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Cruise Missiles & Anti-Access Strategies

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Definition

Unpiloted and self-powered aircraft using aerodynamic lift during flight and fitted with a destructive warhead. The missiles considered in this monograph are either ground attack systems (regardless of their range) or anti-ship missiles with a range of more than 150 km.

Introduction

Cruise missiles have become a central instrument in military action by Western States over the last two decades, and have demonstrated their advantages in operational and political terms. Their repeated use (admittedly alongside other precision weapons) during recent conflicts (in Iraq, Kosovo and Afghanistan) and also during international crises (Iraq, responses to attacks on the USS Cole and Nairobi embassy) is an illustration of this.

In fact, the success of these weapons, which are precision vectors with high penetration capacities fired from a safe distance, has not escaped the attention of States who might one day be confronted with Western forces.

The characteristics of cruise missiles appear to be particularly attractive for countries that, in a time of crisis and in a context of military inferiority with regard to Western countries, would like to hinder the capacity of these Western countries to deploy their forces, organize their logistics, and finally to move about unfettered on the operation theatre.

The acquisition of cruise missiles, although apparently difficult at first sight, has several technical and operational advantages for such a country:

- ⇨ The cost-efficiency ratio for bombing missions using this type of missile is better than ballistic missiles or fighter aircraft[1].
- ⇨ Due to their range, cruise missiles do not require air or sea supremacy for use and can be used from a wide range of platforms (aircraft, surface ships, submarines, ground launchers)[2].
- ⇨ The directly associated infrastructure is relatively small compared with the infrastructure for a ballistic missile or a fighter aircraft.
- ⇨ The most modern cruise missiles have a large penetration capacity and ranges sufficient to allow firing from a safe distance[3].
- ⇨ The flexibility of their path is such that approach vectors can be varied, making the defender's task more difficult.
- ⇨ In a first analysis, cruise missiles appear to be more efficient for biological or chemical spreading missions.
- ⇨ Their development can be easily dissimulated.

[1] David J. Nicholls, « Cruise missiles and modern war », pp. 10-11.

[2] The vulnerability of platforms to enemy means must be taken into account even if it is actually limited by the range of the cruise missiles that the enemy means are carrying.

[3] Which reduces the risk to carriers by moving them further away from the enemy defense.

Since the beginning of the 1990s, some regional powers have committed themselves to acquiring cruise missiles following an anti-access logic. In particular, the objective is to be able to:

- ⇨ Slow or even prevent the deployment of American forces and means close to the operations theatre.
- ⇨ Weaken the will and / or the capability of future host countries to host American forces.
- ⇨ Slow the rhythm of military operations carried out by the United States and their allies.

Everything suggests that cruise missiles will be used to exploit the current vulnerability of protection systems and to neutralize or destroy some fixed strategic targets (embarking/debarking point, ammunition depot, air defense control centers) and mobile targets (aircraft carriers). Some civil targets may also be selected to weaken the determination of host countries that accept or support the coalition: vital economic infrastructures (electricity generation, ports, oil industry) political decision centers (ministries, government).

Setting up this type of strategies assumes that the proliferating country is in possession of large intelligence, mission preparation and operational planning means, essential for programming and coordination of strikes. Furthermore, we should not exclude the possibility of seeing this type of means used in heterodox (or degraded) modes corresponding to the operational constraints of a given military situation.

At first sight, American military power based on technological dominance does not appear to be jeopardized solely by the acquisition of cruise missiles, no matter how efficient they are, as was illustrated in the « *Iraqi Freedom* » operation. However, during the same conflict, it appears that the coalition forces' greatest difficulties were caused by the use of this type of missile (combined with the use of unsophisticated Al-Samoud-2 ballistic missiles). Thus, Iraqi air missiles penetrated the American air defense twice without being detected or intercepted, and one of these missiles detonated close to a Kuwaiti shopping center[4]. Furthermore, the level of the "missile" threat obliged American air defense forces to simplify engagement rules, thus facilitating friendly firing[5].

A worrying proliferation…

The rate at which cruise missiles are proliferating is worth estimating to determine when and how the risk related to current developments in China, Iran or North Korea, might materialize. It is highly probable that this phenomenon will not be sequential and that a large number of unsophisticated missiles and a few modern missiles, in other words precise, discrete and long range missiles, will eventually coexist in the arsenals of proliferating countries.

[4] In its analysis of Iraqi firing into zones occupied by coalition forces, Dennis Gormley emphasized particularly that one of these missiles landed close to an American air base without causing any damage.

[5] To the extent that PATRIOT system operators did not have access to a single integrated air picture. An American F-18 and a British Tornado were shot down by PATRIOT firing batteries. See the study carried out by the MIT http ://www.globalsecurity.org/space/library/report/2004/patriot-shot-friendly_20apr2004_apps1-2.pdf

Technical difficulties associated with the development of missiles will have a strong influence on this rate. Although most necessary technologies are relatively accessible and financially affordable, some are still subject to strong restrictions in terms of export by MTCR members (for example propulsion, stealth techniques). The main technical challenge lies in the integration of all of these techniques into a reliable and efficient system. Therefore access to the technical support in the subject provided by advanced countries is an accelerating factor essential to proliferation of this type of missile. Two acquisition means appear equally possible, in addition to local development:

- ⇨ Conversion of anti-ship missiles or drones for ground attack missions.
- ⇨ Off-the-shelf purchase of complete systems.

The world stock of cruise missiles is estimated at 80 000, consisting of 75 systems held in 81 countries. Twenty States use ground attack missiles and 42 new systems are under development[6]. This macroscopic panorama of the world of cruise missiles conceals a more complex reality; about 90% of these missiles are actually short range anti-ship missiles, for which engineering expertise and a large financial investment would be necessary for conversion for ground attack missions[7]. In any case, few countries are capable of developing modern cruise missiles completely independently.

The People's Republic of China has developed and acquired high performance missiles from Russian companies since the beginning of the 1990s to counter American air defense systems and to threaten their deployment (for example Fleet Air Arm) or installation in the region (Okinawa). These missiles complement the existing range of tactical ballistic systems with which they could be used in a coordinated manner. In this respect, Peking now prefers asymmetric strategies to compensate for its operational and technical inferiority, within the context of a possible confrontation with the United States, for example around a Taiwanese crisis.

Iran initiated a cruise missile acquisition program near the end of the 1980s with the help of China, initially for anti-ship missions. This effort could eventually allow it to possess an internal ground attack capability. These means would probably have an essential role to play in a conflict against a Western coalition led by the United States. In all cases, its systems provide it with additional means of hindering its environment in crisis situations.

... Against which it is still difficult to produce responses

Politically, the capability of MTCR members to efficiently control distribution of the most sensitive equipment and key knowledge in the field appears increasingly problematic faced with an increasing demand and the fact that key technologies are becoming commonplace. In this respect, Russia's development of an export version of the AS-15 missile (called the Kh-65) and its cooperation with India for the development of the BRAHMOS supersonic missile (anti-ship and ground attack missions) are worrying indications. It is also necessary to control flows from China to its partners (Iran and Pakistan) that in the long term could materialize by technology transferred used for

[6] David Tanks, « Assessing the cruise missile puzzle », p. 3

[7] See Steven Zaloga, « The cruise missile threat: exaggerated or premature » that summarizes conditions for transformation of the Chinese HY-2 into HY-4.

modern missiles in the HN series or unsophisticated HY-4 missiles[8] (presented as being exportable).

