials and parts that might be used for missile production (M5).

According to one source, North Korea received about 240 Scud B missiles from the Soviet Union between 1985 and 1988 (L1). In 1991, ten Soviet-made Scud C missiles were reportedly transferred from Russia to North Korea (L2).

Country

Aspects that are not directly related to, but are important for, the missile and nuclear programs are covered in this section.

General Aspects

Some basic aspects should be noted. First, the North Korean way of thinking is different from the Western one, potentially resulting in approaches and decisions that look irrational in Western eyes (H1). Second, the same technical and physical limits as for the rest of the world are in effect in North Korea (H2).

Classification of the Missile Program

The North Korean government seems to place an emphasis on its missile and nuclear programs.

In North Korea, the missile program has a very high priority (M1). Even short-range missiles are seen as strategic tools (M2).

Financial, Economic, and Industrial Situation

Certain prerequisites have to be met for demanding engineering programs.

The electrical power situation in the North is very poor (H1), as illustrated by the lack of lights over North Korea that is easily identified on satellite images of North Korea at night (see Figure 5.17). Food production was and still is insufficient, leading to regular famines, which left perhaps several hundred thousand dead in the mid- to late-1990s alone (H2).

The economy is very weak: North Korea's gross domestic product (GDP), even when corrected by purchasing power parity (PPP), is comparable to that of Costa Rica or to that of the cities of Caracas or Oslo alone (M1), as shown in Table 5.3.

Other Industrial Programs

Several aspects of North Korean programs in other fields of engineering may provide insight into its missile program.

North Korea has only a very small automotive industry, with no indigenous developments and only a few car types that are assembled from pre-produced foreign parts (H1). The current North Korean copy of an Italian compact car still displays the Italian company's sign and brand name on the body and on the engine (H2).

North Korea has no aerospace industry, and its air force still relies on foreign aircraft mainly from the 1950s and 1960s (H3). A new North Korean battle tank was presented in 2010, showing strong resemblance to various Russian tanks (H4).

Figure 5.17
Korean Peninsula at Night

SOURCE: GlobalSecurity.org, 2011c.
RAND *TR1268-5.17*

Table 5.3
Gross Domestic Product (2008/09), Nominal and PPP

	GDP (nominal)		GDP (PPP)	
Country or City	**Millions, $**	**Rank**	**Millions, $**	**Rank**
United States	14,120,000	1	14,120,000	1
Germany	3,339,000	4	2,815,000	5
Los Angeles, USA			792,000	(19)
Austria	382,100	23	321,600	36
Iran	325,900	28	825,900	18
St. Louis, USA			126,000	(58)
Syria	52,640	69	100,800	66
Costa Rica	29,320	88	48,830	88
Caracas, Venezuela			41,000	(93)
North Korea	27,300	89	40,000	94
Oslo, Norway			40,000	(94)
Panama	24,860	94	40,760	93

North Korea claims to have produced many surface-to-surface missiles for decades, but until 2010, there were no reports that it produced surface-to-air missiles (H5).

The quality of North Korean cars is very poor (M1). There also seem to be severe problems in spare parts production for the North Korean aircraft, since the majority of the North Korean air force is grounded because of a lack of spare parts (M2).

The battle tank mentioned above has been in production for almost 20 years, but production numbers are said to be in the low hundreds at best (M3).

Even though the North Korean currency notes are made of poor quality, the country is accused of producing the “Superdollar,” a U.S. $100 bill of higher quality than the original (M4).

Links to Other Countries

Close ties to other countries might indicate collaboration.

North Korea is internationally isolated, with ties and a common border to both China and Russia (H1).

Figure 5.18 provides a satellite view of a railway connecting North Korea and Russia that seems to be in good shape (H2). Russian President Vladimir Putin was one of very few heads of state who has visited North Korea, with the visit taking place within two months after his inauguration in 2000 (H3).

There are several crossings along the border between China and North Korea, some of them by railway, as shown in Figure 5.19 (H4). Smuggling activities are common and are tolerated by officials on both sides (H5).

Other Aspects

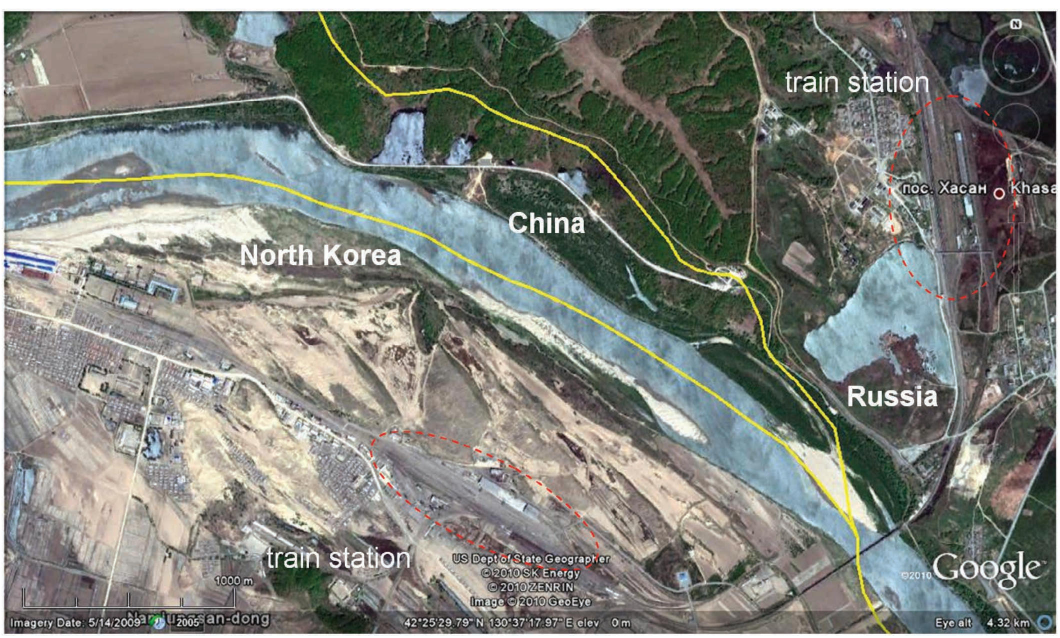
This section includes aspects that did not really fit into any previous sections.

The Russian government and the respective production companies never filed official protests against the North Korean product piracy of missile designs (H1). But Russian authorities are said to complain about this behind closed doors (M1).

North Korea limits its reverse engineering skills only to surface-to-surface missiles (H2).

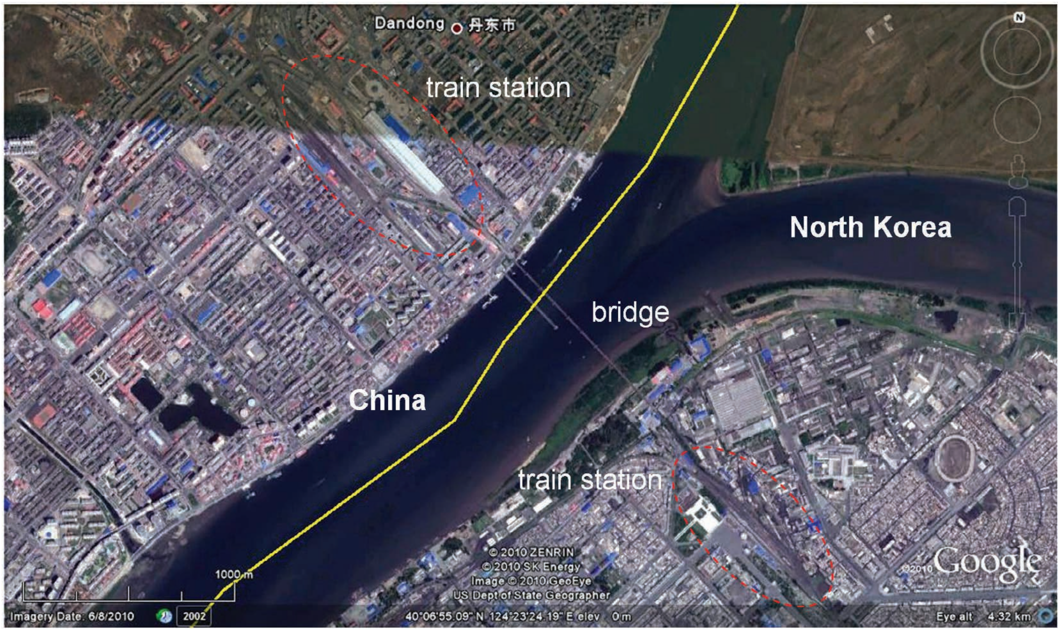
In 1998, the old Soviet Scud production line in Votkinsk was incomplete (M2).

Figure 5.18
Railroad Connecting North Korea and Russia



SOURCE: © 2010 Google Earth; © 2010 SK Energy; © 2010 Zenrin; image © 2010 GeoEye.
RAND *TR1268-5.18*

Figure 5.19
One of the Railroads Connecting North Korea and China



SOURCE: © 2010 Google Earth; © 2010 Zenrin; © 2010 SK Energy; image © 2010 GeoEye.
RAND *TR1268-5.19*

CHAPTER SIX

Consistency Check

The data presented in Chapter Five represent many pieces of a puzzle, all with different qualities. These pieces can be combined in different ways to produce a broader picture, which can then be checked for consistencies and inconsistencies within the presented data. Each of the five hypotheses described in Chapter Four represents such a broader picture.

In this chapter, I methodically check each hypothesis for consistency with each of the presented data points. Of course, the results are only a snapshot of the current situation as represented by available data, and may change in the future with refined hypotheses and new data.

Scoring System

I match the presented data points against each of the five hypotheses and evaluate the hypotheses for compliance with the data. I assign scores for compliance based on the credibility of the information and the extent to which it contradicts the hypothesis. This scoring system is shown in Table 6.1. The system is a penalty system, with higher scores representing greater inconsistencies.

Table 6.1
Inconsistency Scoring System

Compliance	Comments	Credibility Levels		
		High	Med	Low
Perfect match	Consistent with the respective hypothesis.	0	0	0
Anomaly	Not inconsistent, but also not quite consistent—seems or feels strange.	5	2	1
Inconsistency	Not discrepant, but inconsistent—makes no sense, but is still possible.	10	5	2
Discrepancy	Clear discrepancy with the respective hypothesis.	50	10	5
Not applicable	Irrelevant for the consistency check.	0	0	0

Consistent data points have a zero penalty value, while clear discrepancies have a high penalty value; the higher the confidence in a certain data point, the higher the penalty for inconsistency with it.

I have tested the scoring system with several combinations of specific numbers for the scores. The results are robust to the assigned specific numbers.

Evaluation Matrix

For each category of the presented data, I created a single evaluation matrix and estimated the consistency of each single data point. The judgment of each data point can, of course, be disputed, and such dispute is encouraged to further improve the findings.

To clarify the evaluation process, I present an exemplary evaluation matrix as Table 6.2. This matrix covers the empirical evidence that I considered for the technical aspects of the North Korean Scud B (category: missile, subcategory: Scud B).

Combining the results of all evaluation matrices gives the total inconsistency score.

Table 6.2
Evaluation Matrix: Scud B

Scud B		Consistency Check				
		RE	*Bluff*	*Licensed*	*Mixed*	*Buy*
H1	Resembles R-17	Consistent	Consistent	Consistent	Consistent	Consistent
H2	Same details	No Soviet support?	Is Soviet R-17	Could be an imported R-17	Could be an imported R-17	Is Soviet R-17
H3	Same launch acceleration	Missile was not from N. Korea	Consistent	Consistent	Consistent	Consistent
H4	R-17 range	Dismissed	Dismissed	Dismissed	Dismissed	Dismissed
H5	R-17 diameter	Dismissed	Dismissed	Dismissed	Dismissed	Dismissed
H6	TEL	Tels imported	Consistent	Consistent	Consistent	Consistent
H7	R-17 Makeev	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant
H8	R-17 Isaev	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant
M1	Reliability in Iran	Too high for new program	Soviet R-17s	Very high for new prod. line	Soviet R-17s	Soviet R-17s
M2	Life Extension	Could be done by N. Korea	Required	Supportive	Required	Required
L1	Perfect clone	Impossible	Is soviet R-17	Hardly credible	Not a clone	Is soviet r-17
L2	Range increase	Consistent	Impossible	Impossible	Possible	Impossible
L3	Diameter incr.	Consistent	Mock-up	Impossible	Possible	Impossible
L4	New fuel	Possible	Impossible	Impossible	Impossible	Impossible
Inconsistency Score		*85*	*10*	*29*	*17*	*15*

Condensed Discussion of the Matrices

A detailed discussion of each single data point would go far beyond the scope of this report. Instead, for each matrix, I discuss the data points with significant inconsistency scores of ten and higher, which are assigned for red and dark orange fields in the matrices (meaning medium/high-confidence discrepancies and high-confidence inconsistencies, see Table 6.1). For matrices with no such data points, I give a general statement.

The whole assessment is based on falsification, not on verification. I therefore do not mention the numerous cases in which data points might verify a hypothesis because they fit in well with the respective theory.

Missile

Scud B

See Table 6.3. Due to the same details of Soviet and North Korean Scuds (H2), it seems obvious that there was some cooperation between North Korea and Russia, but the "Reverse Engineering" hypothesis claims that North Korea reverse engineered their Scuds without any external help—a clear discrepancy. The high reliability of North Korean Scuds in Iran (M1) is unheard of for an untested first-generation missile program—also a clear discrepancy. That Iranian Scuds show exactly the same performance as Soviet ones (H3), even though they reportedly are from North Korean production, is not totally impossible—Iran might have somehow acquired Soviet Scuds elsewhere. But this is an inconsistency with the "Reverse Engineering" hypothesis, in which only North Korea transferred Scuds to Iran, and probably even instructed Iran in production.

Table 6.3
Scud B

Scud B		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Resembles R-17					
H2	Same details					
H3	Same launch accel					
H4	R-17 range					
H5	R-17 diameter					
H6	TEL					
H7	R-17 Makeev					
H8	R-17 Isaev					
M1	Reliability in Iran					
M2	Life Extension					
L1	Perfect clone					
L2	Range increase					
L3	Diameter incr.					
L4	New fuel					

Scud C

See Table 6.4. It seems noteworthy that there already was a Scud C in the Soviet Union.

Nodong

There are two clear discrepancies with the "Reverse Engineering" hypothesis: The shape of the Nodong is an exact copy of the nuclear Scud B, but North Korea only had the conventional Scud B (H5); and the Nodong engine is a Soviet development (H13). There also are several inconsistencies with the "Reverse Engineering" hypothesis: The Nodong can only be vertically fueled (H9), which is a design flaw that was overcome more than 50 years ago and would not have been implemented in a newly developed missile; Russians, not North Koreans, taught the Iranians how to produce the Nodong/Shahab 3 engine (H12); the first Nodong in Iran was covered with Cyrillic letters (H16); and the North Korean TEL obviously is a Soviet/Belarusian product (H17), which is inconsistent with the claim of a purely North Korean weapon system development. See Table 6.5.

Scud D

See Table 6.6. The sketch found aboard the North Korean freighter (H1) might be part of a bluff, but this seems not fully consistent for the "Licensed Production" or the "Buy" hypothesis, since such a drawing would not be required in either case.

Taepodong I

See Table 6.7. It seems unlikely that the complete rocket was bought, but completely independent design also seems unlikely.

Taepodong II/Unha-2/Unha-3

See Table 6.8. For the "Reverse Engineering" hypothesis, the North Korean approach of dismissing the successful Taepodong I basic design and opting for a totally new design philosophy for the Unha-2 (H4) is inconsistent.

KN-02

See Table 6.9. The totally new design approach for the KN-02 is not very consequent for an indigenous development program.

Table 6.4
Scud C

Scud C		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Torus tank					
H2	Iran: Design verif.					
M1	Availability					
M2	General design					
M3	Shahab 2					
M4	Makeev					
M5	Soviet Scud C					

Table 6.5
Nodong

Nodong		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Parallels Sh3/Gha					
H2	Mock-ups					
H3	Configuration R17					
H4	√2 Size					
H5	Based on R-17nuc					
H6	Guidance size					
H7	Aerodynamics					
H8	Fuel					
H9	Vertically fueled					
H10	Engine pressure					
H11	Launch accel.					
H12	Eng. in textbook					
H13	Soviet Sh3 engine					
H14	R-1 analogy					
H15	ND in NK factory					
H16	Cyr. letters on Sh3					
H17	TEL					

Table 6.6
Scud D

Scud D		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Kuwolsan sketch					
H2	Length					
M1	Available in NK					
M2	Syrian Scud D					
M3	Range					
M4	Separable warh.					
M5	Scud B engine					
L1	Mod. Scud engine					

Table 6.7
Taepodong I

Taepodong I		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Three stages					
H2	1st stage: ND					
H3	2nd stage: 0.88m					
M1	3rd stage failure					
M2	Separation					
M3	Traj. available					
M4	2 thrust phases					
M5	2nd,3rd RusDesig					
M6	Launch Accel.					
L1	R-55 design paral.					
L2	2 Scud, 3 SS-21					

Table 6.8
Taepodong II/Unha-2

Taepodong II/Unha-2		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	No TP2 imagery					
H2	Three stages					
H3	Uh2 = Uh3					
H4	Different design					
H5	TP2 = Uh2 ?					
H6	2nd not R-27					
M1	Likely 4 ND eng.					

Table 6.9
KN-02

KN-02		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Analogue SS-21					
H2	Data					
H3	Tochka-U Range					
H4	Solid, G&C, …					
H5	SS-21 vs. Luna					
H6	Warheads					
H7	TEL					

Musudan

See Table 6.10. There are several inconsistencies between high-confidence data and the "Reverse Engineering" hypothesis: If North Korea independently develops missiles, it would hardly opt to develop a land-based version of an existing submarine-based missile (H8); the selected air-frame design approach is too fragile for a land-based mobile use (H10); the propellants are too temperature-sensitive and have never been used for any previous North Korean missile (H11); the whole design approach is very different than the Scud technology that North Korea is supposedly familiar with (H12); and the production methods required for this missile are even more complicated than those required for Scud technology (H13), which also makes this point somewhat inconsistent if indigenous licensed production is assumed, since the new production line should have been verified by testing. The observed oversized TEL (H17) indicates that North Korea just used what it could get instead of developing a new and indigenous TEL, which it should have been capable of according to the "Reverse Engineering" hypothesis.

Table 6.10
Musudan

Musudan		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Presentation					
H2	Mock-ups					
H3	Resemblance R27					
H4	Differences R27					
H5	Makeev					
H6	Isaev					
H7	R27 parts in Iran					
H8	SLBM design					
H9	Fueled					
H10	Fragile					
H11	Fuel is sensitive					
H12	Different design					
H13	State of the art					
H14	Range					
H15	Predictions					
H16	TEL					
H17	TEL Size					
M1	R-27M					
M2	Based on ND					
L1	Land and sea					

KN-08

See Table 6.11. As with the Musudan, the observed oversized TEL (H4) indicates that North Korea bought a vehicle instead of developing a new and indigenous TEL, which it should have been capable of according to the "Reverse Engineering" hypothesis. The KN-08's design either might be subject to existing components and elements that North Korea had to make use of or is not representing a real missile.

Table 6.11
KN-08

KN-08		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Presentation					
H2	Mock-ups					
H3	TEL					
H4	TEL Size					
H5	Design					
M1	Range					

Program

Tests and Training

See Table 6.12. Assuming that the missiles were reverse engineered or produced by license, the missiles were not sufficiently tested to guarantee operational capability (H1). It is not possible to develop missiles of the observed reliability without foreign help with only the observed small number of tests (H5), which is a magnitude lower than the test numbers of other known programs, and it is also hardly possible to set up a new licensed production line without sufficient flight test verifications. Without significant help, the observed test numbers are too low for Scud B (M1), Scud C (M2), Nodong (M3), Scud D (M4), and Musudan (M8) development. The KN-08 is claimed as being in development, so tests should be expected long before it is operational. That no telemetry was observed in the 1993 tests (M11) is a discrepancy with the requirements for development and verification tests of new products, but no telemetry is required if an existing missile system was purchased.

Personnel

See Table 6.13. If North Korea successfully produces missiles, it makes no sense that the North Korean experts' knowledge and skills observed in Iran were "very unimpressive" (M2). Russia admitted that Russian experts had supported the North Korean program before 1998 (M3)—a clear discrepancy to the claimed lack of foreign help. The North Korean programs and efforts also seem much too small compared with other similar programs (M4 and M5).

Infrastructure and Facilities

See Table 6.14. The test facility at Musudan-ri looks very improvised (H1), which is strange for a country that, according to the "Reverse Engineering" hypothesis, had put so much emphasis into its own missile programs. The reports about many facilities involved in some sort of missile programs (M3) are a discrepancy with the "Buy" hypothesis, which assumes no indigenous activities at all.

Table 6.12
Tests and Training

Tests and Training		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Tests for operat.					
H2	Not for strat.					
H3	Imagery available					
H4	Numbers vary					
H5	Others' tests					
M1	Scud B tests					
M2	Scud C tests					
M3	Nodong tests					
M4	Scud D tests					
M5	TP1 tests					
M6	TP2 tests					
M7	KN-02 tests					
M8	Musudan tests					
M9	KN-08 tests					
M10	ND limited range					
M11	No telemetry 1993					
L1	Train. w/o launch					

Table 6.13
Personnel

Personnel		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Skilled personnel					
M1	Makeev in NK					
M2	NK in Iran bad					
M3	RUS till 1998					
M4	Manhattan project					
M5	Soviet nuc project					
M6	NK nuc project					
M7	U.S. ICBM efforts					

Table 6.14
Infrastructure and Facilities

Infrastructure and Facilities		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	E site improvised					
H2	W site huge					
M1	ND launch					
M2	1 launch from W					
M3	Facilities involved					
M4	Underground fac.					
M5	Scud in factory					

Development and Production

See Table 6.15. No successful reverse engineering effort is known in any field of machinery (H1)—a clear discrepancy with the successes that are attributed to North Korea. That the quality of North Korean missile parts observed in Zurich was poor (H2) also speaks against successful reverse engineering and is inconsistent with licensed production, but also with the hypothesis that all missiles and parts are bought from abroad. The same is true for the parts reportedly observed in Iran (M1). The claim itself that North Korea reverse engineered the Scud B (M2) does not comply with any hypothesis except for the "Reverse Engineering" hypothesis. All reported timeframes for production setup or development (M3 to M8) may be the case in one way or another, but buying existing missiles never takes that long.

Table 6.15
Development and Production

Development and Production		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	No RE known					
H2	Zurich parts poor					
M1	Parts in Iran poor					
M2	Scud B RE in 3y					
M3	Scud C in 3-7 y					
M4	ND in 5-10 y					
M5	TP1 in 8 y					
M6	TP2 in 16 y					
M7	KN-02 in 7-9 y					
M8	Musudan in 3-5 y					
L1	Scud B to C/D					

Numbers and Deployments

See Table 6.16. That 300 Scud B were produced in North Korea (M4) is a clear discrepancy with the "Buy" hypothesis.

Exports

See Table 6.17. If North Korea only bought existing missiles, it could not have given technical assistance for missile production to other countries (M3 to M5).

Imports

See Table 6.18. If North Korea only bought existing missiles, it would hardly have tried to import materials and parts for missile production (M5).

Table 6.16
Numbers and Deployments

Numbers and Deployments		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	R-17 in Germany					
M1	500+ Scuds in NK					
M2	B, C, N warheads					
M3	600 Scuds in NK					
M4	300 S/B produced					
M5	200 S/C, 50 TEL					
M6	100s ND in serv.					
M7	5-10 TP2 deploy.					
M8	50 Mus., 50 TEL					
M9	KN-02 IOC					
L1	Scud C in Afghan.					
L2	20-30 TP1 avail.					

Table 6.17
Exports

Exports		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Kuwolsan 1999					
H2	Sosan 2002					
M1	Scud B Iran					
M2	Scud B UAE					
M3	S/B help to …					
M4	S/C help to …					
M5	ND help to …					
M6	Musudan to Iran					
M7	80% around 1990					
L1	S/B to …					
L2	ND to …					

Table 6.18
Imports

Imports		Consistency Check				
		RE	Bluff	License	Mixed	Buy
M1	Luna from SU					
M2	S/B Egypt					
M3	SAMs SU/RUS					
M4	SAMs China					
M5	Materials, parts					
L1	S/B SU 1980s					
L2	S/C SU 1991					

Country

General Aspects

See Table 6.19. Considering that North Korea is subject to the same limits as any other institution in the world (H2), it seems very exceptional that it succeeded so easily in all its missile programs while other countries suffered many hardships in implementing comparable programs.

Classification of the Missile Program

See Table 6.20. No indications against any hypothesis.

Financial, Economic, and Industrial Situation

See Table 6.21. A starving population (H2) seems hardly capable of fulfilling the feats that are claimed for the "Reverse Engineering" hypothesis. The low North Korean GDP indicates that the claimed programs are not sustainable (M1)—this is the same as claiming that the city of Caracas alone, which has the same GDP, is capable of having nine different missile programs and two different nuclear programs running.

Other Industrial Programs

See Table 6.22. It makes no sense that North Korea is not able to produce cars (H1) and has not produced a single surface-to-air missile until 2010 (H5), but should be capable of easily reverse engineering any given surface-to-surface missile system.

Links to Other Countries

See Table 6.23. No indications against any hypothesis.

Table 6.19
General Aspects

General Aspects		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Way of thinking					
H2	Given limits					

Table 6.20
Classification of the Missile Program

Classification of the Missile Program		Consistency Check				
		RE	Bluff	License	Mixed	Buy
M1	High priority					
M2	SRMs strategic					

Table 6.21
Financial, Economic, and Industrial Situation

Financial, Economic, Industrial Situation		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Power situation					
H2	Food situation					
M1	GDP situation					

Table 6.22
Other Industrial Programs

Non-Missile Programs		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	No indigenous car					
H2	Fiat signs on car					
H3	No aircraft					
H4	Tank presented					
H5	No SAMs					
M1	Poor car quality					
M2	Grounded A/C					
M3	Low tank produc.					
M4	Fake $ unclear					

Table 6.23
Links to Other Countries

Links to Other Countries		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	Russia and China					
H2	Russian border					
H3	Putin visit					
H4	China border					
H5	Smuggling					

Other Aspects

See Table 6.24. The lack of any official Russian protests (H1) is inconsistent with the repeated North Korean product piracy. It also seems strange that the North Korean reverse engineering talents are only limited to guided ballistic missiles (H2).

Table 6.24
Other Aspects

Other Aspects		Consistency Check				
		RE	Bluff	License	Mixed	Buy
H1	No RUS protests					
H2	No other REs					
M1	RUS protests					
M2	RUS Scud line					

Results

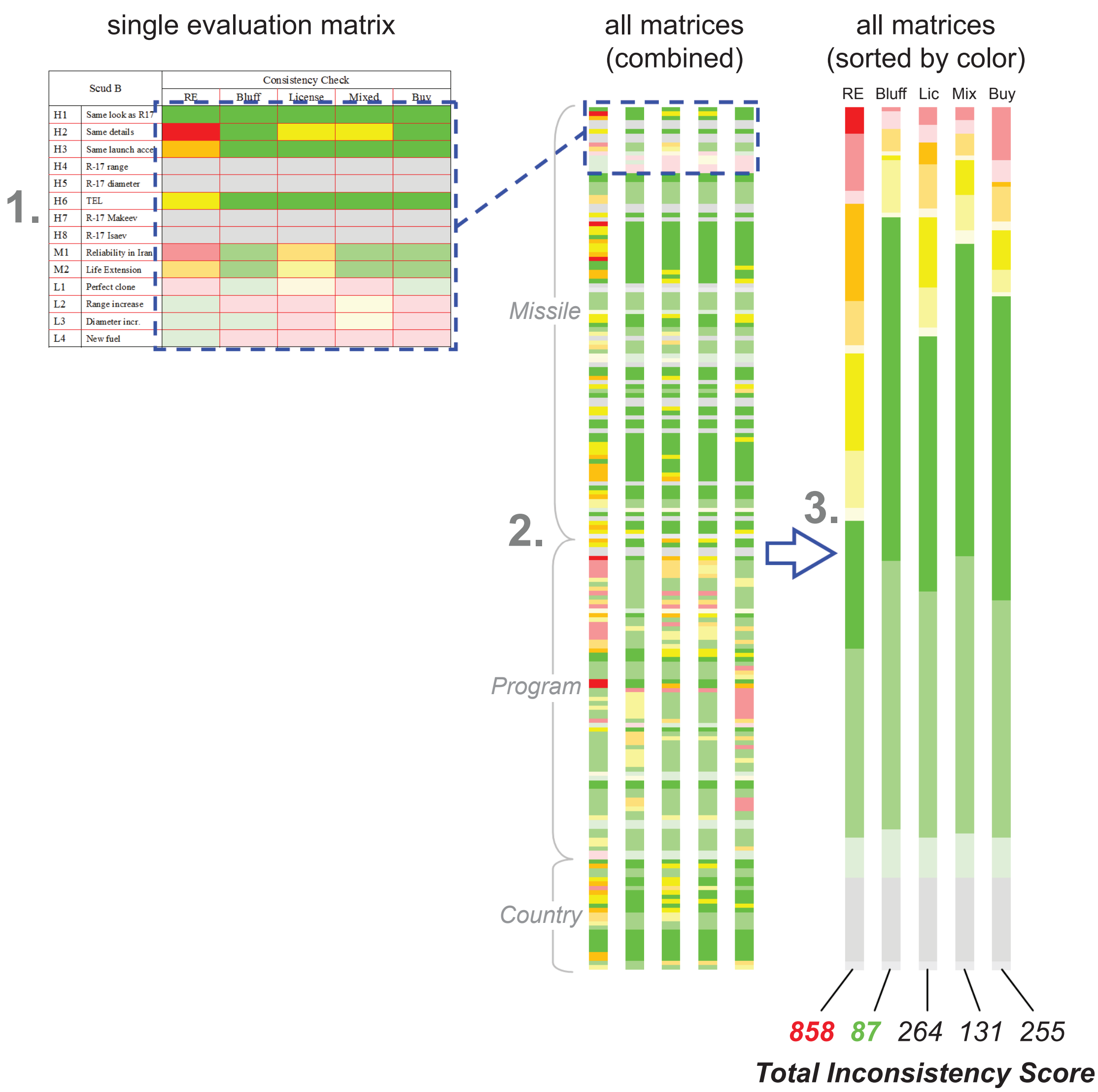
The procedure of evaluation and the results are presented in Figure 6.1. The overall inconsistency scores for each hypothesis are summarized in Table 6.25.

According to analysis, the "Reverse Engineering" hypothesis is the least plausible of the five defined hypotheses. For six data points of high credibility, a clear discrepancy with the hypothesis was discovered, resulting in a penalty of 300 points for these data points alone. But even ignoring these six data points, the remaining score of 558 points is still significantly higher than any of the other four hypotheses' scores.

The lowest inconsistency score is achieved by the "Bluff" hypothesis.

The "Mixed Sources" hypothesis achieved an acceptable score, while both the "Licensed Production" and the "Buy" hypothesis show more inconsistencies.

Figure 6.1
Evaluation Results



RAND *TR1268-6.1*

Table 6.25
Inconsistency Scores

Data Category		Consistency Check				
		Reverse Engineering	Bluff	Licensed Production	Mixed Sources	Buy
Missile	Scud B	85	15	34	22	20
	Scud C	10	0	0	0	0
	Nodong	165	0	5	0	5
	Scud D	1	0	5	0	5
	Taepodong I	22	0	13	0	10
	Taepodong II/Unha-2	15	0	5	0	10
	KN-02	10	0	5	0	0
	Musudan	84	2	22	2	7
	KN-08	20	5	0	0	5
Program	Tests and training	138	0	66	50	5
	Personnel	62	2	26	16	10
	Infrastructure/facilities	10	0	10	10	22
	Development/production	114	27	25	10	90
	Numbers/deployments	7	24	2	2	19
	Exports	2	12	2	2	30
	Imports	14	0	0	0	5
Country	General aspects	10	0	5	5	0
	Classification of missiles	0	0	0	0	0
	Financial, economic, and industrial situation	25	0	15	2	0
	Other industrial programs	42	0	19	5	5
	Links to other countries	0	0	0	0	0
	Other aspects	22	0	5	5	7
Total Inconsistency Score		858	87	264	131	255

As previously mentioned, the results should be continuously refined: Some data point evaluations might have been subject to unintended bias on the author's side, and additional data points that were not included in the analysis might have an effect on the results. Also, additional consistencies are supportive for the various hypotheses, but falsification by additional inconsistencies is certainly better suited to further refine the findings.

CHAPTER SEVEN

Discussion

The findings of the matrix analysis require some comments. In this chapter, I discuss a few general considerations, followed by the threat situation that results from the findings, and then the implications for defense-related issues and policies toward North Korea.

General Considerations

Reverse Engineering

Based on the analysis presented here, the "Reverse Engineering" hypothesis should be questioned as the most plausible explanation for the North Korean missile program—too many data points hint toward Soviet Scuds in North Korea and substantial Russian support in the 1990s. If the Scud B was not reverse engineered in North Korea, the first link in a chain of evidence for this hypothesis would be broken: The Scud C and Nodong could not have been developed without the experience gained by successfully reverse engineering the Scud B, especially if the Nodong engine and the complete Scud C missile really are Soviet designs. And since there was no experience gained by developing Scud C and Nodong, it seems unlikely that Taepodong I and Taepodong II could have been developed and produced without external help. The same argument then has to be applied to the Musudan, KN-02, and KN-08 missiles: Without prior experience, the existence of a North Korean missile industry that is capable of quick and independent indigenous developments seems unlikely.

Russian Support

Signs for strong Russian support are visible all over the program. For most of the North Korean missiles, Soviet counterparts have been identified. Cyrillic lettering was found on North Korean missile parts, on North Korean Scuds, and on a Shahab 3 in Iran that most likely was a North Korean Nodong previously transferred to Iran. There are insider statements as well as strong indications that the Nodong engine is an old Soviet design, as is the Scud C. Russian missile experts were present in North Korea in the 1990s, and there are reports of Soviet/Russian missile transfers to North Korea.

Most of the revelations are related to the Soviet/Russian Makeev design bureau in Miass, formerly known as SKB-385. Makeev experts were in North Korea in the 1990s, the Scud B was a Makeev development, Makeev also developed the longer-range version that seems to be the Scud C, the Nodong engine was developed by Isaev for Makeev, the SS-N-6 is a Makeev missile, and Makeev also developed an elongated version of the SS-N-6 that is compatible with the attributed Musudan configuration. Makeev also conducted research on Scud B service life extension in 2005.

Program Intent

An important reason for the low inconsistency score of the "Bluff" hypothesis is its assumption that the North Korean missile program is intended for strategic leverage and political reasons, and not as a reliable operational tool for wartime use.

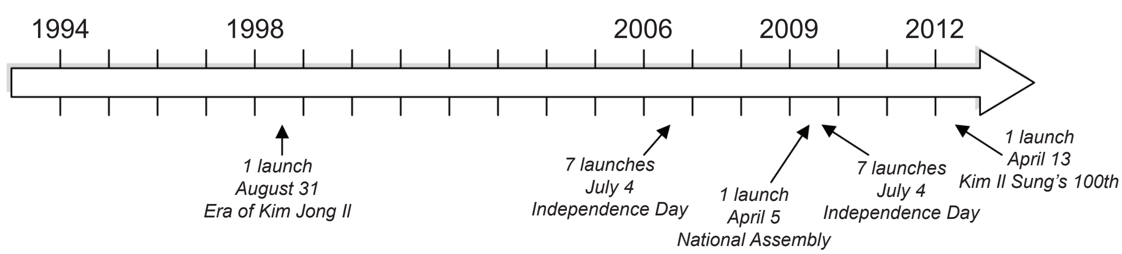
The pattern of testing strongly suggests a political intent. According to the previously identified numbers,[1] and ignoring the short-range KN-02 launches, North Korea launched a total of only 26 missiles in the 28 years since the first Scuds were launched in 1984. Out of these 26 launches, 14 took place on only two occasions, namely at launch campaigns in 2006 and 2009, both on July 4 (U.S. time), the U.S. Independence Day—clearly a political signal. Besides these, there were only three other launch events since 1993: the Taepodong I launch of 1998, which is seen as having been significant for North Korean domestic politics[2]—it heralded the era of Kim Jong Il; the Unha-2 launch of 2009, during the national assembly shortly before Kim Il Sung's birthday; and the Unha-3 launch at the celebrations of Kim Il Sung's 100th birthday in 2012 (see Figure 7.1). With that, all North Korean missile launches since 1993 (excluding the short-range KN-02) took place on politically significant dates and were therefore not primarily dictated by technical development requirements.