Operationally, there is a two-fold difficulty. The appearance of supersonic missiles (see Brahmos) makes it necessary to own fast and agile interceptors. Conversely, the risk of large raids of unsophisticated cruise missiles requires the purchase of large numbers of inexpensive systems (the cost of a *PATRIOT advanced capability-3* interceptor is about 3 million dollars per unit, knowing that in current rules of engagement, two missiles are fired for each detected incoming missile; to be compared with the predicted $ 300 000 given for the *Joint Air to Surface Stand-off Missile* (JASSM)[9]). However, the main difficulty is efficient detection of cruise missiles flying at very low altitude. Radar systems currently in use in Western armies are incapable of detecting this type of threat early and therefore this type of threat cannot be engaged by ground-air defense means. Similarly, counter-force operations (destruction of launchers) is also difficult due to the lack of efficient launch detection means. This is particularly true for missiles capable of changing environment that can be fired from submerged submarines. However, current progress in the detection-decision-firing loop could considerably improve the feasibility of such operations.

In conclusion, military responses to the risk of this proliferation should probably involve a mix of means with a high technological content (hyperfast and maneuverable missiles, passive radar systems, networking of warning systems) and unsophisticated solutions (lookouts, passive protection).

[8] The HY-4, baptized Sadsack, forms part of the HY-Silkworm family. However, no missile in this family is called Silkworm.

[9] Since the middle of the 1990s, the American Ministry of Defense has committed itself to the development of a low cost cruise missile, wherever possible using commercially available equipment. However, remember that acquisition costs of Western cruise missiles are of the order of one million Euros.

Cruise Missiles as instruments of anti-access strategies

1 – Anti-access strategies

Western States, led by the United States, get involved in geographic conflicts far from their own territory. In this context, as a first step they need to transfer and deploy equipment and human resources necessary to wage war, and they have to be able to set up local command centers and bases for use by their forces.

The success of this military build up phase is dependent on:

- ⇨ fluidity and safety of transferring the resources (embarkment, transport and debarkment);
- ⇨ existence of grouping and accommodation areas in the immediate vicinity of the crisis area (host countries);
- ⇨ access for air, sea and land forces to the theatre of operations.

The speed and success of this part of an operation are essential factors for its success. In particular because it is a period during which the forces moving into position and the equipment being deployed are particularly vulnerable to the enemy's use of weapons to destroy or neutralize them.

Anti-access strategies are intended to hinder the military build-up and execution of operations by:

- ⇨ Slowing or preventing the transfer of resources;
- ⇨ Dissuading potential host countries from accepting western deployment;
- ⇨ Preventing western forces from accessing the theatre of operations or some essential zones of this theatre.

Current and foreseeable conflicts are characterized by the battlefield being dominated by western forces (air and sea supremacy, superiority of equipment and organization of forces, access to information, etc.). In this context, organizations or States confronted with these forces cannot hope to win using conventional strategies and must make use of asymmetric logics.

Therefore, effective means for implementing anti-access strategies must reach and neutralize targets by circumventing enemy defenses (often deployed in advance in the case of the United States) so as to reach targets far from their immediate periphery.

This is the perspective within which long range ground attack or anti-ship cruise missiles appear to combine several characteristics that make them ideal means for anti-access strategies.

2 – Motivations for the acquisition of cruise missiles

Three types of motivations can be envisaged for a proliferating country:

- Military/strategic credibility: the possibility of demonstrating that the possessing country is capable of efficiently penetrating enemy air defenses.
- Operational advantage: flexibility of use (range of carrying means, small launching infrastructure), possibility of dissimulation during development (cruise missile tests are difficult to detect by satellite means) and during a crisis period; potential efficiency in terms of penetration (precision and range). Advantages in terms of cost/efficiency ratio.
- Efficiency for carrying and dissemination of biological or chemical substances[10]: flight profiles are adapted to dispersion of BC agents. The altitude and speed are particularly important for spreading missions. Flight characteristics of ballistic missiles during the terminal phase are not ideal for this type of mission. Even so, it may be difficult to disperse biological agents by cruise missiles. The quality of the dispersion mechanism for a liquid, for example the size of nozzles[11] has an influence on the particle size and therefore the efficiency of the agent. Release, altitude and velocity conditions also affect the efficiency. An altitude of less than 50 m and a velocity of 150 km/h are optimum conditions for the release of biological agents. A mass of a few kilograms of an agent in liquid form would then be sufficient to affect areas of several tens of square kilometers[12]. The damage caused would be much greater if an agent in freeze dried form is used.

It should be emphasized that cruise missiles are particularly attractive to the extent that they can limit the number of carriers engaged in protected or defended areas, consequently reducing their vulnerability.

Cruise missiles carry smaller warheads than a fighter aircraft or a ballistic missile, therefore they are generally more efficient against targets with little protection than against military targets that are protected.

3 – Vulnerabilities of military dispositions and asymmetric policies and uses

3.1 – *Possible action types, objectives and effects*

There may be three types of objectives to be achieved:

- Dissuade[13] action by a coalition: the dissuasion capability of cruise missiles depends very much on their credibility as a military tool. Consequently, the objective for a State is to demonstrate the efficiency of its missiles in penetrating the air defense of coalition forces and their regional allies. Another objective of firing may be to demonstrate that missiles are capable of effectively carrying and disseminating unconventional warheads (for example biological or chemical)[14].

[10] Dennis Gormley, « Hedging against the cruise missile threat », *Survival*, vol. 40, 1998.

[11] The option to use a freeze dried agent, which is usually more efficient, assumes that drying and packing processes of the agent are well controlled.

[12] A mass of 25 kg of anthrax can thus affect a 4x4 km area.

[13] In other words, assure that a military action is renounced before it is undertaken.

[14] The simple possession of cruise missiles will create a dissuasive effect if their penetration or carrying capacity is proven.

- Slowing a deployment by hindering movements of logistics and resources necessary for operations (as a reminder, moving around missile defense systems is extremely expensive – deployment of a battalion of 96 PAC-3 units would require 16 C-5 turnarounds – and planners also have to choose when to send them to the theatre). This tactic may also consist of forcing allies to dedicate a significant part of their resources to the search for launchers, as was the case for the Gulf War in which it was estimated that 20% of coalition air sorties were for "SCUD hunts"[15].
- Inflict a tactical defeat: by destroying essential or high value resources (aircraft carrier, control centers, satellite reception stations), the country can effectively hope to defeat the coalition by obliging it to stop its deployment or even to evacuate the conflict area.
- Increase the economic or political costs of an action: damaging some resources and destroying essential political or economic targets can quickly make the cost of an operation unacceptable for some allies and even for the United States itself, and consequently may oblige the allies to refuse access to allied forces, and the United States to renounce the operation.
- Send a warning: the country can fire precision warning shots into uninhabited areas or at low value targets, accompanied by political and/or diplomatic messages, to demonstrate its operational capability and to send a political warning.