This is further underlined by the nature of the few observed tests. As pointed out in Chapter Five, no telemetry was observed in the 1993 tests, making them unlikely candidates for development tests. And since all North Korean missile tests are reportedly aimed at the ocean, it is hard or impossible for the North Koreans to recover the missile bodies, or to clearly identify the impact point and the missile's accuracy.

It seems that the regime never was very serious about learning how well its missiles performed. It rather used its few launches for diplomatic signaling.

Since launches until 1993 were rare, but seemingly not linked to political events, it might well be that the program at first was actually intended as a serious effort toward reverse engineering. At that time, Iraq was still trying hard to reverse engineer Soviet missiles, and reverse engineering was generally seen as possible. But continuous lack of success in North Korea—as in Iraq—might have soon led to changing the program's intent toward creating the *impression* of success. It should be pointed out that this does not rule out continued static engine tests

Figure 7.1
North Korean Launch Rocket Launches Since 1993 (except KN-02)



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[1] See the section on "Tests and Training" in Chapter Five and the appendix.

[2] Pinkston, 2008, p. 26.

and production activities, not only for the Taepodong rocket prototypes but also to uphold the impression of activities.

Taepodong I and II

There is the problem of the Taepodong I and Taepodong II/Unha-2/Unha-3 missiles that obviously were launched by North Korea, if not fully successful. There are no Soviet counterparts known for these missiles, even though the R-55 concept hints at a similar configuration, and the Unha-2/-3 shows some eye-catching parallels to the Soviet UR-200 design, if only from appearance but not technically (different diameters, propellants, etc.).

A look at other countries' programs might be helpful in this case. Iraq assembled and launched a large rocket in 1989. This so-called Al-Abid consisted of a cluster of five Scud missiles for the first stage, a Scud-derived second stage, and a small third stage. The rocket broke apart later in flight, but it successfully lifted off, hinting at the potential of using existing and proven rocket parts to assemble larger rockets of longer range.

Iran's successes with the Safir satellite launcher since 2009 further underline the potential of this building-block approach. The Safir consists of a modified Shahab 3 or Ghadr-1 as a first stage, and an upper stage that apparently uses components of the Soviet R-27/SS-N-6.

Other countries show a similar approach. The ROK Naro-1 satellite launcher is based on a Russian first stage, with an indigenous small upper stage. Though both launches in 2009 and 2010 failed, the rocket lifted off and might still be successful in its third attempt.

These examples should make clear that singular launches of larger rockets are possible with a building-block approach and foreign support. But a single launch (failed or successful) does not automatically imply serial production and operational deployment by the armed forces, and it does not guarantee sufficient reliability and accuracy for a nuclear weapon delivery system. It only proves basic functionality of a prototype design concept.

Missile Transfers

North Korea is frequently named as being the world's largest proliferator of missiles and related technologies. This ignores, though, that more than 80 percent of North Korea's missile exports took place from 1987 to 1993,[3] at a time when the North Korean missile program clearly was supported by the Soviet Union or Russian entities. In a similar way, the number of known interdictions of North Korean shipments of ballistic missile–related parts, materials, or equipment was high between 1996 and 2000 only, with seven seizures in five years; before that, only one ballistic missile–related seizure is known, and between 2001 and 2010, only three.[4] There are four possible explanations: (1) Since the 1990s, North Korean transfers have been better concealed; (2) global interest in ballistic missiles has rapidly declined; (3) an improved Western ability to interdict shipments makes transfers too risky; or (4) North Korea does not have many missiles to offer anymore.

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[3] Pollack, 2011, p. 413.

[4] Pollack, 2011, p. 413.

The North Korean Threat Situation

Even though the "Bluff" hypothesis is the most likely scenario, other scenarios are also included in the discussion of the missile arsenal.

The Available Missile Arsenal

Open source literature agrees that an estimated 500 Scud missiles are currently deployed in North Korea, along with several hundred Nodongs and perhaps several dozen Musudan and KN-02 missiles.[5] Due to lack of information, I will use these numbers as a basis for the discussion that follows. However, I will make some comments on these numbers in light of the previous findings at the end of this section.

According to the open source literature, roughly 1,000 missiles are estimated to be deployed in North Korea. However, according to the empirical evidence that was previously presented, the bulk of this missile force is not sufficiently tested, lacking lot acceptance tests and firing tables, and is operated by crews that have never launched a missile before—only a limited number of launch crews can have launched the few missiles in 2006 and 2009. It seems reasonable that these launch crews are the elite of North Korean rocket troops, with access to the most reliable missiles (most likely of Soviet/Russian production).

Therefore, assuming a fixed number of 1,000 missiles, there are several restrictions to their operational capabilities:

- Only a small number of launch crews can be well trained. Even assuming that the production quality of North Korean–produced missiles is high, or that North Korea's missiles are all of Soviet design and production, the lack of crew training will result in moderate results at best, with handling failures and low accuracy.
- If missiles are produced in North Korea, they are not of excellent reliability and accuracy because of the lack of firing table creation and lot acceptance tests.
- The number of imported and well-tested Soviet missiles is limited and might be only a fraction of the total missile force.

For these reasons, I further distinguish between the bulk of missiles and a limited number of missiles. Table 7.1 gives an idea of what might be expected from the North Korean missile arsenal, and which of the hypotheses are compliant with these cases (named case 1, 2, 3, and 4). If North Korea has access to large numbers of Soviet missiles, their performance could be good or moderate (depending on various issues, including training standards and shelf-life issues). For the "Reverse Engineering" scenario, the missiles would all be of the same quality, depicted as good by most open source assessments but more likely moderate due to rare testing, but the training issues remain the same. For the other scenarios, the bulk of missiles, which are indigenously produced, are most likely of poor quality.

These four cases can be used for further thoughts on how the missiles would probably be used in conflict, as is illustrated in Table 7.2. These considerations are only for conventional armed missiles—it is assumed that any WMD-armed missiles would not be used early in con-

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5 See the section titled "Numbers and Deployments" in the appendix.

Table 7.1
North Korean Missile Arsenal Cases

Missile Case	Reliability/Accuracy: For the Bulk of 1,000 Missiles	Reliability/Accuracy: For a Limited Number	Hypotheses Supported
1	Moderate	Moderate	Reverse Engineering, Buy, Licensed Production
2	Good	Excellent	Reverse Engineering, Buy, Licensed Production
3	Poor	Excellent	Bluff, Licensed Production, Mixed Sources
4	Poor	Moderate	Bluff, Licensed Production, Mixed Sources

Table 7.2
North Korean Missile Target Categories in Case of Conflict

Missile Case	Political	Military	City
1	–	Barrage	Good
2	Focus	Focus	Less important
3	Early demonstration	Early demonstration	Good
4	–	–	Good

flict for various reasons.[6] In most cases, the conventional-armed missiles are likely to be used as weapons of terror against cities, as was done by Germany in World War II, during the Iran-Iraq War, and by Iraq against Israel during Desert Storm. If a large number of good missiles was available, North Korea would likely focus on political and military targets. With only a limited number of good missiles, demonstrations of their capabilities would be expected early in conflict, for example, targeting of the National Assembly building in Seoul.

A look at the likely target categories in times of peace, as in Table 7.3, is more revealing. If missiles of the same quality are available in large numbers, frequent demonstrations of capabilities should be expected. Land targets would be preferred in case of high-quality missiles, to demonstrate accuracy. If the number of good missiles is limited, though, one would expect a low frequency of launches. In case of a few excellent missiles and launch crews, target demonstrations would be sensible; but if even the few good missiles are not very accurate, it would be wise to fire them into the sea to hide this fact. This last case is what has actually been observed in North Korea's test launches.

[6] First use of WMDs would invite a very strong response from not only the United States but probably the whole international community, and therefore is generally seen as very unlikely at the early stages of a conflict with North Korea. This might change if the regime sees the use of WMDs as its last resort at the final stages of a war. In the author's opinion, there are too many unknown parameters to seriously discuss potential target categories for that case, and an adequate discussion would go far beyond the scope of this chapter.

Table 7.3
North Korean Missile Target Categories in Times of Peace (tests, provocations, etc.)

Missile Case	Land Target	Sea Target	Frequency
1	–	Preferred	High
2	Preferred	Occasional	High
3	Preferred	–	Low
4	–	Preferred	Low

Compliant with the most likely hypothesis, the “Bluff” hypothesis, it seems therefore likely that the number of both reliable North Korean missiles and trained launch crews is limited.

However, it has to be noted that I have come to these conclusions on the assumption of North Korea having approximately 1,000 missiles. Considering other “known truths” about the North Korean program, this figure should be taken with a grain of salt, which is underlined by simple calculations: According to the sources cited in the appendix, 600 Scuds (B, C, and D) were deployed in North Korea in 2006. The same sources state that 100 to 150 Scud Bs remain in North Korea, and that around 200 Scud Cs are deployed. Consequently, there should be 250 to 300 Scud Ds (!) in North Korea (600 minus 100 minus 200)—this is nowhere claimed, though, and seems very unlikely. It can be therefore stated that the reported numbers of missiles are inconsistent.

Some speculation that is in compliance with the “Bluff” hypothesis offers an alternative scenario. In this “Bluff” scenario, the North Korean regime is interested in pretending that a large number of missiles are deployed. Usually, only a small fraction of the missile force is deployed with the TELs.[7] The high numbers might be a product of observed TELs with missiles (or even mock-ups or training devices) multiplied by an unknown factor to arrive at the expected numbers. In any case, since, according to the “Bluff” hypothesis, North Korea is not able to produce operational missiles itself, the numbers are limited to the missiles that were transferred from Russia. During the late 1980s and early 1990s, Scud B missiles were available in large numbers in Russia,[8] so a transfer of several hundred missiles to North Korea cannot be ruled out. Even taking North Korean exports into account, it is possible that a few hundred Soviet Scud Bs still are in North Korea. Having been built before 1990, however, these missiles are now at the end of their guaranteed service life. The number of Scud Cs in North Korea is hard to estimate, since nothing is known of the available numbers in Russia, but it seems reasonable that the number is lower than for the Scud B. Accuracy is a severe problem for the Scud C. Being an unknown modification, the Scud D probably is available in even lower numbers, perhaps only a few dozen, if at all, with accuracy probably comparable to the Iraqi Al-Hussein, meaning very poor. The Nodong most likely was a prototype and is therefore limited to the early production lots of a few dozen missiles. Subtracting the exported Ghauri and

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7 At East German Scud batteries, only one missile per TEL was stored at the brigade. Two more missiles per TEL were stored at the mobile rocket support brigade, and two more at a central rocket support base. See NVA Forum, 2011.

8 As previously mentioned, the Soviets moved, for example, 1,660 Scud type missiles to Afghanistan from 1989 to 1991, after the formal withdrawal of Soviet ground forces (Pollack, 2011, p. 413).

Shahab 3, there will be only a small handful available in North Korea. Even though seemingly reliable, these missiles' accuracy is most likely worse than that of the Scud B. The Musudan is probably also a prototype missile, and only a few will be available (if at all), also with poor accuracy and untrained launch crews. The situation of the KN-02 is very hard to estimate, but fewer than 100 should be expected. If the KN-02 is indeed the SS-21, accuracy and reliability are high.

Nuclear Warheads?

For warheads armed with biological, chemical, and nuclear weapons, verification of their functionality is a must. During flight, warheads suffer extreme mechanical loads, vibrations, accelerations, wide temperature ranges, and pressure differences from near vacuum to extreme dynamic pressures at reentry. Chemical and biological agents are highly sensitive to temperatures, as are nuclear weapons.[9] A nuclear weapon is a complex mechanical device, and the ejection mechanisms of biological and chemical weapons are complex, as well. The same is true for the respective detonators and fuzes. The functionalities of these devices can only be proven under real conditions, thus requiring flight tests. No test flights with nuclear, biological, or chemical warheads in North Korea are known. The functionality and reliability of these weapons is therefore unknown, even to the North Koreans. If these warheads exist, either they have been imported from Russia or China, which seems highly unlikely,[10] or they are unlikely to perform well once launched.

It should also be considered that even speculative sources estimate that North Korea cannot have more than a few nuclear weapons available. If they exist, these devices are very precious to the regime, and it seems unlikely that they would be mounted on inaccurate and unreliable missile systems—the risk of "loosing" a weapon is simply too high. Of course, a singular shot can never be totally ruled out, but the chances of success are very low. And even if this unlikely event was to happen, with North Korea unable to repeat this feat on short notice, this scenario should be seen more like a terrorist attack than nuclear warfare.

Implications

The "Bluff" hypothesis achieved the lowest inconsistency score and is therefore seen as the most plausible hypothesis. If the "Bluff" hypothesis is correct, this would have several implications.

Under the "Bluff" scenario, the North Korean missile arsenal is limited. The Taepodong missiles are single prototypes that were launched for effect. Scud, Nodong, Musudan, and KN-02 numbers are limited to the available Russian supplies. Once the proliferation lines are cut, no new missile types can be expected in North Korea in the short term because North Korean engineers would have to start development from zero, for the first time. Being proven Soviet/Russian systems, only the KN-02, the Scud B, and the Scud C can clearly be considered operational weapon systems suited for combat use. The operational status of the other systems

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[9] In case of war, the East German Scud Bs were to be equipped with Soviet nuclear warheads. Up to minutes before launch, these warheads were wrapped in special isolating blankets to ensure constant temperatures.

[10] Transfer of functional WMDs is something different than transfer of conventional delivery systems. While missile transfers have happened frequently in the past, transfer of nuclear warheads or biological agents to other countries is unheard of.

is unknown, though it is likely that the programs were stopped in the Soviet Union early into development, that their reliability and accuracy are low, and that other drawbacks might be expected (similar to the Nodong's restriction to vertical fueling). North Korea is therefore likely limited to existing Soviet/Russian missiles and prototypes, without the means to indigenously develop and produce operational missiles.

Arming these missiles with nuclear warheads seems basically possible, but unlikely due to a very low chance of successful use.

Defense Issues

The following section describes the North Korean missile situation for each rocket. The depicted situation is speculative. It is based on the best estimate of the author according to the previous findings.

- The Scud B is probably available in large numbers (perhaps hundreds), since the R-17 had a very high production rate and was produced for three decades, if not longer, and many decommissioned or mothballed R-17s existed in post-Soviet Russia. The system is combat proven. Its nominal range is 300 km with a 1 ton warhead. Its real accuracy is probably around 1 km (CEP).[11] Launch procedures are complex, and only few well-trained crews are expected.
- The Scud C is probably available in smaller numbers (perhaps 100). The system is likely combat proven.[12] Its range is about 500 km with a 0.7 ton warhead. Its accuracy is worse than that of the Scud B. Launch procedures are analogous to those for the Scud B, and only few well-trained crews are expected.
- The Scud D is probably available in small numbers (perhaps a few dozen). Its range is about 700 km with a 0.5 ton warhead. Its accuracy is worse than that of Scud C. Launch procedures are analogous to those for the Scud B, and only few well-trained crews are expected.
- The Nodong is limited to a small number of a few dozen at best. Its range is about 900 km with a 1 ton warhead. Its accuracy is worse than that of the Scud B. Launch procedures are comparable with those for the Scud B, with additional time-consuming fueling procedures once the missile is in vertical position.
- Other Taepodong I prototypes are unlikely to exist.
- One or two more Taepodong II/Unha-2/-3 might exist. Launch procedures are lengthy and easily visible.
- If available at all, the Musudan is only available in small numbers.
- The situation of the KN-02 is hard to judge. It might be available in sufficient numbers. Its accuracy might be high. Its range with a 0.5 ton warhead is most likely limited to 70 km, but might reach 120 km, if the newer version of SS-21 found its way to North Korea.

Except for a singular launch event comparable to that for the Unha-2, a North Korean ICBM threat seems highly unlikely. The displayed KN-08 was a mock-up design, and it is very unlikely that North Korea can develop and deploy an operational KN-08 type ICBM.

[11] The scoring system for East German training launches hints at that value.

[12] Probably used by the Soviets in Afghanistan.

It seems that accuracy and availability of the missiles correlate with their range—the shorter the range, the higher the expected numbers and accuracies. Therefore, an ROK theater ballistic missile defense system that is capable of defending against Scud B, Scud C, and KN-02 seems sensible, especially since cities are expected to be preferred targets in case of war.

WMD attacks are possible, but not very likely—even if available, these weapons are most probably held in reserve for purposes of deterrence. Attacks with chemical agents are more probable than with biological agents. Nuclear and biological attacks seem unlikely.

The number of trained launch crews and operational TELs is most probably lower than expected. Consideration of how special forces might be used to quickly disable the few experienced launch crews and TELs is recommended. Lessons learned from the hunt for Iraqi Al-Hussein TELs during Operation Desert Storm should be incorporated.

Policy Issues

North Korean launch campaigns are primarily done for political purposes: to increase domestic support for the regime and to draw U.S. and global attention. The second part can be neutralized by downplaying or even ignoring any future North Korean missile launches.

Concerns about North Korea's missile launches are overblown. Every launch further depletes the limited North Korean arsenals, and North Korea gains no real experience from these events. For the North Korean government, launch moratoriums are therefore more supportive than restrictive.

Concern about North Korea's missile test launches should increase only if the test patterns change. Indications for an increasingly serious development program are telemetry transmission and regular single launches within a few months of each other, with various grades of success. Only if this is observed should the North Korean missile program be discussed again in public—everything else plays into the hands of the North Korean regime.

Increased nonproliferation efforts are recommended, in cooperation with Russia to identify the extent of its past involvement with the North Korean missile program, but also in cooperation with China to prevent any future proliferation of technologies for larger solid-fuel missiles, since there are indications of increased proliferation activities of Chinese rocket technology to other countries that also have ties to China.

CHAPTER EIGHT

What We Would Like to Know

Answers to many key questions might help to further strengthen or weaken the most plausible hypothesis:

1. Are reports of North Korean missile deliveries to Libya true? If true, are these missiles accessible? If they are, what can be learned from them?
   (A close look at North Korean missiles can clarify their true origin.)
2. Are reports of Hwasong 5 deliveries to the United Arab Emirates around 1989 true? If true, are these missiles accessible? If they are, what can be learned from them?
   (Again, a close look at North Korean missiles can clarify their true origin.)
3. Do we actually see anything coming *out* of a North Korean missile production line? If yes, what goes *into* the production line?
   (Investigating this might help to figure out the real level of indigenous production.)
4. What is the true number of missile test flights in North Korea? What is the true number in other countries, especially in those with ties to North Korea?
   (Verifies or disproves the lack of development test flights.)
5. Is information about range and trajectory of these test flights available?
   (Answering this would provide information on successes or failures, allow for better technical reconstruction of the missiles, etc.)
6. What are the true failure rates of these flights?
   (Verifies or disproves the assumed high success rate of North Korean missiles—without failures, an indigenous development is unlikely.)
7. What happened to the Soviet Scud production lines in Zlatoust and Votkinsk?
   (They might have ended up in North Korea.)
8. What happened to the Soviet SS-N-6/R-27 production lines?
   (They, too, might have ended up in North Korea.)
9. Where are the decommissioned and mothballed Soviet R-17s and R-27s?
   (They, too, might have ended up in North Korea.)
10. What happened to the decommissioned Soviet TELs and support vehicles?
    (They, too, might have ended up in North Korea.)
11. Were there trucks for TELs produced by Minsk Automobile Plants (MAZ) in the 1990s? Were they outfitted as TELs by Petropavlovsk Heavy Industries and then exported?

(Since there was no need for them anymore in Russia, they might have ended up in North Korea.)

12. Is there a complete list of missile projects that were in development in the Makeev design bureau, reaching back to the 1950s?
(The Nodong, Scud D, and Musudan might be on that list, and perhaps also the Taepodong I and II.)
13. Is there a complete list of engines that were developed by the Isaev design bureau, reaching back to the 1950s?
(The Nodong engine should be on that list.)
14. What happened to the prototypes and respective production lines of Soviet missile developments that were never accepted for deployment?
(They might have ended up in North Korea.)
15. What else can be learned from the missile components and materials that were found on the freighter *Kuwolsan* in Kandla, India, in 1999 (Indian authorities)? Is more information accessible?
(Was that really a "missile factory," or only a few machines and bad quality parts?)
16. What else can be learned from the missiles that were found on the freighter *Sosan* in the Gulf of Aden in 2002 (Spanish navy)? Is more information accessible?
(Again, a close look at North Korean missiles can clarify their true origin.)
17. What can be learned from the debris of the Scud D that reportedly disintegrated over Turkish territory in 2005?
(A close look at this debris can clarify the missile's true origin.)
18. Are there indications of indigenous rocket engine production? Are frequent static tests observed? If yes, what size do these engines have?
(No engine production without frequent tests. All sizes for all missiles should be observed.)
19. Is there a vacuum or high-altitude engine test stand in North Korea?
(If not, the second and third stages of the Taepodong I and II could not have been tested in North Korea, or they are capable of ground launch.)
20. Is imagery of the 2006 Taepodong II launch available?
(If the design is different from that of the Unha-2, it is very unlikely that North Korea developed two different missiles of the same size.)
21. What was the true trajectory of Taepodong I?
(Data would help to verify the assumed configuration.)
22. What do the North Korean missile system support vehicles look like?
(If all of them look like the Soviet vehicles, Russian support is likely.)
23. Are details available of the Scud B launches that were reportedly done in Afghanistan in the 1990s by inexperienced crews? What were the success rates? How accurate were they?
(With this, the probability of success for untrained launch crews can be determined. This has consequences for North Korea, but also for the Iranian launches of North Korean Scuds in the late 1980s.)

24. Are frequent training exercises of North Korean rocket troops observed that are comparable to the rigid training of Soviet and Warsaw Pact rocket troops?
(If not, the launch crews are not well trained for conflict.)

25. What happened to the Soviet SS-20 TELs that were decommissioned due to the Intermediate-Range Nuclear Forces Treaty?[1]
(They might have ended up in North Korea.)

26. Where did the missiles come from that were launched during the 2006 and 2009 campaigns? Were they moved from garrisons all over North Korea or from a single storage site?
(A single site hints at a limited number of missiles and launch crews.)

27. How many Scuds were moved to Afghanistan by the Soviets from the mid-1980s to 1991? How many before 1989? How many were actually fired?
(Some of them might have ended up in North Korea.)

28. Are any static engine tests observed that might not be linked to the Taepodong II/ Unha development, but actually to a future KN-08 ICBM?
(ICBM development requires huge efforts, and large numbers of static engine tests are only one of many observable signs for an active program.)

[1] The demilitarization procedures for the SS-20 TELs that were required by the INF Treaty (see State Department, 1987) are compatible with the observed North Korean Musudan TEL configuration. It cannot be excluded that the North Korean TELs actually are based on decommissioned Soviet ones.

CHAPTER NINE

Conclusions

This chapter summarizes the findings, their implications, and the resulting recommendations.

Findings

The evidence compiled in this report suggests an alternative hypothesis to the current consensus in open source literature. According to this alternative hypothesis, the North Korean missile program is neither completely indigenous nor very sophisticated. There was significant support from Russian entities in the program's initiation in the 1980s and 1990s. The present amount of foreign support is unknown.

The North Korean missile program largely appears to be a political tool to gain strategic leverage, to fortify the regime's domestic power, and to deter other countries, particularly the ROK and the United States, from military action. Operational readiness seems to be secondary.

Potential delivery of nuclear warheads by North Korean missiles cannot be completely ruled out, but seems highly unlikely.

The North Korean nuclear missile program can be characterized as a "paper tiger."

Answers to the Research Questions

What is the most plausible hypothesis to explain the nature of the North Korean missile program?

- The "Bluff" hypothesis (detailed in Chapter Two), which assumes that the North Korean missile program is intended to create the impression of a threat.

What consequences might these findings have for U.S. (and ROK) policy and strategy toward North Korea?

- The threat is lower than often stated in the open literature, even in worst-case scenarios. As long as no dramatic change in the patterns of North Korea's missile tests is observed, the tests are unimportant and should be ignored. North Korea possesses no real long-range missile threat, but taking steps to defend against a conventional short-range threat seems sensible.

What data would be most valuable for better understanding the nature of the North Korean missile program?

- Verification of the presented flight test numbers, information about the Libyan Scuds, the whereabouts of decommissioned Soviet R-17/Scud B and R-27/SS-N-6 missiles, and the status of their respective production lines. See the list of questions in Chapter Eight.

Implications

The number of missiles available to North Korea is limited. Their reliability and accuracy is most likely not very good. Both the availability and reliability/accuracy of North Korea's missiles decrease with longer range. If proliferation is subdued, no new missile types are to be expected for many years, since North Korea has neither the experience nor the capabilities for indigenous development and production. In a conflict, the missiles would probably be used as a means of terror against cities, but not as tactical military tools.

Launch moratoriums play into North Korean hands, since North Korea gains nothing out of its current launches and instead only depletes its arsenal with each launch.

Future North Korean missile test events are hardly relevant and should be ignored; as long as no dramatic change in the test patterns is observed, the launches are intended solely as acts of provocation.

A singular nuclear missile attack cannot be completely ruled out, but then an analogous nuclear terrorist attack by other means of delivery cannot be ruled out, too.

The analysis approach is applicable to other countries and assessments of other threats. There are strong indications that, similar to North Korea, the missile situation in Iran and Pakistan also is somewhat different than commonly depicted in open source literature.

Recommendations

To verify the findings:

- **Do** look at the Libyan Scuds.
- **Do** find out about Soviet missile prototypes of the 1950s and 1960s.
- **Do** locate the decommissioned Soviet Scud and SS-N-6 systems.
- **Do** identify the status of the old Soviet Scud and SS-N-6 production lines.
- **Do** approach Russian authorities for cooperation.
- **Do** approach North Koreans at key positions and ask defectors the right questions.

The current findings suggest the following defense-related actions:

- **Do** focus on theater ballistic missile defense.
- **Do** expect conventional warhead attacks with poor accuracy (similar to Iraq).
- **Do** expect few precise conventional short range attacks (by KN-02).
- **Do** identify the few well-trained and well-equipped missile batteries.
- **Do** consider plans for quickly neutralizing these threats, for example by special forces.
- **Don't** expect comprehensive and repeated nuclear missile attacks.
- **Don't** expect large numbers of precise long-range missile strikes.

The current findings suggest the following actions for policymakers:

- **Do** accept that the North Korean missile launches are provocations that are largely done for political reasons.
- **Do** be aware that the standard U.S. reaction is one that the North Korean regime usually anticipates and intends.
- **Do** downplay or ignore further North Korean missile activities and tests when they occur.
- **Do** be wary for signs of a changing test pattern, which could mean a change in the North Korean missile program's direction and intent.
- **Do** cooperate with Russian authorities to shed light on the North Korean missile situation and proliferation from Russian entities.
- **Do** include China in non-proliferation efforts to prevent North Korea from moving from Russian entities to Chinese entities for support.
- **Don't** give the North Korean regime credit by being publicly concerned about any further missile tests.
- **Don't** elevate the North Korean threat—this is exactly what the North Korean regime wants.

APPENDIX

Details on What We Know

This appendix offers details on the data presented in Chapter Five. It also contains information on the sources for each data point and backs up facts and reports that might otherwise be seen as claims without further substantiation.

Missile

Scud B

High-Confidence Data Points

H1. A missile with outer appearance and geometrical dimensions identical to those of the Soviet R-17/Scud B is frequently presented in North Korean parades. Image analysis indicates that the missile's length is the same as the conventionally armed R-17 (the original Soviet R-17 was designed with a nuclear warhead that was slightly longer, thus increasing the total missile length).[1] Nominal length of the missile's nuclear version was 11,164 mm, that of the conventional version 10,944 mm.

H2. The aft section is identical to the Soviet Scud B. This was proven with the Spanish Navy's discovery of North Korean Hwasong missiles aboard the North Korean freighter *Sosan* en route to Yemen in 2002.[2] Published imagery[3] shows the aft section that is identical to the Soviet Scud B up to smallest details and the Cyrillic lettering, for example the typical "ш37" and "ш38" at the two covers left and right of the nozzle. Details include the engine plug position within the engine nozzle and the red plastic cover. No details of other missile sections are available. (The engine plug is inserted into the nozzle throat to protect the combustion chamber against dirt and dust. It is a disc made of acrylic glass, fastened by four brackets that are easily visible at the photographs.)

H3. A Scud launched in Iran during the Great Prophet 2 maneuver in 2006 shows the exact nominal launch performance of the Soviet R-17.[4] Since North Korea reportedly shipped Hwasong 5s to Iran, the launched missile might be a North Korean import. The performance identity is depicted in Figure A.1, which is a result of detailed video analysis. The line repre-

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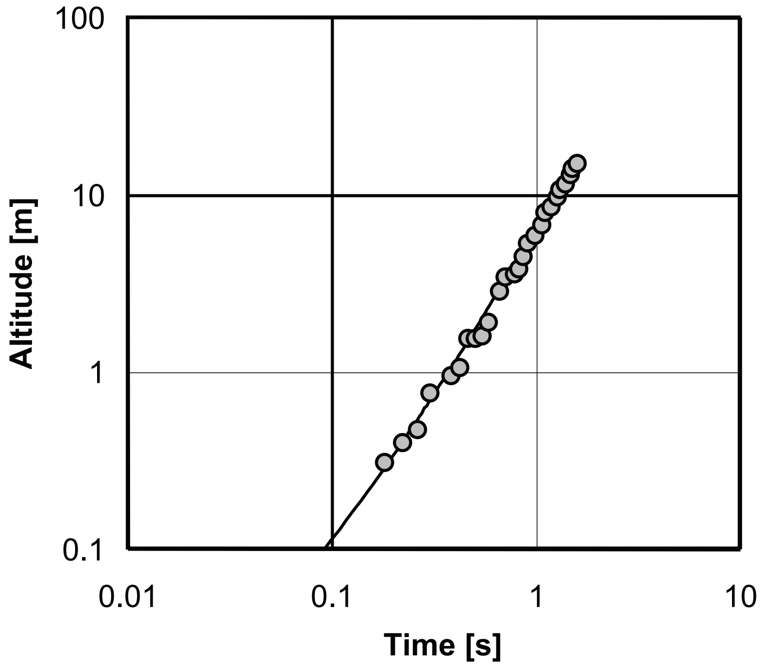
[1] As a source for R-17 data, the original R-17 Handbook is available to the author, both the original Russian version and the German version for the East German Army (see MfNV, 1967, and NVA, 1988).

[2] See for example CNN, 2002.

[3] Available at Wikimedia, 2011.

[4] See for example YouTube, 2006.

Figure A.1
Nominal and Measured Launch Acceleration



RAND *TR1268-A.1*

sents nominal Soviet R-17 acceleration, and the dots are the result of the video analysis of the Iranian launch.

H4. With the standard 1 ton warhead, the maximum range of the Soviet R-17 is 300 km, and the guaranteed range is 270 km. Technical data, handling procedures, support requirements, and service life details are well known.[5]

H5. The Scud B's nominal diameter is 0.88 m. The external diameter of the Soviet R-17 is 0.883 m.[6] Taking measurement errors into account, this can be seen as being the same as the claimed North Korean 0.884 m diameter.

H6. The Hwasong 5 is presented on a TEL that looks like the Soviet 9P117M1, which is based on the MAZ 543 chassis. The only observed difference is the position of the air vent for the ADP-8 auxiliary power unit (APU). The MAZ TEL is also produced under license in China. The four-axle version is used for the Chinese DF-11/M-11 missile, which is compatible with the Scud B in size. The Chinese vehicle features distinct differences from the Soviet/Russian original.

H7. The R-17/Scud B was designed by the Soviet Makeev design bureau SKB-385 in the late 1950s.

H8. The 9D21 engine for the R-17 was designed by the Soviet Isaev design bureau in the late 1950s.

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[5] As mentioned, the original R-17 Handbooks are available to the author.

[6] Information from Dr. Olaf Przybilski, Dresden University of Technology, according to measurements taken on a Soviet R-17 in the *Militärhistorisches Museum der Bundeswehr* (Military History Museum) in Dresden.

Medium-Confidence Data Points

M1. One source claims that 90 to 100 Scud Bs were delivered to Iran, and approximately 77 of these missiles were fired at Iraqi cities over a 52-day period in 1988.[7] A total of eight North Korean Scuds might have exploded at launch, and these failures are not necessarily credited to the missiles but might have resulted from operational failures due to inexperienced crews.[8] This would mean a high missile reliability of 90 percent, and even higher if handling failures are taken into account (which might have led to launch failures even though the missile itself was free of failures).

M2. In 2005, the Makeev design bureau conducted research on the service life extension of the R-17. This research was done on behalf of Rosoboronexport (the Russian Defence Export Agency).[9] Rosoboronexport is the single-source, government intermediary agency for Russian arms exports and related services. According to various sources, Scud production in the Soviet Union stopped in the late 1980s. Standard service life with regular maintenance was up to 22 years, but service life extensions up to 24 years were conducted in 1989.[10] Since the Scud B was phased out of the Russian army and is being replaced by the Iskander missile system, it is not clear why this research was conducted.

Low-Confidence Data Points

L1. The North Korean Scud B is a perfect clone of the Soviet Scud B.[11] According to the author's research and personal interviews, the hypothesis of perfect reverse engineering is mainly supported by political scientists, while engineers appear very skeptical about it.

L2. Some sources claim that, after reverse engineering exact copies of Scud B, some modifications were done to the missile, resulting in a range increase of 10 to 15 percent (to roughly 320 km with the same payload) and, perhaps, increased accuracy. The nomenclature is not consistent between sources. Common designations for the improved version are Scud Mod B or Scud-PIP (Product Improvement Program), while the later designator is also in use for the Scud C. Some sources claim that the 300 km version was the Hwasong 5 prototype (Scud Mod A), while the improved version is the actual Hwasong 5.[12]

L3. At 0.883 m, the original Scud's external diameter is about the same (see also H5). Assuming 0.880 m as the original external diameter might have led to this rumor.

L4. The missile uses unsymmetrical dimethylhydrazine (UDMH) as a fuel instead of the original kerosene. This claim is hardly plausible for several technical reasons, among them the differences in propellant densities and burn characteristics. It is also known that Iraq made a static test run with a Scud engine fueled with UDMH. The results were poor.[13]

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7 Bermudez, 1999, p. 10.

8 Gerardi and Bermudez, 1995.

9 See Military Russia, 2011.

10 NVA, 1988, RWD-MB3, 2011, and Military Russia, 2011.

11 It is widely assumed in open literature that North Korea reverse engineered Soviet Scud Bs. The widely acknowledged identity in performance and technical details is hereby seen as a proof of the North Korean reverse engineering capabilities.

12 See for example the websites GlobalSecurity.org and NTI.org; Bermudez, 1999; or Pinkston, 2008.

13 Personal conversation with former United Nations Special Commission (UNSCOM) inspector Robert H. Schmucker.

Scud C

High-Confidence Data Points

H1. A torus-shaped pressure tank was among the components found on the North Korean freighter *Kuwolsan* in the Indian harbor of Kandla in 1999.[14] The tank is compliant with the commonly assumed configuration of the Scud C. The tank contains pressurized gas that is required for several purposes. In the Scud B, this task is accomplished via pressure bottles mounted in the missile's aft section. A torus-shaped pressure tank was also used for Iraq's later Scud modifications.