Three possible types of operations can be selected in a first analysis:

- Sneak attack: using a few missiles, but possibly carrying unconventional warheads.
- Saturation attack/raid: the enemy may consider saturating the defense and destroying strategic targets, by means of a coordinated attack using several tens of missiles (the main difficulty being coordination).
- Combined ballistic/cruise missile attack: the objective is to use cruise and ballistic missiles on the same targets so as to multiply the effects (e.g. neutralization of defense means by cruise missiles then destruction of targets by ballistic missiles; saturation of defense means by ballistic missiles and destruction of targets by cruise missiles). Such a combination requires a certain amount of operational coordination, to assure that all missile salvos reach the fixed targets at the same time. However, degraded use of cruise missiles is possible and some countries might choose to use their arsenals even under non-optimum conditions[16].

[15] The study performed by McCausland concluded that 20-30% of air sorties performed after Iraq used missiles in 1991 were related to attempts to neutralize the SCUD launch system.

[16] In this respect, see minimum use of its capabilities by Iraq during Iraqi Freedom as an extreme example.

Possible effects include:

- cutting off the supply chain, which can have devastating effects (see the *Iraqi Freedom* supply line – tight logistics, for which even a short term interruption can have a catastrophic effect on the operation);
- zone pollution;
- reduction of political support/breakage of the coalition;
- polarization of some means;
- increased friendly fire. Unintended but plausible effect, depending on the nature of engagement rules selected by the air defense forces.

3.2 – Typology of potential targets

Several types of targets would be potentially vulnerable to the use of cruise missiles during the period before the conflict, in other words the period during which resource movements are made and during operational preparation[17],

- First type of target, fixed military infrastructures, means of transporting logistics or mobile systems. The purpose of neutralization of these targets is to slow or even stop operational deployment or to affect the ability of a coalition to complete an operation.
- Logistics flows:
  - transport, debarking and embarking means: RoRo (*roll-on roll-off ships*), cranes and docks, bridges and roads, control towers, runways;
  - associated resources: generation and transmission of electricity, transit zones.
- Fixed military means: control centers, ammunition storage areas, fuel storage areas, spare parts areas, camps.
- High value mobile military means (fixed or moving targets); heavy aircraft (AWACS, J-STAR, tanker aircraft, transporters), fighters and bombers[18], radar and air defense sites including antimissile defense, aircraft carriers, vehicles.

Cruise missiles also appear useful for striking political, economic or industrial targets which, if neutralized, have an impact on the determination of the States concerned to continue the operation undertaken[19]:

- political targets: decision centers of the host country (ministries and/or government) hospitals, densely populated areas;
- economic targets: generation and transmission of electricity, industrial installations (e.g. production of natural gas), essential companies (e.g. oil infrastructures).

[17] As an illustration, the « *Iraqi freedom* » operation that is a model of fast deployment, required about 4 months to transport slightly more than 100 000 fighters and their equipment.

[18] In deployment areas. The density of the ground deployment of aircrafts has a direct influence on the effect of an attack.

[19] This is typically the use chosen by the Clinton administration during some bombing missions in Serbia.

Note that not all targets are equally accessible, and therefore the degree of operational planning necessary to neutralize them is not the same (size of salvos, programming of approach vectors). Nevertheless, almost all are potentially interesting because they remain vulnerable to the use of low mass warheads[20].

Even if some military resources can be stored in infrastructures protected against bombardment, the cost of this protection is very high and it is not extended to include all the military resources that could be protected[21].

[20] Aircraft are particularly vulnerable, for example if they are not in hangars, because any damage will immobilize them. Note for example that AWACSs are very rarely deployed in hardened hangars, but however they are moved onto an air base once they have been deployed.

[21] For example, Taiwan has an underground air base at Chiashan that it can use to store some of its F-16s, which account for not more than one third of its air resources. (See J.-P. Cabestan, pp. 111-112.)

Proliferation of Cruise Missiles

1 – Procurement methods and constraints

Three solutions for the procurement of cruise missiles may be explored :

- Conversion of anti-ship missiles or drones: a priori, conversion is considered to be a simple operation, but it actually creates complex technical problems. For most existing missiles, it requires a modification to propulsion systems[22] and the navigation-guidance system (e.g. modification of the terminal guidance system). For example, conversion of an HY-2 would require a complete modification of the internal architecture. Conversion of some drones appears to be easier in comparison. This is the case for target drones that have characteristics similar to cruise missiles (e.g. Indian Lakshya, American MQM-107, Italian Mirach-100).
- Local development: several stumbling blocks have to be taken into account (propulsion, navigation), plus the integration problems that have already been raised. At this stage, few countries have undertaken development of unsophisticated or modern cruise missiles (apart from Russia, the EU and US); the exceptions are India (Lakshya, Brahmos in cooperation with Russia), South Africa (Torgos) and China (C-802, HY-4 and HN series in cooperation with Russia).
- Off-the-shelf purchase: China and Russia already offer high performance products for export: KH-65 (modified version of the AS-15), HY-4. The demand already exists as is clearly demonstrated by the "illegal" sale of six AS-15 missiles through a Ukrainian-Russian network to China and Iran since 2001.

One factor that might accelerate the rate of development of this type of missile is the deliberate or non-deliberate technological support. In this respect, we should note the possibility of obtaining complete missiles to perform reverse engineering. Thus, China apparently obtained a few intact Tomahawk missiles from Pakistan[23], on which it based the design of the turbojets fitted on the HN series. Iran has also succeeded in copying the French TRI60-2 engine, probably with the assistance of China and/or Pakistan.

Taking account of the operational concept is another constraint in terms of acquisition of cruise missiles. In this respect, the choice of the launcher(s) is of overriding importance, since not all are equally useful[24] in all scenarios and not all require the same level of engineering for integration. Similarly, aspects related to mission preparation and operational coordination (intelligence and digital mapping, integration of systems into forces, coordination between different armed forces) will affect technical and military choices.

[22] On the other hand, in some cases some missiles are pre-arranged for this type of conversion: this is the case for the Chinese HY-4 that is already fitted with a turbojet.

[23] This unconfirmed information appears plausible. They would be Tomahawks fired in Afghanistan. Iraqis have recovered unexploded Tomahawks on which they had undertaken reverse engineering work.

[24] Take account of the internal vulnerability of each carrier faced with means capable of neutralizing them. Thus, submarines and ground launchers are some of the systems less vulnerable to strikes.

2 – Cruise missile inventories

⇨ Several types of missiles are classified as cruise missiles, however they do not all have the same performances or characteristics:

- Long range anti-ship missiles (>100 km).
- Drones and unpiloted aircraft: some drones (fast drones, drones derived from model aircraft) or unpiloted airframes may be attractive as ground attack machines.
- Unsophisticated cruise missiles: this category includes all short-range missiles (<300 km), with no or little capacity for low altitude flight, or with target precisions more than a few tens of meters.
- Modern cruise missiles: all missiles with range >300 km, with low altitude flight capabilities and/or stealth characteristics and target precision of the order of one meter.

⇨ The concept of the cost/efficiency ratio must be taken into account to measure the advantage of cruise missiles. This relates to comparative costs between this type of missile and firstly fighter aircraft and secondly ballistic missiles. These costs take account of the missile itself and the directly associated operational infrastructure.

	Penetration capacity	**Range**	**Possible carrier**	**Payload**	**Types of targets in anti-access strategies**
Anti-ship missiles	+	-	All	-	⇨ Surface ships or submarines
Drones	-	++	Launched from the ground	+	⇨ Fixed unprotected military targets ⇨ Political or economic targets
Unsophisticated cruise missiles	-	-	All	-	⇨ Fixed unprotected military targets ⇨ Political or economic targets
Modern cruise missiles	++	+	All	-	⇨ Fixed or mobile military targets ⇨ Political or economic targets

++: Very good performances
+: Good performances
-: Poor performances

3 – Status and prospects for proliferation of cruise missiles (outside the United States and Europe)

3.1 – Russia

Russia, alongside the United States, is still one of the main producers of cruise missiles for anti-ship or ground attack purposes.

Moscow has developed long-range cruise missiles and supersonic missiles for anti-ship attack, that can also be used against ground targets. These supersonic missiles are available for export and can be the subject of international cooperations, like that existing with India on a variant of the SS-N-26 Yakhont [25].

The Russian organization specialized in the development and integration of cruise missiles is the Raduga design office (also NPO Mashinostroyenia) set up in Dubna near Moscow, but it has several plants, for example in St-Petersburg.

Without discussing all of the programs, it is interesting to summarize the main systems that the Russian authorities consider to be "exportable"[26]:

Turbofan missiles:

- ⇨ KH-55: this cruise missile using a turbofan engine was designed as a thermonuclear weapon carrier and can be fired from fighter aircraft (AS-15 version) or submarines (SS-N-21 version). Its theoretical range is between 2 500 km and 3 000 km for a 280 kg payload.
- ⇨ KH-65: export version of the AS-15 ground attack missile (given range 300 km) equipped with a turbofan engine, the national version having a range of 1 500 km.
- ⇨ KH-101: missile under development with conventional payload, designed to replace the KH-55; the KH-101 will have a range of 5 000 km and a payload of 400 kg[27].

Supersonic missiles:

- ⇨ Klub/3M54E/SS-N-27: already sold to India. China would like to acquire it. Its range is 250 km and it carries a 200 kg warhead. The Klub uses a turbojet for the cruise phase and contains a separable head with supersonic speed.
- ⇨ Yakhont/SS-N-26: under development, China would like to acquire it. The BRAHMOS[28], a derived version of the missile with a range of 280 km for a payload of 220 kg, has been under development in cooperation with India since 2003 and should come into service in 2005 for deployment on submarines[29].
- ⇨ Moskit-Sunburn/SS-N-22: supersonic cruise missiles with a range of 250 km.

3.2 – China

The performances of Tomahawk missiles during the Gulf war clearly convinced Peking that it should acquire equivalent missiles for its own arsenal. After this operation, the Chinese military authorities started a study on the doctrine and resources of the People's

[25] See analysis of the program on www.globalsecurity.org

[26] For the MTCR and the Wassenaar arrangement, systems with a range of less than 300 km and a payload of less than 500 kg.

[27] See D. Tanks, « Assessing the cruise missile puzzle», pp. 11-12.

[28] For Bramhaputra–Moscow, names of two rivers on which the manufacturers concerned are installed.

[29] Therefore, note that the Russians make a difference between India and China.

Liberation Army[30]. It apparently considered several technological fields essential for the development of ground attack missiles in priority:

- stealth techniques;
- structure and command and control means;
- targeting systems.

3.2.1 – Cruise missile programs and acquisitions

The heart of the Chinese technological effort is the *Hai Ying Electro-mechanical technology academy (CHETA).* This structure, essentially based in Peking, has plants in several Chinese towns. In now employs about 15 000 persons distributed in several departments including propulsion, guidance and navigation, onboard data processing, military warhead design, integration, etc. The *Hai Ying Electro-mechanical technology academy* started by designing anti-ship missiles and then turned to the conversion of these missiles for ground attack missions.

Since 1992, cooperation with Russia appears to have become the pillar for Chinese development of cruise missiles. After this date, the Chinese reportedly received support from one or several teams of Russian technicians and engineers to make a national copy of the KH-65E (export version of the KH-55/AS-15)[31]. The 8359 research institute (division of the CHETA) apparently participated in this work. This support also reportedly included technology transfers in the stealth field (reduction of signature).

The CHETA is exploring three main methods for development of missiles themselves:

- Conversion program: the C-802/YJ-82 missile (Saccade) demonstrates the Chinese ability to design a cruise missile from an anti-ship missile. The C-802 would be based on the C-801 anti-ship missile, with an entirely modified propulsion and navigation system to increase the range and precision of the missile. A longer range version (200 km) of this missile was deployed on the JH-7 fighter aircraft. This missile was exported to North Korea and Iran.
- Acquisition of anti-ship missiles. Peking already has SS-N-22 Sunburn supersonic missiles with a range of about 200 km installed on Sovremenny class destroyers purchased from Russia. China would also like to acquire Russian SS-N-26 supersonic missiles (Yakhont-300 km range, Ma2.5)[32] for deployment on an Su-30 bomber and possibly on destroyers of the Sovremenny class. It would also like to buy missiles in the Klub/3M54 family (export version of the SS-N-19 Granat – actually proposed for export by Russia with a range of 250 km and a final speed of Ma2.5), that can potentially be deployed on the ground or on Kilo and SONG submarines. Since these submarines have an immersed firing capacity, the missile could be proposed in an environment change version or China could adapt it to such a configuration.

[30] Which is the source of the principle of the "limited local war in a high technology environment", see Howard, « The Chinese's People Liberation Army, short arms and slow legs », pp. 17-18

[31] Persons from the RADUGA design office that designed the KH-55 missile.

[32] Designed to replace the Moskit/Sunburn SS-N-22 already purchased by Peking.

⇨ Development of a modern cruise missile: the development program for a cruise missile called the X-600 apparently began in 1977[33]. This missile, which could be the *Hong Niao-1* (HN-1), would be similar to the Russian KH-55/AS-15 by the *Raduga* design office. Apparently Russian experts were also engaged on this program, or China may have benefited from direct transfers of Russian missiles[34]. The missile with a range of 600 km was apparently deployed in the early 1990s equipped with a turbofan[35] and an inertial control unit updated by GPS (or GLONASS)[36]. An improved version (range between 1 500 and 2 000 km) with a modified propulsion system apparently came into service in 1996. Improvements to this second version included an updating system based on a ground comparison and altimetry, enabling a cruise altitude of 20 m. A new system, the HN-3, is apparently being developed with a range of 2 500 km. These missiles would be launched from land vehicles for the moment, but could eventually be deployed on a bomber or attack submarine.

[33] Richard Fisher, « China's new strategic cruise missiles: from the land, sea and air », June 2005.

[34] http://www.sinodefence.com/missile/tactical/lacm.asp

[35] This turbofan is apparently a Chinese design, although external assistance may have been received.

[36] The use of a constellation of 3 BEIDU Chinese satellites appears improbable, since this is a system in geostationary orbit not capable of providing sufficiently precise positioning data.