H2. A photograph from the Iranian Great Prophet 2 maneuver in late 2006 confirms the commonly assumed Scud C configuration and the range potential for up to 500 km.[15] Obvious modifications include the tank configuration and the airframe structure.

Medium-Confidence Data Points

M1. Apparently, there is an advanced version of the Scud B available in North Korea. This missile, commonly designated the Scud C, is almost identical to the Scud B in its outer appearance but has a range of roughly 500 km.[16]

M2. Most sources agree that the Scud C's increased range is achieved via a lighter airframe, some minor mass reduction modifications, and increased propellant tank volume with a common bulkhead. Engine modifications are rarely mentioned and technically not required.

M3. The Iranian Shahab 2 is commonly seen as being the same missile.

M4. During the mid-1960s, the Soviet Makeev design bureau (SKB-385) worked on a range extension for Scud B.[17] The project for this missile, dubbed R-17M/9M77, was approved in 1963, developed and tested from 1964 to 1968, and produced at Factory 235 in Votkinsk; while the outer appearance remained the same as that of the Scud B, modifications at tanks and airframe allowed for a 500 km range; it seems that the designation of the complete missile system was 9K77 "Рекорд" ("Rekord"), analogous to 9K72 "Эльбрус" ("Elbrus") for the Scud B system.[18] It is likely that R-17M is equivalent to the Soviet missile with the Western designation Scud C (see M5), though the R-17M program was reportedly terminated in the late 1960s in favor of the SS-12/Temp-S.

M5. A longer-range Scud C existed in the Soviet Union and was allegedly deployed since 1965. Scud C is listed in Barton Wright's *World Weapon Database:* Volume 1—*Soviet Missiles* of 1986, with a range of either 450 km or 450 miles. It is further stated that "The existence of a longer range Scud C was confirmed in a U.S. Armed Services Committee reference in hearings of April 1978 to the KY-03 Scud, when it was stated that this version was first deployed in 1965."[19]

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[14] See for example Warrick, 2003.

[15] Photo by Satyar Emami, *Fars News Agency*, 2006.

[16] See, for example, Pinkston (2008) and Bermudaz (1999).

[17] See for example Military Russia, 2011b, or Claremont Institute, 2011.

[18] For more information see Karpenko, 2011.

[19] Wright, 1986, p. 381.

Nodong

High-Confidence Data Points

H1. In spite of reports that Nodong is identical to the basic Ghauri (Gha) in Pakistan and the basic Shahab 3 (Sh3) in Iran, this is not exactly true for the missiles that were presented in October 2010. The missile body with propulsion unit and tanks might be the same, but the guidance compartment and warhead seem to be related to the advanced Iranian version, often called the Shahab 3M or Ghadr-1 (Gh1). Available Shahab 3, Ghauri, and Ghadr-1 imagery and video footage allows for detailed reconstruction of these missiles. This in turn allows conclusions on Nodong.

H2. Before October 2010, the Nodong was never displayed in public. The missiles that were displayed in the October 2010 parade were obvious mock-ups: A thick weld line is clearly visible at their rear cone of the reentry vehicle. This weld would not survive a real reentry. The separation plane also looks not quite right—it seems the "warhead" was welded onto the missile body. Combined with the fact that, in general, no functional operational missiles are displayed on parades (only training devices and mock-ups), it is highly likely that the presented device is a mock-up. Therefore, the actual Nodong configuration still remains unknown to the public—fact-based and reliable statements can be made only about the Sh3/Gha and Gh1.

H3. The geometric outer appearance of the Sh3/Gha is that of a scaled Scud B. Propellant tanks are separated as in the Scud B. Contrary to that configuration, the Scud C features a common bulkhead for the two tanks.

H4. The Sh3/Gha is larger than the Scud by a factor of $\sqrt{2}$. The Sh3/Gha's diameter of 1.25 m is larger than the Scud's diameter of 0.88 m by a factor of $\sqrt{2}$. This also means that the cross-section area is twice that of the Scud.

H5. Dimensions for the Scud are well known from the available Handbooks, and many available photos of Sh3/Gha allow for accurate geometrical reconstruction of the missile's dimensions. The nuclear version of the R-17/Scud B featured a nuclear warhead with a slightly longer cylindrical section, resulting in an increased total missile length. Scaled up by the previously mentioned factor of $\sqrt{2}$, the length of the cylindrical section of the nuclear R-17 is the same as that of the Sh3/Gha (both are 12.55 m), even though the Egyptian Scuds (that were reportedly transferred to North Korea and then reverse engineered) were conventional ones. The Sh3/Gha design therefore is an enlarged version of the nuclear R-17 design that was never available in North Korea.

H6. The Sh3/Gha guidance compartment length is about 1 m. This size is not required for modern guidance systems.

H7. Analogous to the Scud B, the Sh3/Gha aerodynamic design is stable through the whole flight. This is not required with modern guidance systems.

H8. Analogous to the Scud B, the propellants for the Sh3/Gha and Gh1 are inhibited red fuming nitric acid (IRFNA) and kerosene, while Tonka (also known as Samin) is used as igniter fuel.[20] This propellant combination is typical for early Soviet missiles. Other current missiles only use this propellant combination when they are derived from old Soviet technology (for example, the Prithvi in India or the Al-Samoud in Iraq).

H9. Internal propellant lines and external fill and drain lid positions indicate that the Sh3/Gh is fueled in a vertical position, as is also indicated by a transparent Shahab 3 model

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[20] This is obvious due to the tank size ratios, color, and shape of the exhaust flame (light contrail and yellow shining flame—UDMH would have shown a transparent flame), and the engine design that is known from various photographs.

shown in 2006 at an exhibition in Iran. Only the very early mobile missiles had this drawback (e.g., the German A4, Soviet R-1, U.S. Redstone). This was changed in subsequent missile generations, since it significantly increased the system's vulnerability. The Scud B, developed around 1958, was already capable of horizontal fueling.

H10. The engine design is analogous to the Soviet 9D21 Scud B engine: corrugated metal sheets (welded and soldered), gas generator, starter charge, regulator, etc. With 5.5 megapascals, the combustion pressure is at the same level as most Soviet engine designs of the 1950s and 1960s, but different from that of the Scud B engine, which features a chamber pressure of 6.8 megapascals. Engine thrust at sea level is roughly 27 tons.[21]

H11. A launch acceleration of about 1.8 g is observed for the Shahab 3, the Ghauri, and the majority of old Soviet liquid missile systems. This differs from the Scud B's exceptionally high launch acceleration of roughly 2.3 g.

H12. In a textbook[22] compiled by Russian experts for lectures on missile production held in Iran in the mid-1990s, a manufacturing device is depicted that has exactly the dimensions required to produce the Sh3/Gha/Nodong engine.

H13. One of the book's authors claimed that the respective engine that was to be produced with the device is a Soviet design that is more than 30 years old. Later, he stated that the engine is a very old design from the Isaev bureau (developed for the Makeev bureau), and that this is the engine for the Shahab 3.[23]

H14. The Sh3/Gha's thrust level, dimensions, and weight are roughly equal to those of the Soviet R-1, which was a copy of the German A4/V2. The Nodong therefore duplicates the R-1's size and mass with Scud technology, while the R-17/Scud B duplicates the R-1's throw-weight performance with Scud technology.

H15. An open source photograph of a Nodong missile body is available.[24] The photo was made by a Burmese delegation that visited a North Korean "Scud missile factory" in November 2008. It is not clear whether the missile body is a mock-up. The ratio of the distance between fin and cable duct and the missile's diameter and is roughly 0.5, as it is for the Shahab 3 and Ghauri. For the Scud, it is roughly 0.7. There might be some inaccuracies in the photo's measurement due to perspective distortion, but it seems highly likely that the missile body is either a bad mock-up of a Scud, a Nodong mock-up, or a real Nodong.

H16. Video footage of the Shahab 3's first public appearance in Iran in 1998 shows several Cyrillic markings on the missile body. These markings are analogous to that of old Soviet missiles, especially of the R-17/Scud B. The video was made by a Japanese TV team and is available to the author.

H17. The Nodong is presented on a five-axle version of the North Korean Scud B TEL, which looks very similar to the Soviet 9P117M1, which is based on the MAZ 543 chassis. There is a Chinese five-axle TEL that is used for the Chinese DF-21 missile, but this vehicle features distinct differences if compared with the North Korean vehicle.

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[21] Data and characteristics are a result of detailed analysis and reconstruction of this missile at Schmucker Technologie, Munich. See also Schmucker and Schiller, 2009, and Schiller and Schmucker, unpublished.

[22] Vorobei and Loginov, 2001.

[23] Personal conversation with Michael Elleman of the International Institute for Strategic Studies (IISS), who interviewed the textbook's author in June 2010 and May 2011.

[24] See *Burma Today*, 2011.

Scud D

High-Confidence Data Points

H1. A drawing found on the North Korean freighter *Kuwolsan* in the Indian harbor of Kandla in 1999 shows an enlarged Scud that is in compliance with common reconstructions of the Scud D. The drawing was one of many that was found on the freighter. Several missile components and various machinery also were on board.

H2. Available reports of the Syrian Scud D launches in 2000 and 2005, the mentioned drawing, and personal reconstruction of the missile indicate that the Scud D is roughly 12.4 m in length.

Medium-Confidence Data Points

M1. There has been another Scud modification available in North Korea since around 2000. It has a longer range than that of the Scud C.[25]

M2. Not much data are available about the Scud D. It is mentioned that the missile was either developed in North Korea and exported to Syria[26] or developed in Syria with North Korean assistance.[27]

M3. The Scud D has a maximum range of 700 to 800 km. This also is the maximum range for missiles based on single Scud engines and Scud diameter.[28]

M4. The warhead is separable.[29] This feature is technically sensible and required at ranges beyond 500 km for reasons of accuracy and loads at reentry.[30]

M5. The Scud D performance given in open literature, with more than a 700 km range for roughly a 500 kg payload mass, can be replicated with a missile model that uses the standard Scud B engine.

Low-Confidence Data Points

L1. The Scud D engine is claimed to feature throttling capability down to 65 percent of nominal thrust, and it was also used for the second stage of the Taepodong I rocket.[31] These modifications are complex and highly demanding. They are not required for the missile (see M5).

Taepodong I

High-Confidence Data Points

H1. The rocket is a three-stage rocket. Launch video is available.

H2. Available imagery indicates that the first stage is a basic Shahab 3 missile (which is the same missile as Nodong—see the section on the Nodong).

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[25] See various claims in open literature.

[26] See for example *Jane's*, 2010a.

[27] See for example GlobalSecurity.org, 2011a.

[28] See various open source literature or Schmucker and Schiller, 2009

[29] See for example *Jane's*, 2010a

[30] Personal conversation with Robert H. Schmucker.

[31] GlobalSecurity.org, 2011b.

H3. The dimensions of the second stage obviously resemble that of the Scud B or C. It is therefore widely assumed in open source literature that the second stage is based on the Scud B or C.

Medium-Confidence Data Points

M1. It is a common consensus in open source literature that the launch failed due to a third-stage malfunction just before engine cutoff.[32]

M2. Both stage separation events were successful, since failure obviously occurred during third-stage operations. Problems at stage separation are a frequent failure mode for rocket launches. The Taepodong I launch was the first known North Korean multi-stage rocket launch. Flawless staging events at first flight are an impressive feat.

M3. Various trajectory data are available, allowing various reconstructions. Data points vary, depending on source. Within available sources, claims for first-stage impact range from a 180 km to a 375 km distance from the launch site. Claims for second-stage impact range from a 1,100 km to 1,646 km distance from the launch site, with the lower number possibly subject to an erroneous diagram interpretation. First-stage burn time is generally agreed to be 95 seconds.[33]

M4. With the trajectory data mentioned in M3, there are two options for the operation mode of the second stage. Option one is that the stage featured a high thrust burn in compliance with the claimed Scud B engine, followed by a coasting phase. In this case, an independent attitude control system would have been required to stabilize the rocket attitude until third-stage ignition. This is highly complicated and unlikely. Option two is the use of a second-stage engine capable of at least two thrust levels.[34]

M5. Open source literature claims various design options for the second and third stage. All of these options are based on utilization of Russian missile elements. Claims for the second stage include a modified Scud B, a modified Scud C (which itself is based on Scud B), and a modified SA-5 or combination of their elements. Claims for the third stage include a modified SA-2 and a modified SS-21. Completely indigenous developments are generally ruled out. See arbitrary open source literature on the Taepodong I.

M6. The open source video footage of the Taepodong I launch shows a relatively high acceleration that is not consistent with reconstructed rocket mass and engine thrust. Correcting the video with a factor that may be the result of a video conversion between NTSC and PAL standards leads to a typical space launch acceleration of roughly 1.2 g, which is also consistent with the reconstructed missile mass of roughly 23 tons and the reconstructed standard Nodong engine thrust of about 27 tons.[35]

Low-Confidence Data Points

L1. A combination of the R-5 and the R-11 was under consideration in the Soviet Union in the late 1950s or 1960s. A drawing of this rocket, dubbed R-55, shows parallels to

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[32] See for example Nuclear Threat Initiative, 2009.

[33] Schmucker, 1999, Bermudez, 1999, and Postol, 2009.

[34] Personal conversation with Robert H. Schmucker. See also Postol, 2009.

[35] See also Schiller, 2004.

Taepodong I. The design is linked to the Makeev design bureau. The drawing appeared in a Soviet textbook.[36]

L2. The Taepodong I second stage is a Scud missile, and the third stage is a rocket that is smaller than the SS-21 Tochka.[37]

Taepodong II/Unha-2/Unha-3

High-Confidence Data Points

H1. A satellite image from June 22, 2006, shows the rocket on the launch pad but enclosed by the launch gantry.[38] Combined with the low-image resolution, serious conclusions on the rocket's configuration and stage number are not possible. Aside from this, no open source imagery of the Taepodong II missile and its 2006 launch is known to the author.

H2. The Unha-2, launched in 2009, is a three-stage rocket. Launch video is available.

H3. The first two stages of the Unha-2 and the Unha-3 seem to be identical. The third stage of the Unha-3 seems to be slightly longer than the third stage of Unha-2. High-resolution photos of the Unha-3 prior to launch are available.

H4. Contrary to the Scuds, the Nodong, and the Taepodong I, the Unha-2 has only small fins, hinting at an aerodynamically instable design and a different guidance system. Contrary to the Taepodong I, the Unha-2 interstages do not feature the steel truss design, but are fully mantled, with consequences for the stage separation procedure. It seems that retro rockets are used for Unha-2 stage separation.

H5. It is not clear, at least in open source, whether the 2006 rocket and the 2009 rocket were identical, since no 2006 imagery is available.

H6. The size and length of the Unha-2 second stage had seemed consistent with the option of using a modified SS-N-6/R-27 missile for that stage.[39] However, high-resolution photos of the Unha-3 second stage indicate a completely different design. The hull shows several rows of rivet joints at the stage's top, at the bottom, and in the stage's lower third. This indicates separated propellant tanks inside, which is further underlined by the retro rocket that is mounted at a location between the tanks, allowing the structure there to easily accommodate the resulting forces. The propellant tanks' volume ratio of 1.7 (considering tank domes) is typical for IRFNA and kerosene, the well-know propellant combination of the Nodong and the Scud. An SS-N-6-derived stage would require UDMH/NTO (nitrogen tetroxide) propellants with a different tank volume ratio of 1.4. Therefore, it seems more likely that the stage might be equipped with a standard Nodong engine. It might be that the stage is derived from or identical with the Musudan missile, which in that case would be based on Nodong technology (see also M2 at the Musudan section).

Medium-Confidence Data Points

M1. According to several open source analyses, the rocket's exhaust flame and the first-stage diameter are indications for a cluster of four Nodong engines in the first stage.[40] But the

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36 Personal conversation with Robert H. Schmucker.

37 Personal source available to the author.

38 *Digital Globe*, 2011, slide 14.

39 See Postol, 2009.

40 See for example Forden, 2009, and subsequent responses on *Arms Control Wonk*.

first stage might as well use other engines. For a cluster of four standard Nodong engines with about 27 tons of sea level thrust, the observed launch acceleration of about 1.35 g hints at a launch mass of roughly 80 tons.

KN-02

High-Confidence Data Points

H1. A missile with outer appearance and geometrical dimensions similar to that of the Soviet OTR-21/Tochka was presented on North Korean parades in 2007 and 2010. There are at least two versions of the Tochka in Russia. The original Tochka 9M79 looks almost identical to the newer Tochka-U 9M79-1, but the characteristic position of the fins allows for easy identification of the version. The presented North Korean KN-02 looks like the Tochka, not the Tochka-U.

H2. With the standard 482 kg warhead, the maximum range of the Soviet Tochka is 70 km, and the minimum range is 15 km. Technical data, handling procedures, support requirements, and service life details are well known.[41]

H3. The newer Russian Tochka-U has a maximum range of 120 km, with the same warhead mass of 482 kg.[42]

H4. The Tochka is very different from the Scud technology and SS-N-6/R-27 technology. Tochka is a short-range solid-fuel missile with active guidance from launch to impact. The Scud B, Scud C, Scud D, Nodong, and Musudan are higher-range liquid-fuel ballistic missiles with active guidance from launch to main engine cutoff. This means significant differences in airframe design (tanks and structural design), in engine design (liquid versus solid), and in guidance system design.

H5. The Tochka is quite different from FROG/Luna technology: While the Tochka is a sophisticated guided missile, the FROG/Luna is a rugged unguided artillery missile. Experiences gained from FROG/Luna operations (and perhaps from reverse engineering efforts) can hardly be applied to KN-02 development and production.

H6. Available warheads for the Tochka system in the Soviet Union were the 9N123F high-explosive splinter warhead, the 9N123K cassette-type cluster warhead with 50 splinter cassettes, and the special warheads 9N39 and 9N65—"special" means nuclear. No known evidence indicates that chemical or biological warheads were intended for the Soviet Tochka system.