CHINESE CRUISE MISSILES

Missile	Propulsion	Range	Payload	Type	Status
C-801 (YJ-8)	Anaerobic	42 km	165 kg	Anti-ship	Deployed (SONG class submarine)
C-802 (YJ-802)	Turbojet	120 km	165 kg	Anti-ship / ground attack	Deployed (ground/air/sea versions)
HY-2 (silkworm family)	Anaerobic	90 km	500 kg ?	Anti-ship	Deployed
HY-4	Turbojet	150 km	500 kg	Anti-ship /ground attack	Deployed
HN-1	Turbofan	400-600 km	400 kg	ground attack	Deployed
HN-2	Turbofan	1 500 km	400 kg	ground attack	Deployed
HN-3	Turbofan	2 500 km	400 kg	ground attack	Under development
SS-N-27 Klub	Turbojet +supersonic head	250 km	400 kg	Anti-ship	Being purchased (Kilo submarines)
SS-N-26 Yakhont	Turbojet	300 km	220 kg	Anti-ship	Being purchased (Type 093 submarine + Sovremenny destroyer)
SS-N-22 Moskit/ Sunburn	Turbojet	200 km	300 kg	Anti-ship	Deployed (Sovremenny destroyer)

3.2.2 – Launchers

The main Chinese problem is now the carriers; their existing arsenal – ships – bombers, submarines – is largely obsolete and therefore particularly vulnerable to counter-force actions, or at least limited to deployment areas close to China. It is probable that missiles will be deployed either on new systems acquired from other countries (Kilo submarines, Su-30 fighter or possibly a Tupolev bomber), or on new carriers developed by Chinese industry (Type 093 submarines). The solution that appears most plausible in the short term consists of deployment on ground launchers (which would enable their operational control by the second Chinese artillery). In the mid-term, it is probable that combat ships (destroyers) and submarines (particularly to exploit air-to-underwater and underwater-to-surface missile solutions) will become the preferred carriers.

Peking has recently acquired or developed a series of carriers that could carry cruise missiles:

- ⇨ Several Su-30 squadrons (between 78 and 120 multirole fighters). This aircraft can carry anti-ship missiles. Peking has apparently negotiated the transfer of a license for its production.
- ⇨ 2 Sovremenny class destroyers (in 1999 and 2000, delivery of 2 additional cruisers is planned for 2005) each carrying 8 SS-N-22.
- ⇨ 4 Kilo class diesel submarines (with another 8 considered to be stealthier under production, that are apparently equipped with SS-N-27 Klub anti-ship missiles[37]).
- ⇨ 3 SONG class diesel submarines equipped with YJ-8 anti-ship missiles (and probably 5 in 2010)[38].
- ⇨ Peking is developing the class 093 nuclear powered attack submarine and should have 4 of these ships in 2010 capable of launching ground attack missiles (HN-3) or SS-N-26 anti-ship missiles.

3.3 – Taiwan

The *Chungshan Institute of Science and Technology* (CSIST) developed a copy of the Israeli Gabriel anti-ship missile in the early 1980s: the *Hsiung Feng*. The first missile, which started production in 1981, is provided with a rocket/anaerobic engine and has a range of about thirty kilometers[39]. The next version currently deployed on a surface ship, the *Hsiung Feng-II*, has a turbojet and its range is about 80 km[40]. Finally, several sources report the development of a *Hsiung Feng-III* (or *Hsiung Feng-II-E*) since 2001, which is described as being a long range ground attack or a supersonic anti-ship missile[41].

[37] Up to 6 per ship (see http ://www.sinodefence.com/navy/sub/kilo.asp).

[38] According to the DoD report to Congress in 2005, this submarine would have an emerged firing capacity.

[39] http://www.netmarine.net/armes/missiles/international.htm

[40] http://www.globalsecurity.org/military/world/taiwan/hf-2.htm

[41] « Missiles test successful, report says », *Taipei Times*, June 2005.

Apparently this missile was tested on June 5 2005 with a range given at 1 000 km[42]. However, this range appears exaggerated considering the existing capabilities of the Taiwanese development Institute[43], and the real existence of a supersonic version is also in doubt. However, the existence or the development of a cruise missile with a range of several hundred kilometers and with two roles (anti-ship/ground attack) is realistic[44]. Such a system could be effectively deployed in the long term under an aircraft and on a surface ship and thus provide Taiwan with an offensive capability against some Chinese towns.

3.4 – India

- ⇨ The Lakshya is a target drone equipped with a turbojet but for which a ground attack version could be developed. The first flight tests date from 1985. The maximum range is apparently 600 km.
- ⇨ Cooperation with Russia on the Yakhont will produce a joint supersonic anti-ship missile that can be deployed on a surface ship or submarines (Delhi has apparently acquired Russian Kilos[45]) and that could be used for ground attack missions[46]. This missile, called the PJ-10, was first tested in flight on June 12 2001. The most recent operational qualification test took place on April 16 2005 from an Indian ship.
- ⇨ India has apparently also acquired Klub missiles from Russia for integration on destroyers (also Russian) and on Kilo submarines[47].
- ⇨ India also concluded a contract with France for acquisition of Scorpene diesel submarines equipped with an SM-39 missile (missile with 50 km range launched from immersion).

3.5 – Pakistan

Pakistan has apparently initiated a cruise missile program called HATF-7/Babur with a range of 500 km. This missile would apparently be fired from a ground launcher and it seems improbable that it will be used on Agosta submarines in its current configuration. Pakistan already possess SM-39 missiles (Exocet).

A missile test was made on August 11 2005[48]. This was the first recorded flight test for this missile that would tend to suggest that the program is still in a development phase.

The possibility that this missile is to be developed in cooperation with China cannot be eliminated. Available pictures show a strong similarity between the Babur, the HN-1 and

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[42] The announced figures are not unimportant. The speed of the anti-ship version given at Ma2.5, corresponds to the speed of the SS-N-22 deployed on Sovremenny destroyers and the range of 1 000 km would allow Taiwan to threaten Hong Kong and Shanghai.

[43] J.-P. Cabestan, « China–Taiwan: is war conceivable? », pp. 86-87.

[44] « Taiwan Successfully Test-Fires Anti-Ship Missile: Report », AFP, November 2005.

[45] See D. Tanks, « Assessing the cruise missile puzzle », p. 13.

[46] Moscow is apparently applying pressure on Delhi so that it will only be possible to integrate this missile onto Russian carriers. Bulbul Singh, « Russia threatens to retain Brahmos source code », *Battlespace*, Update Vol. 7, Issue 40, October 2005.

[47] See M. Jasinsky, « Russia and India step up cruise missile cooperation », *Jane's Intelligence Review*, March 2002.

[48] « Cruise missile technology proliferation takes off », *Jane's Intelligence Review*, September 2005.

consequently the AS-15/Kh-55. Some sources also claim that South Africa and the Ukraine are involved in Pakistani program[49]. These countries could supply some subassemblies or components used for development of the missile (propulsion, electronics).

3.6 – Iran

China apparently supplied several tens of C-802 and HY-2 missiles and their launchers to Iran at the end of the 1980s[50]. Apparently, Teheran also acquired the capability of manufacturing and assembling these two missiles locally.

China/North Korea/Iran cooperation is sometimes mentioned in the literature describing modification of the C-802 missile for ground attack missions[51]. The announce from Teheran about deployment of a Ra'ad anti-ship cruise missile in spring 2004 is apparently the result of a cooperation initiated with Peking in 1995[52].