H7. One report claimed that the North Korean TEL is based on a Russian KAMAZ truck, and North Korea has an assembly line for KAMAZ trucks, using components built in Russia.[43] However, the TEL is clearly not based on a KAMAZ truck. The KN-02 missiles were presented on a TEL that also looks very different than the Soviet/Russian 9P129 TEL for the Tochka system. The North Korean TEL is based on a MAZ 630305-040 or MAZ 630308-040 truck from the Belarusian MAZ–Minsk Automobile Plant (МАЗ – Минский автомобильный завод),[44] the same company that builds the MAZ 543 and MAZ 547 trucks

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[41] The original Tochka Handbook is available to the author in the German version for the East German Army.

[42] Common knowledge—see various sources in literature.

[43] Richardson, 2010.

[44] It seems that the chassis is the same for both versions, but engines and gearbox are different. For technical details, see *Ihzmaz.ru*, 2011.

that several Soviet TELs were based on. It is not known whether MAZ has an assembly line in North Korea.

Musudan

High-Confidence Data Points

H1. A missile with outer appearance and geometrical dimensions that fit previous open source descriptions of BM-25/Musudan was presented at a North Korean parade in October 2010. The presented missile is roughly 12 m long with a diameter of 1.5 m. It resembles the Soviet R-27/SS-N-6 missile.

H2. Before October 2010, no Musudan imagery was available. The missiles that were displayed in the October 2010 parade were mock-ups: No separation plane is visible at the Musudan—it seems the "warhead" was welded onto the missile body. The characteristic brackets are also missing. Combined with the fact that, in general, no functional operational missiles are displayed on parades (only training devices and mock-ups), it is quite clear that the presented device is a mock-up. If a Musudan missile really exists, its configuration therefore still remains unknown to the public. No fact-based and reliable statements can be made about the missile—only statements about the configuration of the presented mock-up are possible.

H3. The presented mock-up shares various details with the Soviet SS-N-6/R-27. The diameter seems to be the same as that of the R-27, which is 1.5 m. The general outer appearance looks very similar to that of the R-27. The diameter and the shape of the Musudan front section are analogous to the R-27.

H4. The presented mock-up also shows various differences from the Soviet R-27. The presented mock-up is more than 2 m longer than the original R-27. The cable duct position at the missile's front is different, indicating a bad mock-up design job or a different inner layout with modified tank dome position and a different guidance system design.

H5. The R-27 was designed by the Soviet Makeev design bureau SKB-385 in the 1960s.

H6. The 4D10 engine for the R-27, consisting of the main engine and two vernier engines, was designed by the Soviet Isaev design bureau in the 1960s.

H7. Components that bear strong resemblance to R-27 components were used in the Iranian Safir satellite launcher: The R-27 vernier engines and turbo pump look identical to components that were used in the Safir upper stage. Reconstruction of the Iranian Safir satellite launcher with known trajectory and payload data verifies that the R-27/SS-N-6 vernier engines might have been used for upper-stage propulsion—thrust levels, burn time, and propellants are consistent with the reconstructed parameters and the observed values.

H8. The most important design differences between missiles designed for submarine deployment and those designed for mobile land deployment are in regard to structural integrity, propellant types, and fueling procedures. These aspects are addressed in the subsequent paragraphs. The R-27 is designed for deployment in a submarine, with various consequences that make it unsuited for mobile land deployment.

H9. The R-27 was fueled at land, sealed, and then deployed (it was lowered into the submarine's launch tube in a fueled condition). A land-mobile missile either has to be transported in fueled condition, with high loads for the structure and limited service life, or has to be fueled in the field, requiring design modifications and in-field handling of toxic propellants.

H10. The R-27 airframe is made of thin aluminum sheets to reduce net mass to a minimum. The resulting fragility was not problematic because in its vertical position in the submarine's launch tube, the missile was safe from any cross loads and well protected.

H11. The missile's oxidizer, NTO, has a melting point of 12 °F (–11 °C) and a boiling point of 70 °F (21 °C). This is far from the standard operational spectrum of mobile land-based missiles, which is between –40 °F (–40 °C) and 122 °F (50 °C).[45]

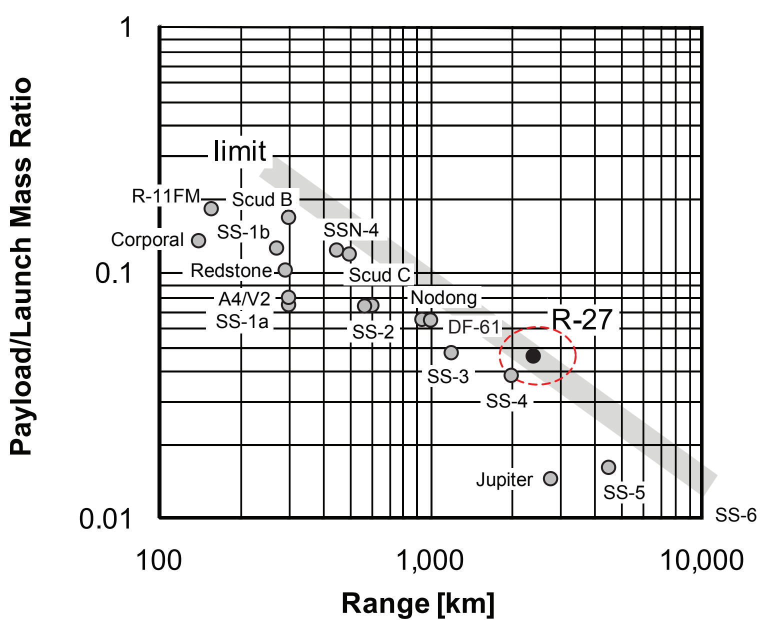
H12. The technical design approach is very different from that of the Scud family. The structure is not a rugged steel design, but a wrung out aluminum design. The engine is a multi-chamber design with two different thrust levels. Propellants are UDMH and NTO instead of kerosene and IRFNA. Steering is done with gimbaled engines and not with jet vanes. There are several other differences.

H13. Even in 2010, the R-27 still is a state-of-the-art missile close to the technical limits. Compared with other Soviet, U.S., and Chinese missiles of the 1950s to 1970s, the R-27's official nominal performance is so good that the official numbers must almost be doubted. The R-27 is very close to the technical limits of missiles with storable liquid propellants, and a leap in technology compared with other missiles of that era (see Figure A.2). The ratio of payload mass and launch mass is a good indicator for rocket performance.

H14. Reconstructions with the presented missile configuration give a range of around 3,000 km for a Musudan based on R-27/SS-N-6 technology, and of around 1,500 km or less assuming that the Musudan uses Scud/Nodong technology and an aluminum structure (Figure A.3). The range is even less for a steel structure.[46]

H15. *Jane's Defence Weekly* stated in August 2004 that North Korea had developed a missile based on the Soviet R-27, with a length of 12 m. North Korea would be able to develop and deploy the missile without a significant test and evaluation program.[47] This is consistent with

Figure A.2
R-27 Nominal Performance



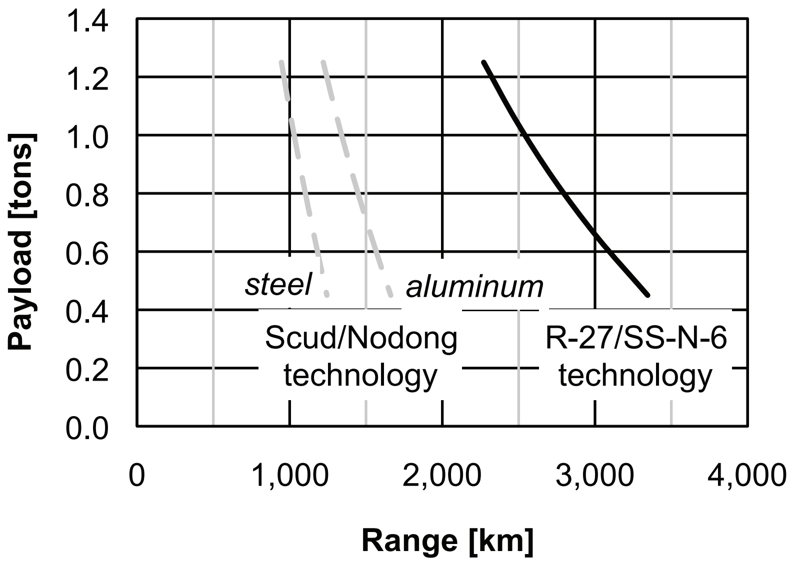
RAND *TR1268-A.2*

45 Nominal operating conditions of the Soviet R-17/Scud B and OTR-21/Tochka, according to the original handbooks.

46 Author's reconstructions.

47 Bermudez, 2004.

Figure A.3
Reconstructed Musudan Range



RAND *TR1268-A.3*

the Musudan configuration that was presented in 2010 and with the attributed development that did not require a single test flight.

H16. The North Korean TEL for the Musudan looks very similar to the Soviet MAZ 547 based TEL for the RSD-10/SS-20 missile.

H17. The TEL is clearly oversized for the missile. Aside from the obvious length issue, there is a weight issue. The Musudan weighs around 20 tons at best. The analogous Soviet six-axle TEL carried the SS-20 with roughly a 37 ton launch mass plus the weight of the launch canister. Even a four-axle TEL would have been sufficient for the presented Musudan configuration.

Medium-Confidence Data Points

M1. In the mid-1960s, the Soviet Makeev bureau designed a R-27 derivative with increased length and launch mass. It was part of the missile complex D-5M. The missile was designated R-27M, GRAU Index 3M30. The original code for the R-27 missile complex was D-5. The addition of the letter M usually refers to an advanced version. According to the source, Makeev "in the mid 60-ies performed design considerations of the missile complex D-5M with increased length and launch mass relative to the missile complex D-5" ("В середине 60-х гг. выполнялись проектные проработки ракет комплекса Д-5М с увеличенной длиной и стартовой массой относительно ракет комплекса Д-5").[48] Another article claims that, in 1971, Makeev competed with a larger version of R-27, the R-27M, against the R-31 (missile complex D-11). Makeev lost and the D-11 was deployed.[49] Nonetheless, development seems to have continued. In 1973, the engine 3D20 for the missile complex D-5M was tested at a

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[48] Horoshih, 2011a. The cited text is referred to as being an excerpt from the book "Конструкторское бюро машиностроения имени академика В. П. Макеева."

[49] Horoshih, 2011b.

Soviet research and development facility.[50] Another source offers detailed data on the missile for complex D-5M (here attributed to the GRAU Index 4K10M), including a length of 11 m and a range of up to 4,000 km with a 700 kg warhead.[51]

M2. In April 2012, high-resolution photos of the Unha-3 revealed that its second stage is probably based on Nodong technology (see also H6 at the Taepodong II/Unha-2/Unha-3 section). It cannot be excluded that a modified Musudan served as the second stage for the Unha launches, and the Musudan is therefore based on Nodong technology, using a Nodong engine.

Low-Confidence Data Points

L1. Two versions were developed in North Korea: A land-based system and a sea-based system.[52]

KN-08

High-Confidence Data Points

H1. In 2011, there were reports that U.S. officials indicated on several occasions that North Korea was working on a road-mobile ICBM. Such a missile was presented to the public on April 15, 2012, at the parade in honor of Kim Il Sung's 100th birthday. The presented missile seems to be a three-stage design. Total length is more than 17 m. First-stage length is perhaps 7.5 m, with a diameter of less than 2 m. Second-stage length is less than 5 m, with the same diameter as the first stage. Third-stage length is more than 2 m, with a diameter of around 1.3 m. Warhead length is around 3 m.

H2. The missiles that were displayed in the April 2012 parade were mock-ups, of better quality than the 2010 Musudan mock-ups, but still poor: No separation planes are visible between the stages or at the warhead. The presented missiles show various differences: different cable duct lengths, different positions of hatches, and small acceleration rockets that are mounted on one mock-up and missing on others. The positions of some of these rockets, used for stage separation or pre-acceleration prior to stage ignition, makes no sense considering structural loads. The warheads show an undulated surface structure, suggesting that either a thin metal sheet was fixed to a simple stringer structure inside or a thicker metal sheet was stepwise bended into conical shape. Both designs are only applicable for simple warhead mock-ups but not for a real warhead. The missile mock-ups also are not bolted to the launch table with their rear ends, as is always done with real missiles. Combined with the fact that, in general, no functional operational missiles are displayed on parades (only training devices and mock-ups), it is quite clear that the presented devices are mock-ups. If a KN-08 missile really exists, its configuration therefore still remains unknown to the public. No fact-based and reliable statements can be made about the missile—only statements about the configuration of the presented mock-up are possible.

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[50] Niichimmash, 2001, p. 288.

[51] Karpenko and Shumkov, 2009, p. 99.

[52] Bermudez, 2004.

H3. The eight-axle TEL is based on the Chinese WS51200 truck, a product of the Hubei Sanjiang Space Wanshan Special Vehicle Co., Ltd., which is part of the China Sanjiang Space group and a subsidiary of the China Aerospace Science and Industry Corporation (CASIC).[53]

H4. The TEL is clearly oversized for the missile. While the missile's length seems appropriate, it is not unusual for larger missiles to extend beyond the vehicle's front. In the displayed design, the KN-08 would weigh between 30 and 40 tons. The maximum total weight for the WS51200 truck is stated as 122 tons.[54]

H5. The design makes not much sense from an engineer's perspective. A liquid-fueled missile of this size would offer better performance with two stages instead of three. It is unknown why North Korean engineers would opt for a three-stage configuration, even if they decided to design an ICBM based on existing components—for example, SS-N-6 engines or Nodong engines. To achieve ICBM range, the rocket would at least have SS-N-6 technology and propellants, which requires NTO as an oxidizer, but NTO is not suited for use in a road-mobile missile (see also H11 at the Musudan section). Three stages are sensible only for a solid-fueled ICBM, but solid rocket technology in North Korea is limited to small artillery rockets and the small KN-02 missile. Thus, there is consensus among experts that North Korea lacks the experience and the capabilities to successfully develop a solid-fueled ICBM.

Medium-Confidence Data Points

M1. With a 0.7 ton warhead, the presented design could achieve intercontinental range of perhaps 9,000 km if based on R-27/SS-N-6 or comparable technology. This number is reduced to 5,000 km for Scud or Nodong technology and an aluminum airframe.[55]

Program

Tests and Training

High-Confidence Data Points

H1. Weapon systems are generally only deployed once their reliability in operations at any conditions is guaranteed, including cold temperatures or humid days, for example. Therefore, the weapon has to be tested under the full range of potential operational conditions.[56] Reliability is probably the most important aspect of a weapon system. This is true for any type of weapon, ranging from handguns and ammunition to tanks and aircraft. Once a weapon system has proven its reliability in actual combat deployment, with satisfying performance in conflict situation, it is seen as combat-proven, which is commonly seen as the ultimate seal of quality for any weapon system.[57]

H2. The reliability requirement can be different for weapon systems with solely strategic or political meaning that are not intended for actual use in conflict. Deterrence policy, for

[53] Pollack, 2012.

[54] Pollack, 2012.

[55] Author's reconstruction.

[56] See for example any arbitrary development program (civil or military) in any country at any time. Only ballistic missile (and nuclear weapon) programs in India, Iran, Israel, North Korea, Pakistan, South Africa and Syria show different patterns.

[57] According to various conversations with defense analysts and military personnel.

example, can be based solely on the *availability* of strategic weapon systems, even if they have low reliability or are not combat-proven.

H3. Open source imagery of test launches is available only of the Taepodong I launch in 1998 and the Unha-2 launch of 2009, making these two launches in fact the only proven North Korean rocket launches in open source literature. Of the Unha-3 launch in 2012, only imagery of the launch preparations is available so far, but not of the launch itself.

H4. Reconstruction of North Korean launch numbers is difficult, since the available reports are controversial. The exact numbers of different sources may vary, but the order of magnitude is the same.[58] Several launch events are commonly agreed upon in open source literature; others are based on hearsay or found in single media reports. It is not known whether the estimated numbers are close to the actual test flights; however, it seems likely that the numbers are close to real numbers.

H5. Launch numbers in the Soviet Union/Russia and the United States were high in the 1950s, 60s, and 70s. They still are in the range of a dozen or more until initial operating capability and missile system deployment, and at least one missile is launched each year for test and training purposes. High test numbers in Soviet Union/Russia and the United States can be seen as a fact. The exact numbers in Table 5.2 may vary from source to source, but the order of magnitude is correct.

Medium-Confidence Data Points

Test numbers vary from source to source. Subsequent numbers are compiled from various sources.[59] Test success or failure is stated according to the claims in the respective reports.[60]

M1. Launch numbers for the North Korean Scud B are shown in Table A.1.

The Hwasong 5/Scud B was launched either three or six times in or before 1984. Since then, there might have been three additional launches in 1993, but with reduced range (these might have been Scud C launches, too). The total estimated number is therefore between

Table A.1
Hwasong 5/Scud B Launch Numbers

Launch Site	Comment	Launches	Year	Range [hundred km]	Success/ Failure
North Korea	Several reports	3	1984	?,?,?	S,S,S
North Korea	Few reports	3	1984	X,X,X	F,F,F
North Korea	Few reports	3[a]	1993	1,<1,<1	S,S,S
Iran	War of the Cities	~80	1988	3	+90% S

[a] Scud B or C (not clear).

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58 See any open source literature about North Korean missile tests.

59 Nuclear Threat Initiative, 2009; various missile articles at GlobalSecurity.org; Shin, 2009; and Pinkston, 2008.

60 Statements about the success of a missile flight test are difficult. Non-catastrophic failures, such as deviation from the intended course or imprecise engine cutoff, are barely visible from the outside. Even tests with obvious failure can be claimed as success, as was done with the 1998 Shahab 3 test in Iran: The missile exploded roughly 100 seconds into flight. Nonetheless, the test is generally seen as a success—it is stated in literature that the missile was intentionally blown up at the end of its powered trajectory.

three and nine launches. Three launches were reported as failures, but it is not commonly accepted that these three launches occurred at all. The most likely number (according to the author's estimate) is a total of three development launches and three life cycle test/training launches after North Korea's claim of operational capability in 1987.[61] The 1988 launches in Iran occurred at wartime conditions and therefore are unlikely to be test launches. No statements are possible about other Scud B launches in Iran, including those in 1999 and 2001 and at maneuvers, since it is unknown whether these Scuds were imported from North Korea.