Furthermore, Iran illegally acquired six AS-15 missiles from the Ukraine in 2001. The transfer was revealed by Mr. Olmenchenko, Ukrainian MP in February 2005, and since then has been the subject of a legal investigation in Ukraine. According to this investigation, intermediaries of this operation including a Russian national employed by the Rovosoboronexport weapons export company, apparently used false end-use certificates to circumvent Ukrainian export control regulations. This missile with a theoretical range of 2 500 km was apparently part of a batch of Soviet missiles for which the nuclear warheads had been returned to Moscow as part of a bilateral agreement in the middle of the 1990s. It appears realistic to believe that Teheran has attempted to copy the delivered missiles since this sale, and particularly the propulsion part and the navigation system. On the other hand, considering available information about the state of the delivered missiles[53] and the relative inexperience of military units in the use of ground attack missiles, it seems improbable that they were immediately deployed in Iranian forces.

It should be quite difficult for Iran to adapt this missile onto an aircraft or submarine platform. The most likely solution would appear to be deployment on a mobile ground launcher or a surface ship. Furthermore, this should not create any particular operational difficulties for Iranians considering the ranges necessary to reach any American deployment areas in the case of a Gulf war.

The purchase of Ukrainian missiles could provide Teheran with a means of continuing the acquisition program of a long-range cruise missile and to have a precise operational system within a few years. Continued cooperation with Peking would enable the Islamic republic to accelerate such a program by allowing it access to work already done by the CHETA.

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[49] *TTU*, No. 554 October 8 2005.

[50] See Rex Kiziah, « Assessment of the emerging biocruise threat », pp. 45-48.

[51] The C-802, equipped with a turbofan is the most probable candidate for such a conversion that would include an improvement to the precision of the system.

[52] See the « Ra'ad cruise missile boosts Iran's military capability » article, *Jane's intelligence review*, April 2004.

[53] These would be missiles delivered to Soviet forces in Ukraine in 1987 to be fitted on long range bombers. Before it could use them, Teheran would have to design an appropriate head and also make modifications for a launch from another platform and to set up means and to do the programming.

Missile	Propulsion	Range	Payload	Type	Status
C-801/Karus	Anaerobic	42 km	165 kg	Anti-ship	Deployed (ground launcher)
HY-2/Noor	Anaerobic	90 km	500 kg	Anti-ship	Deployed (ground launcher)
C-802/Tondar	Turbofan	120 km	165 kg	Anti-ship/ground attack	Deployed (land/sea versions)
Ra'ad	Turbofan	300 km	500 kg	Anti-ship/ground attack	Under development

IRANIAN CRUISE MISSILES

3.7 – Israel

Israel has been developing a cruise missile called POPEYE Turbo/Delilah-Star-1 since the 1990s. This missile, fitted with a turbojet, has a range of several hundred kilometers[54] and was apparently fired for the first time from a Dolphin class submarine in May 2000. It was apparently deployed in a version fired from an aircraft and submarine in 2002 and some sources report integration of nuclear warheads on this missile[55].

[54] Existing sources provide varying figures of up to 1 500 km. However, it is conceivable that Israel has produced a missile of this range that would appear consistent with Tel Aviv's military needs. CRS Report for Congress, « Missile survey: ballistic and cruise missiles of selected foreign countries », p. 36.

[55] http://www.fas.org/nuke/guide/israel/missile/popeye-t.htm

SUMMARY TABLE OF CRUISE MISSILE ACQUISITION MEANS

	ANTI-SHIP MISSILES			GROUND ATTACK MISSILES			DRONES		
design	external	external	domestic	external	external	domestic	external	external	domestic
manufacturing	external	domestic	domestic	external	domestic	domestic	external	domestic	domestic
Russia			**SS-N-26 Yakhont**						
Russia			**SS-N-22 Moskit/Sunburn**						
China	**SS-N-26 Yakhont**		**C-801/YJ-8**			**HN-3**			
China	**SS-N-22 Moskit/Sunburn**								
DPRK									
India	**SM-39 Exocet**			**Klub**	**Brahmos**				**Lakshya**
Pakistan	**SM-39 Exocet**				**Babur**				
Iran	**C-801 *Karus***	**C-802 *Tondar***		**Kh-55/AS-15**					
Iran		**HY-2 Noor**	***Ra'ad ?***						
South Africa	**Exocet**					**Mupsow**			
Taiwan			**Hsiung Feng**			**Hsiung Feng**			
Israel			**Gabriel I - IV**			**Delilah**			
						MSOV			

Under development

Curb proliferation of cruise missiles and counter anti-access strategies

Two specific problems arise as a result of the increase in cruise missile arsenals and their improved operational performances:

- ⇨ How can proliferating countries be prevented from accessing cruise missiles considered to be possible anti-access strategy tools?
- ⇨ How can the use of cruise missiles in anti-access strategies be efficiently countered?

1 – Non-proliferation policies

Unlike other fields in proliferation of weapons of mass destruction, there is no international treaty preventing the design, production and holding of missiles (ballistic and cruise missiles). Such a system should be based on a discrimination logic similar to the NPT. Some States would be authorized to possess this type of missile while others would have to renounce them. Even if counterparts could be envisaged, for example such as easy access to space or civil aviation for countries that have renounced these missiles, it would appear difficult to make a treaty of this type universal.

Firstly, unlike nuclear, biological and chemical weapons, possession of missiles fitted with conventional warheads is considered to be legitimate. Furthermore their legitimacy is strengthened by the fact that, being precision weapons, they reduce the risk of collateral damage. Basically, it would seem unrealistic to prohibit cruise missiles alone without also prohibiting bombs or artillery.

Furthermore, assuming that most countries accept a discriminatory logic based on a counterpart system, how can exceptional cases like India, Israel and Pakistan and proliferating countries (Iran, Syria, North Korea) be dealt with? Starting a negotiation on a ban treaty would introduce the risk that contested subjects in the NPT would be raised again, weakening this treaty.

Alternative solutions based on historic examples have been mentioned[56]. The main solution would be to develop a universal treaty similar to the *Intermediate Nuclear Forces* (INF), obliging States to dispose of some of their arsenal. However, such a proposal would appear inapplicable in fact, due to the disparities of existing arsenals both in volume and in performances. The definition of universally accepted criteria for disposal would add to the difficulties already mentioned.

At the moment, the only realistic basis for missiles counter-proliferation policies is to create efficient tools to enable States that want to restrict and if necessary ban transfer of know how, goods and sensitive techniques, to do so. These elements are locks on missile programs that countries wishing to possess missiles will have to force.

[56] Canada is particularly advanced on these questions. For example, http://www.dfait-maeci.gc.ca/arms/missile2-en.asp

Therefore, the purpose of flow control policies is to increase access costs and thus slow down development programs (reduce the supply). National export control systems play a key role, their efficiency depends on the quality of implementation[57] and the shared will of States and manufacturers to control flows of goods and technologies.

Internationally, several tools have been developed since the end of the 1980s to coordinate the policies of production countries in terms of transfers of property and know how associated with missiles. The Missile Technology Control Regime (MTCR), created by the G7 countries in 1987 is the main regime of missile suppliers. But the Wassenaar arrangement also addresses this proliferation, although it is not dedicated to the question of missiles.

Since 2002, the United States has initiated initiatives to prevent physical transfers of equipment. The *Proliferation Security Initiative* (PSI) – and to a lesser extent the *Container Security Initiative* (CSI) – partly completes the measure by providing a framework for the use of operations to intercept proliferating cargos.

But efforts to reduce demand are still limited. Thus, setting up incentive measures (positive or negative) could weaken proliferation logic of some potential candidates. However, it could be legitimate to question the efficiency of such measures on proliferating countries, for which access to cruise missiles is a major security stake (for example China or Iran).

1.1 – *The missile technology control regime*

By construction, the regime is focused essentially on the question of flow control of ballistic technologies. The structure of the technical annex, that lists goods and technologies to be controlled by directives produced by the partners, highlights changes to concerns of partners at different levels.

Although neither the technical annex nor the guidelines are restrictive, a large number of countries (within and outside the MTCR) use these two documents as references for the definition of their national control systems. Thus, Chinese law on export controls adopted in 2002 defined its own list of controlled goods on the annex. Similarly, Germany and the United States include the entire annex in their national legislation. Finally, it is worth remembering that the list of missile technologies submitted to the Sanctions Committee for the Iraq embargo was produced based on this document.

Ongoing revisions to the annex by MTCR technical experts resulted in it being extended or refined. However, no step has been undertaken to verify if the basic document of the regime is consistent with questions raised by proliferation of cruise missiles.

However, this document appears to be fairly complete in a first analysis[58], and the main early omissions have been corrected since the end of the 1990s:

- ⇨ Definition of the payload, finalized in 2003, to clear the existing ambiguity on subassemblies.
- ⇨ Classification of missiles with a range of 300 km in the second category, so that they can be controlled.

[57] Respect of control procedures, efficiency of customs services.

[58] See the summary table in appendix 3.

- ⇨ Addition of missiles designed or modified for spreading purposes to the list of category 2 equipment in the plenary meeting in 2003 in Buenos Aires.
- ⇨ Elimination of the minimum altitude from which satellite navigation systems are controlled.

Furthermore, most subsystems used in a cruise missile and the technologies associated with their manufacturing and design are included in the appendix.

The technical annex and guidelines could still be improved in many ways. Decontrol of components intended for aviation is now considered to be one of the main weaknesses of the regime, as emphasized by several authors[59]. However, it appears difficult and probably unnecessary to attempt to apply the same conditions everywhere, for example by applying the same level of control to all goods designed for civil aviation. Nevertheless, it could be useful to widen the definition of the control domain for some products. This is the case particularly for satellite navigation systems, for which the parameters could no doubt be further refined[60].

However, the main weaknesses of the MTCR are based on its inherent nature and its current and future composition, rather than the relative imperfection of the founders' texts.

The MTCR suffers from a first structural weakness regarding the question of cruise missiles, since by construction, the regime is only concerned with missiles and ignores environment technologies including space observation, geographic digitization and electronic warfare[61]. Specifically, the regime does not impose any particular controls on the partners for transfers of means for effective use of cruise missiles. However, it appears difficult to extend the scope of the MTCR to these types of technologies that are in no way specific to these missiles. Particularly because the Wassenaar arrangement, another group of suppliers, is considered to be competent in the subject. However, it should be noted that at the moment there is no official external coordination between the two groups of suppliers on these subjects.

The second weakness is that the regime is not at all restrictive and members remain free to take sovereign decisions in terms of exports. The technical annex and guidelines are given for guidance and their translation into national regulations (and facts) is left to the initiative of the legislative authorities of the partners. In short, the implementation and efficiency of the MTCR depend on the good will of its members.

When the regime was created in 1987, it was firstly a means of coordination of export policies for countries *with coherent non-proliferation objectives*. Successive extensions[62], sometimes made on political bases[63], have brought several States that did not share the initial objective around the table. The MTCR is currently becoming a non-proliferation forum rather than an inter-governmental coordination authority, for example the regime has been having repeated difficulties in finding a consensus on some initiatives

[59] See the « Cruise missile proliferation » example, CRS Report to Congress, July 2002.

[60] A threshold velocity fixed at 600 m/s is still in place, which could usefully be reviewed to take account of slow drones.

[61] For example, some types of electronic warfare can be used to position radar sources.

[62] From 7 members to 34 members in 2003, with 13 candidatures still pending including China and Libya.

[63] Case of South Africa (1995), Russia (1995), Ukraine (1998) and also Brazil (1995).

concerning current issues[64]. This trend can only be accelerated by continuing the logic of widening the regime that is supported by several partners. The candidature of China in 2003, fairly broadly supported officially[65], raises the problem of the attitude of Peking towards missile nonproliferation and again the question of changes to the regime's historical objectives.

Furthermore, particularly in the field of cruise missiles, it is important to note that not all partners satisfactorily implement the directives and the technical appendix. The exposure at the beginning of 2005 of illegal sales of several Kh-55/AS-15 airframes by Ukraine in 2000, illustrates the fact that control of cruise missiles technologies by the former Soviet republics is not sufficiently good to put an end to one of the essential sources of proliferation. Cooperation of Russia with China and India and related technology transfers also show the need for Moscow to extend the same control level for cruise missiles as is used for ballistic missiles.

The question now is to know whether Russia, and other former States in the Soviet Union will genuinely choose such a policy, bearing in mind the economic consequences that it might have on the military-industrial complex. Missile transfers are only interesting if they accompany the sale of launchers (aircraft, ships or submarines). China is the leading market for Russian aircraft and warships[66]. China's purchases of military equipment from Russia between 2001 and 2004, amounted to 9.4 billion dollars, out of a total import amount of 10.4 billion dollars[67]. Russia's second largest customer is India with exports of military equipment equal to 6.2 billion dollars over the same period. Iran is Russia's third largest customer but its total contracts with Moscow are only for 1.35 billion dollars.

In the last few years, Russia has accepted technology transfers in the form of cooperation programs and licensed production by its main customers, in order to win new markets[68]. In this context, restrictions imposed by tighter national export control would create an economic and commercial risk that Moscow is apparently not ready to take at the moment.

1.2 – The contribution of the Wassenaar arrangement

The objective that the Wassenaar arrangement has set itself is to « promote transparency and greater responsibility in transfers of conventional weapons and Dual-Use technologies, to contribute to regional and international security and stability »[69].

[64] The case of the press declaration published during the October 1998 plenary meeting in Budapest in which there are only two lines on the North Korean launch in August, leaving the President of the regime free to comment on the subject, illustrates recurrent difficulties of the regime (http://www.mtcr.info/english/press/budapest.html).

[65] See the French-Chinese declaration adopted during the visit by Hu Jintao to Paris in January 2004. http://www.elysee.fr/elysee/francais/ressources_documentaires/asie/chine/declaration_commune_franco-chinoise_visite_d_etat_de_m_hu_jintao_president_de_la_republique_populaire_de_chine.2334.html

[66] CRS report to Congress, « Conventional Arms transfers to developing nations, 1997-2004 », August 2005, pp. 8-12. See also http://www.sipri.org/contents/armstrad/atrus_data.html

[67] Contracts signed with Russia for the year 2004 are equal to 2.1 billion dollars (source SIPRI database on weapon sales).

[68] For example, cooperation with India on the Brahmos program, or production of the Su-27 in China.

[69] See initial elements of the Wassenaar arrangement: http://www.wassenaar.org/2003Plenary/initial_elements2003.htm

The technologies appearing in Dual-Use and military lists of the arrangement cover a much wider scope than the cruise missiles technology alone. However, some technologies have direct applications in this field and are not listed in the MTCR[70]. Therefore, the Wassenaar regime is complementary to the MTCR in terms of the struggle against proliferation of cruise missiles. In particular, technologies related to mission preparation are partly covered by technical lists, although this coverage remains general.