M2. Launch numbers for the North Korean Scud C are shown in Table A.2.

The Hwasong 6/Scud C was launched twice in 1990 and 1991. Since then, there might have been three additional launches in 1993, but with reduced range (these might have been Scud B launches, too). Scud Cs reportedly were also launched in 2006 and 2009. The total estimated number is between five and seven or more launches. All launches were reported as success. The most likely number (according to the author's estimate) is a total of two development launches and four or more life cycle launches after North Korea's claim of operational capability in 1992.[62] No statements are possible about other Scud C launches in Iran at maneuvers, since it is unknown whether these Scuds were imported from North Korea.

M3. Launch numbers for the North Korean Nodong are shown in Table A.3.

The Nodong was launched once in 1993. Nodongs reportedly were also launched in 2006 and 2009. The total estimated number is about six launches. All launches were reported as success. All launches were done with reduced range. The most likely number (according to the author's estimate) is a total of one development launch and fve life cycle launches in North Korea after North Korea's claim of operational capability in 1994.[63] More test flights were reported in Pakistan and Iran from 1999 on, also including modified versions of the rocket. Reliability of the reports varies significantly, but it seems that roughly half a dozen original Shahab 3 were launched in Iran, and again the same number of modified Shahab 3. In Pakistan, the current number of Ghauri launches is perhaps ten or fewer.

Table A.2
Hwasong 6/Scud C Launch Numbers

Launch Site	Comment	Launches	Year	Range [hundred km]	Success/ Failure
North Korea	Several reports	1	1990	?	S
North Korea	Several reports	1	1991	5	S
North Korea	Few reports	3[a]	1993	1,<1,<1	S,S,S
North Korea	Several reports	3	2006	~5	S,S,S
North Korea	Several reports	2 (7?)[b]	2009	4–5	all S
Syria	One report	2	1991	?	?
Iran	Several reports	1	1991	5	S?

[a] Scud B or C (not clear).

[b] Nodong, Scud C, or Scud D (not clear).

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61 See the section "Development and Production," M2, p. 99.

62 See "Development and Production," M3, p. 99.

63 See "Development and Production," M4, p. 99.

Table A.3
Nodong Launch Numbers

Launch Site	Comment	Launches	Year	Range [hundred km]	Success/ Failure
China	One report	1[a]	1991	8?	?
North Korea	Several reports	1	1993	5	S
Iran	Several reports	1	1998	8?	S
Pakistan	Several reports	1	1998	8–11	S
North Korea	Several reports	2	2006	8,8	S,S
North Korea	Several reports	3 (7?)[b]	2009	4–5	all S

[a] Missile type unknown—Nodong is pure speculation.
[b] Nodong, Scud C, or Scud D (not clear).

M4. Launch numbers for the North Korean Scud D are shown in Table A.4.

The Hwasong 7/Scud D/Scud ER was launched once in Syria in 2000. Since then, there were two additional launches in Syria in 2005. Scud Ds reportedly were also launched in the North Korean 2006 and 2009 launch campaigns. The total estimated number, including Syrian launches, is about six launches. Only one launch was reported as failure. The North Korean launches were done with reduced range. The most likely number (according to the author's estimate) is a total of one development launch in Syria and perhaps five life cycle launches in Syria and North Korea after attributed operational status. Some sources claim that the Syrian launches were done with missiles developed and produced in Syria, not North Korea.

M5. The Taepodong I was launched only once in 1998. Video footage of the launch is available. The launch failed due to third-stage malfunction.

M6. Launch numbers for the North Korean Taepodong II/Unha-2/-3 are shown in Table A.5.

The Taepodong II/Unha-2/-3 was launched in 2006, in 2009, and in 2012. All three launches were failures. The 2006 launch failed about 42 seconds into flight with a first-stage

Table A.4
Hwasong 7/Scud D/Scud ER Launch Numbers

Launch Site	Comment	Launches	Year	Range [hundred km]	Success/ Failure
China	One report	1[a]	1991	8?	?
Syria	Several reports	1	2000	<6	S
Syria	Several reports	2	2005	4,X	S,F
North Korea	Several reports	1	2006	>4	S
North Korea	Several reports	2 (7?)[b]	2009	4–5	all S

[a] Missile type unknown—Scud D is pure speculation.
[b] Nodong, Scud C, or Scud D (not clear).

Table A.5
Taepodong II/Unha-2/Unha-3 Launch Numbers

Launch Site	Comment	Launches	Year	Range [hundred km]	Success/ Failure
North Korea	Several reports	1	2006	X	F
North Korea	Video footage	1	2009	X	F
North Korea	Photo and video of preparation	1	2012	X	F

malfunction. The 2009 launch failed at separation of the third stage. The 2012 launch failed either late during first stage operations or at second-stage separation.

M7. Launch numbers for the North Korean KN-02 are shown in Table A.6.

The KN-02 might have been launched twice in 2005. Since then, there were three additional launches in 2007, and perhaps five launches in 2009. The total estimated number is about ten launches. Only one 2005 launch was reported as a failure. The most likely number (according to the author's estimate) is a total of two development launches before North Korea's claim of operational capability in 2006.[64] There are unconfirmed rumors of one earlier launch in 2004. The situation is very unclear due to several other missile types within this range class that are repeatedly launched in North Korea (unguided artillery rockets, anti-ship missiles, and surface-to-air missiles).

M8. As of May 2012, the Musudan has never been launched. There are some unsubstantiated rumors of a BM-25/Musudan test in Iran in January 2006. The author tried to trace back these rumors, only ending up at a single article that simply mentions the launch without giving a source for the claim.[65] This claim is therefore dismissed. However, there is the possibility that the Musudan actually is the Unha's second stage. In this case, the Musudan would have flown once, at the 2009 Unha-2 launch (the launches of 2006 and 2012 failed before second-stage operation).

M9. As of May 2012, no KN-08 has ever been launched.

M10. According to available open source literature, the Nodong was never tested at full range. Reported flight distances range from 400 to 800 km; nominal Nodong range is given between 900 to 1,300 km, depending on source.

Table A.6
KN-02 Launch Numbers

Launch Site	Comment	Launches	Year	Range [hundred km]	Success/ Failure
North Korea	Two reports	2	2005	?	F,S
North Korea	Several reports	3	2007	1,1,1	S,S,S
North Korea	UN report[a]	5[b]	2009	?	?

[a] UN, 2010, p. 42.

[b] Missile type unclear.

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[64] See "Development and Production," M7, p. 99.

[65] GlobalSecurity.org, 2012.

M11. No telemetry was detected at the Nodong's first flight in 1993 and the 1993 Scud B/C missile launches.[66] This is very unusual during a first flight. Failure analysis in case of malfunction becomes complicated to impossible without telemetry data. There are rumors that telemetry was also missing at most, if not all of the other launches.

Low-Confidence Data Points

L1. There are intense training activities being observed in North Korea, but without actual launches.[67]

Personnel

High-Confidence Data Points

H1. Missile and rocket programs in general have high personnel requirements, in terms of the number of people required as well as their training and education. Tens of thousands of people were involved in the German V2 missile development and production program. Numbers for the U.S. Atlas and Titan programs are believed to be similar. Modern programs such as Trident D5, Peacekeeper, or ATACMS (Army Tactical Missile System) also require high personnel numbers (including subcontractors!). Though exact numbers are hard to get, it can be taken as a fact that missile and rocket programs as well as nuclear weapon programs require high numbers of skilled personnel.[68] Skilled management and qualified personnel at factory floor levels are the key requirements.[69]

Medium-Confidence Data Points

M1. Personnel from the Makeev design bureau SKB-385 visited North Korea to discuss "modernizing North Korean missiles" in 1992. In the same year, dozens of Russian scientists were detained in Russia as they attempted to travel to North Korea. At least 160 Russian scientists are said to have been assisting North Korea develop missiles since the mid-1980s.[70]

M2. North Korean missile experts were in Iran in the 1990s, with knowledge and skills that were very unimpressive.[71]

M3. Russian nuclear scientists and missile experts provided limited support for the North Korean nuclear and missile programs, but all of them returned to Russia before September 1998. According to a press report in September 1998, "Russian government sources" say that 20 Russian "nuclear scientists and missile experts" provided limited theoretical support for North Korean nuclear and missile programs. The mentioned sources "believe that Nodong and Taepodong I were developed independently by North Korea because of limited Russian support."[72]

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66 Bermudez, 1999, p. 21.

67 Personal interview data with expert on North Korea.

68 Any highly complex machinery is developed and produced only by a fair amount of skilled personnel. Examples are arbitrary.

69 See Schmucker and Schiller, 2009.

70 Several reports are to be found at Nuclear Threat Initiative, 2009. Also see Pinkston, 2008.

71 According to a missile expert visiting Iran at that time.

72 Note of September 5, 1998, at Nuclear Threat Initiative, 2009.

M4. About 130,000 people worked at the Manhattan Project for the U.S. nuclear weapon development.[73]

M5. In the Soviet Union, at least ten closed cities were created for nuclear weapon–related research. This induces a number of people involved similar to that of the Manhattan Project.[74]

M6. According to a report submitted by the Unification Ministry,

> North Korea reportedly employs 3,000 workers in 20 facilities dedicated to developing the country's nuclear program . . . the country runs 20 nuclear facilities—11 in a nuclear complex in Yongbyon . . . and nine uranium-related mines and facilities. . . . Seoul estimates the North employs 3,000 workers throughout the country's nuclear facilities, including some 200 scientists and key research personnel.[75]

M7. "The early U.S. ICBM development effort involved an estimated 80,000 people and extensive industrial participation."[76] "It has been estimated that 18,000 scientists, 17 prime contractors, 200 subcontractors, and 3,500 suppliers, employing about 70,000 people were involved in the early U.S. ICBM development effort in the mid-late 1950s."[77]

Infrastructure and Facilities

High-Confidence Data Points

H1. The Musudan-ri facility was used to launch larger missiles (the Taepodong I and II and Unha-2). The site is small and does not show considerable use. Indications for this estimate are the dirt roads and only a few significant buildings visible on satellite imagery. Compared with other known missile test facilities around the world, Musudan-ri looks improvised.

H2. There is a second launch facility in the North Korean west. This new site is considerably larger and has a more professional look. The large amounts of concrete that were used for this site make it easy to identify on satellite imagery. The launch pad's dimensions are sufficient for a Soyuz-size rocket, and the engine test stand is big enough to hold large engine clusters.[78] It might be large enough to hold complete single stage missiles with warheads.[79]

Medium-Confidence Data Points

M1. According to reports, Nodong was also launched from Musudan-ri. Nodong class and smaller missiles are also launched from other sites, most probably from mobile launchers.

M2. The new launch site was used for the first time in April 2012 for the Unha-3. Therefore, the new launch site achieved an operational status in 2012 that is at least comparable to the Musudan-ri site.

M3. Several other facilities are involved in missile system development and production. Reports are inconsistent. These facilities include the Sanum-dong research and development facility (also known as No. 7 factory), the Sungni Automobile Factory, and the No. 125 factory

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[73] Common estimate, see for example Wikipedia.

[74] Common estimate, see for example Wikipedia.

[75] A South Korean lawmaker cited a report of the Unification Ministry. *Korea Herald*, 2010.

[76] Hildreth, 2008.

[77] Boyne, 2000, p. 85. Cited at Hildreth, 2008.

[78] Compare to Soyuz launch pads at Baikonur and engine test stands at Marshall Space Flight Center, Huntsville, AL.

[79] Idea by Joseph Bermudez, personal conversation.

near Pyongyang.[80] The Sanum-dong facility might actually be the Sanop-dong facility affiliated with the No. 125 factory; various academic institutions may support design and development of missile-related technology; the Man'gyongdae Electric Machinery Factory is reportedly involved in missile production.[81] Since all this information seems to be based on hearsay or defector statements, it might also be categorized as being of low confidence. Various press reports mention several other places for missile production or assembly.[82]

M4. Many missile-related facilities are located underground: "Most of North Korea's critical munitions factories and other sensitive facilities are located underground, so much of the open source information regarding missile production plants is ambiguous, incomplete, or erroneous."[83] Similar statements are repeatedly found in open source literature. Claims of underground missile facilities are common since World War II, probably due to the German underground facilities for A4/V2 missile production at Mittelwerk Dora. Since then, various countries have been attributed as having underground missile facilities, among them the Soviet Union and Libya.

M5. One photograph inside a claimed Scud factory is available, but it shows a missile body that most probably is that of a Nodong. See also H13 under the Nodong section.

Development and Production

High-Confidence Data Points

H1. There are no known examples of successfully using reverse engineering, for any high-tech machine, to produce a perfect clone with identical performance. All known replicas have only similar performance and design, and they always show differences in details. Examples of such reverse engineering include the following:[84]

Missile: German A4 – Soviet R-1
Missile: German Wasserfall – Soviet R-101
Rocket engine: Soviet SA-2 Volga engine – Iraqi replica
Rocket engine: U.S. J-2S – U.S. J-2X
Aircraft: U.S. Boeing B-29 – Soviet Tupolev Tu-4
Car: German/U.S. Opel Frontera – Chinese Jiangling Landwind.

Even products that are manufactured in licensed production seem to show differences to the original.[85]

H2. In 2000, several missile parts from North Korea that were en route to Libya were confiscated at Zurich airport by Swiss authorities.[86] These reportedly included injection elements for Scud engines and other parts that were produced by milling and turning, as well as

[80] IISS, 2004.

[81] Pinkston, 2008.

[82] See Pinkston, 2008; Nuclear Threat Initiative, 2009.

[83] Pinkston, 2008, p. 44.

[84] A vast number of publications and media reports on the respective reverse engineering efforts is available in open source literature and easily accessible at the Internet.

[85] Japanese production versions of U.S. fighter aircraft seem to show small differences to the original, for example.

[86] Pollack, 2011, p. 427.

electronic components that showed Cyrillic lettering; the quality of the machined parts was poor.[87] The parts might have been transferred through Switzerland because Zurich seems to be one of very few destinations that was served by Air Koryo, the North Korean airline, at that time. It cannot be ruled out that this route was deliberately chosen to increase probability of detection and subsequent confiscation, but that is subject to speculation.

Medium-Confidence Data Points

M1. In the 1990s, a Russian missile expert with good knowledge of manufacturing saw North Korean–made missile parts in Iran. He reported their quality as being "very poor."[88]

M2. North Korea reverse engineered the Scud B within three years. Exact numbers vary, but common estimates are that North Korea received the Scud B from Egypt in 1981 and launched the reverse engineered missiles in 1984. "Full-scale production" was reached in 1987.[89]

M3. North Korea developed the Scud C within three to seven years. Exact numbers vary, but common estimates are that North Korea started development of the Scud C in 1984, with first flight tests before or in 1991 and full-scale production in 1992.[90] Other sources claim that development had begun in 1987 or 1988.[91]

M4. North Korea developed the Nodong within five to ten years. Exact numbers vary, but common estimates are that North Korea started development of the Nodong in 1984, with the first flight test in 1993 and completion of development in 1994.[92] Other sources claim that development had begun in 1988 or 1989.[93]

M5. North Korea developed the Taepodong I within eight years. Exact numbers vary, but common estimates are that North Korea started development of the Taepodong I in 1990, with the first flight in 1998.[94]

M6. North Korea developed the Taepodong II/Unha-2 within 16 years. Exact numbers vary, but common estimates are that North Korea started development of the Taepodong II/Unha-2 in 1990, with the first flight in 2006.[95]

M7. North Korea developed the KN-02 within seven to nine years. Exact numbers vary, but common estimates are that North Korea started reverse engineering of the SS-21 in 1997, with the first flight of the KN-02 in 2004 or 2005 and initial operating capability probably achieved in 2006.[96]

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[87] Personal conversation with former UNSCOM inspector Robert H. Schmucker.

[88] Personal conversation with Michael Elleman of IISS.

[89] Jane's, 2010d.

[90] Jane's, 2010a.

[91] Bermudez, 1999, p. 15.

[92] Jane's, 2010e.

[93] Pinkston, 2008, p. 18.

[94] Jane's, 2010b.

[95] Jane's, 2010c.

[96] Jane's, 2010f.

M8. North Korea developed the Musudan within three to five years. Exact numbers vary, but common estimates are that North Korea started development of the Musudan around 2000, with the first deployments of the missile in 2003, or at least in 2005 or 2006.[97]

Low-Confidence Data Points

L1. There are suggestions that North Korea has remanufactured earlier Scuds to the Scud C and D configurations.[98] But, according to the author's understanding of the involved missiles, the Scud B and C differ significantly. "Remanufacturing" a Scud B to a C configuration means substitution of the complete airframe and several key elements (pressurization system, for example). Most likely, the guidance system of Scud C is also different from that of the Scud B. This means that, of the four elements of a ballistic missile (airframe, engine, guidance system, and warhead), only the Scud B's engine is further used in the Scud C. The same is true for the Scud D. Thus, remanufacturing is basically possible but not very likely.

Numbers and Deployment

High-Confidence Data Points

H1. Scud B deployment numbers in Warsaw Pact countries are well known by now. In the late 1980s, East Germany had 20 TELs operationally deployed, with a total of five Scud B missiles for each TEL, resulting in a total of 100 Scud B missiles.[99] This was peak deployment—earlier numbers were lower.

Medium-Confidence Data Points

The author was not able to find substantiated justifications for the claimed numbers, such as observed deployments, production outputs, TEL purchases, or similar arguments. In the author's personal view, the subsequent numbers therefore are of low confidence, but they are generally accepted in open source literature and are therefore categorized as being of medium confidence.

M1. The Scud B has been deployed in North Korea since 1986, the Scud C since around 1992. Total numbers are several hundred. Numbers can be found in most publications about the North Korean missile threat. They are generally in the range of 500 Scuds or more.

M2. Several reports mention operational biological, chemical, and nuclear warheads. The available sources vary significantly.

M3. As of 2006, a total of 600 Scud B, Scud C, and Scud D missiles are said to have been deployed in North Korea.[100] The origin of this number is unknown.

M4. An estimated 300 Scud B missiles were built in North Korea. It is believed that around 100 to 150 remain in North Korea.[101] The origin of these numbers is unknown.

M5. Around 200 Scud C are believed to be in service, with 50 TEL or fixed launch sites.[102] The origin of these numbers is unknown.

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[97] Jane's, 2010f.

[98] Indicated by Joseph Bermudez, personal conversation.

[99] See NVA Forum, 2011, and Hall, 2011.

[100] Common number in literature. See also Jane's, 2010d.

[101] Jane's, 2010d.

[102] Jane's, 2010a.

M6. It is believed that Nodong entered service in North Korea in 1995. An unconfirmed report in 2006 suggested that 450 missiles were operational. U.S. reports in 2009 stated that 200 to 300 Nodong are operational in North Korea, with 50 TELs.[103] The origin of these numbers is unknown.

M7. In July 2009, several reports suggested that five to ten Taepodong II missile deployments had been made.[104] The origin of this number is unknown.

M8. Ten Musudan missiles and five TELs may have been deployed since 2003. Fifteen to 20 Musudan missiles were deployed in 2005. Up to 50 Musudan were deployed in underground facilities since 2006. Up to 50 TELs were available in 2009, with an according number of Musudan missiles.[105] The origin of these numbers is unknown.

M9. The KN-02 missile is currently in service: "Initial operating capability of the KN-02 was probably achieved in 2006, but a full in-service date was not achieved until 2008." Probably around 150 to 250 missiles will be operational in 2013.[106] The origin of this number is unknown.

Low-Confidence Data Points

L1. Several reports indicate that a missile designated Scud C by Western analysts was deployed and launched in Afghanistan during the late 1980s.[107] There are reports of advanced R-17/Scud B versions that were developed in the Soviet Union. See the section on the Scud C.

L2. By June 2006, it was believed possible that 20 to 30 Taepodong I missiles could be available for operational use or further test flights.[108] The origin of this number is unknown.

Exports

High-Confidence Data Points

H1. In 1999, the North Korean freighter *Kuwolsan* was discovered to carry missile components and other missile related cargo. It was boarded in the Indian harbor of Kandla, and its destination reportedly was Libya.[109] Some imagery of the findings is available to the author.

H2. In 2002, the North Korean freighter *Sosan* was discovered to carry complete Scud missiles. It was boarded by the Spanish navy in the Gulf of Aden, and its destination was Yemen. Imagery is available on the Internet.[110]

Medium-Confidence Data Points

M1. Several reports claim that roughly 100 North Korean Scud Bs were delivered to Iran in 1987/1988; one report claims a number between 200 and 300, and another one reports 400.[111]

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[103] Jane's, 2010e.

[104] Jane's, 2010c.

[105] Jane's, 2010g.

[106] Jane's, 2010f.

[107] See for example Claremont Institute, 2011.

[108] Jane's, 2010b.

[109] See for example Warrick, 2003.

[110] Available at Wikimedia Commons. See Wikimedia, 2011.

[111] See Nuclear Threat Initiative, 2009.

M2. A lower number of North Korean Scud Bs (between 25 and 40) was delivered to the United Arab Emirates around 1989.[112]

M3. North Korea provided technical assistance for Scud B production to Iran and Libya. Scud B missiles were exported to Iran and Libya.[113]

M4. North Korea provided technical assistance for Scud C production to Libya and Egypt. Scud C missiles were exported to Libya, Syria, Iran and Yemen.[114]

M5. North Korea probably provided technical assistance for Nodong production to Iran. Nodong missiles were exported to Iran and Pakistan.[115]

M6. In December 2005, the German newspaper *Bild* reported that 18 BM-25 (Musudan) missiles were transferred from North Korea to Iran.

M7. Of an estimated number of 510 ballistic missiles that North Korea exported to various countries until the end of 2009, about 420 were transferred from 1987 to 1993, and no missile exports have been known since 2007.[116]

Low-Confidence Data Points

L1. Scud Bs were transferred from North Korea to Vietnam, Ethiopia, Congo, and Burma.[117]

L2. According to singular reports, Nodongs were transferred to Syria, Libya, Egypt, and Iraq.[118]

Imports

Medium-Confidence Data Points

M1. The first larger missile that North Korea received was the Soviet Luna/FROG unguided solid-fuel artillery missile. The Soviet Union began to provide FROG in the 1960s.[119] Compared with guided ballistic missiles with liquid fuel, the FROG missile is a very simple and rugged design.

M2. In the 1970s, Egypt had Soviet Scud Bs deployed.[120] Egypt gave several of these missiles to North Korea in the late 1970s or early 1980s—"The consensus in the open source literature is that the Soviet Union refused to provide Scuds to North Korea."[121] Though there were rumors in the 1980s that the Soviet Union delivered Scuds to North Korea in the 1970s or 1980s, these rumors were never substantiated.

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[112] Nuclear Threat Initiative, 2009.

[113] Nuclear Threat Initiative, 2003.

[114] Nuclear Threat Initiative, 2003.

[115] See for example Nuclear Threat Initiative, 2003.

[116] Pollack, 2011, pp. 412–413.

[117] See for example Jane's, 2010d.

[118] See Nuclear Threat Initiative, 2003.

[119] See for example Pinkston, 2008.

[120] No imagery of an Egypt Scud B is known to the author. Scud Bs were reportedly fired against Israeli targets in the 1973 Yom Kippur War, but only with a range of less than 200 km. With this limited knowledge, it cannot be ruled out that Egypt only had the Scud A.

[121] Pinkston, 2008.

M3. During the 1980s and 1990s, North Korea imported surface-to-air missiles and anti-ship missiles from the Soviet Union/Russia. Deliveries included SA-14 and SA-16 SAMs and Styx/P-20 anti-ship missiles.[122]

M4. During the 1980s and 1990s, North Korea imported surface-to-air missiles, anti-ship missiles, and cruise missiles from China. Deliveries included HY-2 Silkworm anti-ship missiles and parts, HJ-73 and HN-5A SAMs and C-802 cruise missiles.[123]

M5. North Korea repeatedly imported or tried to import materials and parts from various countries that might be used for missile production. Materials and parts include special steels, gyroscopes, aluminum alloys, powdered aluminum, special chemicals, accelerometers, and much more.[124] There are more reports to be found in open literature.

Low-Confidence Data Points

L1. There are unsubstantiated reports that North Korea received the Scud B from the Soviet Union in the 1980s. According to the Stockholm International Peace Research Institute (SIPRI), North Korea received about 240 Scud B missiles between 1985 and 1988. One hundred of them were then transferred to Iran.[125] *Jane's Defence Weekly* reported in 1985 that North Korea received Scuds from the Soviet Union.[126] Since only these two reports are known to the author, and both are marked as "unsubstantiated," the delivery of Scuds from the Soviet Union to North Korea has to be categorized as information of low confidence. Very few texts in the open source literature mention these two reports.

L2. North Korea imported several Scud C missiles from the Soviet Union: U.S. intelligence agencies are said to have monitored a rail delivery of up to ten Soviet-made Scud C missiles to North Korea in 1991.[127] This incident was only mentioned once in the respective *Washington Times* article. No further references are known to the author.

Country

General Aspects

High-Confidence Data Points

H1. The North Korean way of thinking is said to differ significantly from the Western way—Western standards are not necessarily valid in North Korea. This includes decisionmaking and general approaches on various tasks. What may seem strange in Western eyes may seem logical in North Korean eyes, and what Western policymakers would view as logical, rational decisions are not necessarily the baseline of North Korean decisionmaking.[128]

H2. Physical laws, technical limits, and typical engineering hurdles are in effect in North Korea as well as everywhere, as are simple relations: Without resources, large projects cannot

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[122] Nuclear Threat Initiative, 2003.

[123] Nuclear Threat Initiative, 2003.

[124] See Nuclear Threat Initiative, 2003.

[125] SIPRI, 1989, p. 256.

[126] Pinkston, 2008, p. 15.

[127] See Gertz, 1991.

[128] Personal conversation with Joseph Bermudez and Bruce Bennett.

be realized. With resources, they can be realized, but not necessarily. Small missiles cannot cover great distances. Large missiles can, but not necessarily. Complex machines have to be thoroughly tested to discover design flaws, or they will not function properly.[129] All this is also true for North Korean missiles, nuclear weapons, and warheads.

Classification of the Missile Program

Medium-Confidence Data Points

M1. The missile program is very important for North Korea. It receives very high priority, in the military structure as well as in overall politics.[130] Aside from the military and political importance of missiles, North Korea's missile exports are generally seen as an important source of income for the country.

M2. In contrast to Western strategic views, even short-range missiles have a strategic meaning for North Korea.[131] Missiles can be considered as long-range artillery, and artillery has always had a special meaning for the North Korean military. Hostile air force attacks are seen as a major threat in North Korea, and in case of conflict, singular missile attacks on ROK or Japanese airfields might disrupt their operations long enough to make a difference.[132] However, if these attacks are limited to conventional warheads, this scenario seems unlikely: The accuracy of the North Korean missiles makes direct hits of a runway very unlikely, but debris particles from impacts close by might be scattered on the runway. However, the runways can be cleaned within a few minutes, and even impact craters on the runway can be repaired in a matter of a few hours.[133] Therefore, a closeby impact would have to occur perhaps every 15 minutes to continually disrupt operations at an airbase. With the known Scud CEP of 1 km or more,[134] it seems optimistic (for North Korea) to assume that every second Scud launched at an airbase impacts close enough to do this. This means that eight Scuds have to be fired per hour to keep one airbase out of operations. The complete South Korean peninsula is in range of the North's Scud B and C missiles. Assuming that only nine ROK airbases are to be attacked,[135] the common number of 600 North Korean Scuds is sufficient for about eight hours of continuous interruption—that the North would waste all its missiles for this effect seems not very likely.

Financial, Economic, and Industrial Situation

High-Confidence Data Points

H1. The electrical power situation in North Korea is very poor. On satellite imagery, North Korea is a dark area except for a spot of light that is Pyongyang.[136]

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[129] Every engineer knows "Murphy's Law" that states that "*anything that can go wrong, will go wrong*."

[130] For example, an independent military division solely for IRBMs has been recently established by the North Korean Army. See for example Klingner, 2010.

[131] Personal conversation with Joseph Bermudez.

[132] Personal conversation with Joseph Bermudez.

[133] Personal conversation with B. S. MacNeill, retired military aviator previously based in South Korea.

[134] The scoring system for East German training launches hints at that value. According to former East German rocket soldiers, the best grade was rewarded up to 0.9 km longitudinal error.

[135] Only nine ROK Air Force fighter wings are attributed with a base in Wikipedia, 2011a.

[136] See GlobalSecurity.org, 2011c.

H2. North Korea's food production is insufficient, leading to severe famines. The country suffered a significant famine in the 1990s. There are no official death figures, but estimations vary between several hundred thousand up to a few million. Currently, a third of the population is undernourished, and, according to the Global Hunger Index, the food situation is still labeled as being "serious."[137]

Medium-Confidence Data Points

M1. Though the numbers are only roughly estimated, North Korea's gross domestic product can be assumed of being at least in the given order of magnitude. Even corrected by purchasing power parity, North Korea's gross domestic product is very low, on a level with Costa Rica or the city of Caracas.[138]

Other Industrial Programs

High-Confidence Data Points

H1. Cars are rare in North Korea, with roughly one car for every 1,000 citizens.[139] The North Korean automotive industry is very small, with only two car manufacturers, Sungri Motor Plant and Pyeonghwa Motors, with the latter one founded only in 1999. Their portfolios only offer either cars that are assembled from Chinese and Italian cars' complete knock-down kits or replicas of old Western cars that might also be assembled from pre-produced parts. There are no indigenously developed cars. Annual production numbers are very low, with a total of a few hundred per year.[140]

H2. The Pyeonghwa Hwiparam ("Whistle"), a copy of the Italian Fiat Siena, is currently advertised in North Korea, even though private citizens are not allowed to own a car. The car is assembled from kits of parts.[141] An advertising video clearly shows the Fiat sign on the car's front and the Fiat writing on the engine, raising doubts about whether the car is actually produced in North Korea.[142] In the comments section below the video, it is theorized that the whole production is a "scam" and that the cars are actually produced in Brazil and transferred to North Korea.[143]

H3. North Korea has no noteworthy aerospace industry. There is no indigenous aircraft production. The backbone of the North Korean air force still consists of Soviet or Chinese fighter aircraft from the 1950s and 1960s.[144]

H4. A new tank named Pokpung-ho was presented at the 2010 parade and was witnessed at performance trials in 2002. It shows similarities to several Soviet/Russian battle tanks. There is no evidence for production of the tank on a significant scale in North Korea.[145] No details

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137 See WFP, 2011.

138 Country GDP (nominal and PPP 2009 estimations) according to CIA, 2010. Non-state countries (EU, Hong Kong, etc.) are excluded. City GDP (PPP 2008 estimations) according to PricewaterhouseCoopers, 2009.

139 Martin, 2007.

140 See various sources, for example Wikipedia, 2011b, Martin, 2007, or Berkowitz, 2010.

141 Martin, 2007.

142 See Berkowitz, 2010.

143 See Berkowitz, 2010.

144 See various sources, for example DoD, 1997.

145 See several Internet sources, for example Wikipedia.

about the production are known, such as whether the tank's engine is procured or produced in North Korea.

H5. There were no reports of indigenous North Korean surface-to-air missile (SAM) production until 2010. Militaries, including North Korea's, normally keep a greater quantity of SAMs than ballistic missiles. Since technology is similar to that of ballistic missiles, it is not known why North Korea was not producing and selling SAMs. However, North Korea paraded launch tubes similar to the Russian S-300 system at its October 2010 parade, and reportedly launched the associated SAM, designated KN-06, for the first time in early July 2011.[146]

Medium-Confidence Data Points

M1. All cited sources agree that the quality of North Korean cars still is very poor. About the Kaengsaeng 88, for example, it is stated that "The North Korean automotive 'engineers' imported several Mercedes 190Es and copied most of the parts with workmanship that made the Yugo look like a Rolls-Royce."[147] The car was introduced in 1988—about the same time that the Soviet Scud B was reportedly successfully reverse engineered in North Korea.

M2. Various open source reports claim that the majority of the North Korean air force is grounded because spare parts for the old aircraft are not available. This suggests that these parts cannot be produced indigenously.

M3. A simple Google search for "Pokpung-ho" and "1992" indicates that the Pokpung-ho main battle tank might have been in production since 1992, even though it was only presented at the 2010 parade (see H4 above). Available numbers are estimated in the low hundreds at maximum.

M4. Even though the United States accused North Korea in 2005 of producing the "Superdollar," a copy of the $100 bill with a quality that is higher than the original, it is not clear that North Korea is capable of producing this counterfeit bill, especially considering the poor quality of the North Korean currency bills.[148] As of early 2011, the "Superdollar" case is still not solved. The producer remains unknown.

Links to Other Countries

High-Confidence Data Points

H1. North Korea is widely isolated from the rest of the world. Its closest ally is generally said to be China. North Korea shares a border with China (1,416 km), with the ROK (238 km), and with Russia (17.5 km). Neighboring states that are not hostile are Russia and China.[149]

H2. The infrastructure at the border to Russia is in a good shape. Satellite imagery shows a railroad connection between Russia and North Korea, with train stations of significant size on both sides. Track gauges are different, though: North Korea, as well as the ROK and China, uses the standard track gauge with 1,435 mm. Russia's primary track gauge is 1,520 mm.

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[146] See for example *CNN*, 2011, or *Chosunilbo*, 2011.

[147] Berkowitz, 2010.

[148] Swiss Federal Police, 2006, pp. 24–26.

[149] CIA, 2011.

H3. Russian President Vladimir Putin is one of the very few heads of states that have visited North Korea in decades. Inaugurated in May 2000, he visited Pyongyang in July 2000, making North Korea one of his first foreign-visit destinations. This was the first visit of a Soviet/Russian leader since North Korea's foundation in 1948.[150]

H4. Satellite imagery shows several railroad crossings and connections between North Korea and China. The surrounding infrastructure is in a good shape. The rail track gauge is the same in North Korea and China.

H5. Smuggling activities across the Chinese border, even in daylight and watched by soldiers of both sides, are well known and tolerated by North Korean and Chinese officials—a German film crew filmed these activities in 2010.[151] The journalists visited the Chinese city of Changbai. According to them, conversations with Chinese inhabitants revealed that the inhabitants of Changbai see the border between North Korea and China as being an "open border." At least between the cities of Changbai in China and Hyesan in North Korea, this seems to be true, as is proven with the available video footage: Under the eyes of Chinese and North Korean soldiers, a smuggler wades through the river to Changbai. He takes a man-sized bag out of a bush and pulls it back across the river to North Korea.

Other Aspects

High-Confidence Data Points

H1. The Russian government never filed official protest notes for product piracy against North Korea. The same is true for the Soviet/Russian companies that originally developed and produced the missile systems (or parts of these systems).

H2. North Korea limits its reverse engineering capabilities to missiles and a few other defense products. No cars, aircraft, or other machines are reverse engineered and offered on the global market. Copying high-value industrial machinery, agricultural machinery, cars, and trucks would benefit the North Korean economy and could, if sold abroad, generate a steady stream of foreign currency into the country. None of this is observed.

Medium-Confidence Data Points

M1. Russian authorities are said to be furious about the North Korean product piracy, but only behind closed doors.[152]

M2. In 1998, the Soviet Scud production line in Votkinsk was incomplete, with some of the original Scud production equipment missing, and a facility manager suggesting that it was sold to an undisclosed customer.[153]

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150 Takeda, 2006.

151 A video is available online at *ZDF*, 2011. The smuggling sequence starts at 24:30 minutes.

152 Personal conversation with Bruce Bennett.

153 Personal conversation with Michael Elleman of IISS, who had visited the factory.

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