Like the MTCR, the arrangement is built up around a group of States that are intended to coordinate their policies in terms of export control. Similarly, partners have sovereign rights for application of the directives. These directives are much less constraining than MTCR guidelines. In particular, there are no particular directives about the export of any of the goods or technologies appearing in the appendices, while the MTCR recommends « *a strong presumption of refusal to export* » for category 1 goods. Therefore Wassenaar is like a code of good practice in terms of export control. Essentially, it is based on a transparency mechanism by which the States authorizing transfers refused by another partner must notify this authorization to the entire regime[71]. However, it suffers from a major weakness in the absence of a *no-undercut* clause that would oblige a partner to refuse an export if it has already been refused by another member country[72].

Particular directives for technologies related to cruise missiles alone could be set up. For example in 2003, the regime adopted elements related to export control for ground-air missiles fired from the shoulder (MANPADS) specifying the conditions under which transfers of this type of system can be authorized[73]. However, a consensus was needed between the 39 members of the Wassenaar arrangement to reach such a solution. To be useful, these particular directives must reinforce members' obligations in terms of control of the technologies and goods concerned, in addition to the technical appendix of the MTCR[74]. As we have seen, some members of the MTCR (also members of Wassenaar) now have objective reasons to be reticent about any initiative that would hinder exports of this type of technology. Therefore it seems unlikely that the Wassenaar arrangement would adopt such an approach.

Therefore, the contribution of the Wassenaar arrangement to the nonproliferation of cruise missiles at the moment depends essentially on the existence of the common list of goods and technologies that must be subjected to national control. This list must be exhaustive and upgradeable[75], because it is used as a common denominator between all partners, some of whom include it *in extenso* in their national legislation[76]. Thus, the addition of drones "controllable outside the operator's sight"[77] in 2003 enabled most partners to impose control for the export of drone technologies (including for the civil market).

70 See the table in appendix 3.

71 The MTCR only has an optional refusal notification mechanism.

72 CRS report for Congress, « Cruise missile proliferation », July 2002, p. 5.

73 http://www.wassenaar.org/2003Plenary/MANPADS_2003.htm

74 For example, by applying a « strong presumption of refusal» on transfers participating in the design, production or use of missiles in MTCR category 1.

75 It is amended on an annual basis, like the technical appendix to MTCR.

76 Case of the European Union through the common regulation on the export of dual-use goods or the United States within the *International Trade in Arms Regulations* (ITAR – for military equipment) and *Export Administration Regulations* (EAR – for dual-use goods).

77 Category 9.A.12.

1.3 – *The Proliferation Security Initiative, first element of a response to weaknesses in control regimes*

Although it is desirable to strengthen supplier regimes, it is clear that their degree of efficiency is strongly dependent on the will (and in some cases the real capacity) of the players involved to build and implement efficient export control systems.

Several exogenic phenomena cast doubt on the model of these groups alone as the only international tools:

- ⇨ The organization of criminal missile technology traffic networks; the Ukrainian example demonstrated the degree of refinement of these networks based on weaknesses in control regimes in some States. Thus in this case, according to declarations made by the in-charge Ukrainian judge, the network used false Russian documents (a priori final user contracts and certificates) to obtain authorization to export the missiles[78]. The financial flows accompanying this matter apparently passed through several screen companies set up in various countries including Cyprus and the United States[79].
- ⇨ The development of cooperation between countries not belonging to control regimes; the phenomenon is still much less important than for ballistic missiles. However, Chinese progress in the field of cruise missiles suggests the appearance of technology flows towards its usual partners (Iran and Pakistan). For example, the Babur program for which a flight test was made in August 2005, could be the result of a Sino-Pakistani cooperation.

The Proliferation Security Initiative (PSI), officially launched in May 2003, provides the first elements of a response to these problems. The PSI has several objectives[80] :

- ⇨ Facilitate and accelerate an exchange of information between its members related to proliferation activities.
- ⇨ Coordinate action (including legal) by participants to enable interception of cargos carrying weapons of mass destruction, and their carrying means and associated goods.
- ⇨ Carry out interception and search operations on suspect sea, land or air cargos, respecting applicable national legislations and international conventions.

Since it was set up, participants have been extremely discreet about operations carried out under the auspices of the PSI. It should be emphasized that this initiative is not based on setting up an official international institution, but rather on the principle of informal cooperation agreement between willing States.

Before adoption of the PSI, the Spanish navy had boarded a North Korean ship containing 15 SCUD missiles being sent to the Yemen, in November 2002. However this ship had to be released due to the lack of any legal basis for seizing the cargo[81].

[78] Paul Kerr, « Ukraine admits missile transfer », May 2005.

[79] Bill Gertz, « Missiles sold to China and Iran », April 2005.

[80] « Proliferation Security Initiative », CRS Report for Congress, January 2005.

[81] David B. Rivkin Jr. and Lee A. Casey, « From the Bermuda to the So San », January 2003.

The only PSI-like interception that received a certain amount of publicity occurred in the Mediterranean, and was on the German *BBC China* cargo en route towards Libya in October 2003. The cargo contained thousands of parts for centrifuges, from Malaysia but supplied by the AQ Khan network, and was seized at this time[82].

These operations (and no doubt there are others)[83] show the advantage of the PSI as a tool complementary to supplier regimes in the field of missiles and other unconventional weapons. They are applicable in cases in which these groups are completely powerless, in other words for exchanges that take place outside member countries.

However, it is important to realize that the PSI also has weaknesses, as emphasized particularly by the interception of the *So San*. These weaknesses are legal as well as practical.

Firstly, the PSI is based on the conclusion of interception agreements with the States under which ships are registered, for maritime interception outside territorial areas. The United States has already concluded agreements of this type with Panama and Liberia, two of the States that supply most convenience flags[84]. However, this strategy is limited, as illustrated by the case of the *So San*. If proliferating States choose to use their own fleet for transfers of sensitive equipment, like Pyongyang, and avoid territorial waters (and ports) of member countries of the PSI, there will be only limited legal bases for interceptions of missile-related cargos[85]. North Korea, China and also Iran have large commercial fleets[86] that could be used for this type of operation. Similarly, apparently there is no legal basis at the moment for intercepting air or land vehicles registered by governments[87].

The lack of coherence between national legal frameworks is a second major difficulty for efficient application of the principles of the PSI. This is the case particularly concerning conditions for seizing cargos and for initiating proceedings against the persons involved. In the case of a cargo chartered from country A, that country B considers suspect and requests interception, and that is finally intercepted by country C, the national laws of country C will be applicable. However, if these laws do not criminalize transit or transfer of the goods concerned on its territory, then it becomes impossible to make a seizure; Similarly, the lack of positive law on brokering activities in one of the countries concerned will prevent proceedings from being taken against the brokers involved in such a matter.

In an attempt to overcome this weakness, the United States requested and obtained adoption of a resolution by the United Nations Security Council, applicable particularly to reinforcement of national proliferation control measures. In article 3 of resolution 1540 voted on April 29 2004, the Security Council:

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82 http://www.carnegieendowment.org/publications/index.cfm?fa=view&id=17420&prog=zgp&proj=znpp

83 During a speech given on May 31 2005, Condoleeza Rice mentioned that 11 interceptions were successful during the previous 9 months within the framework of the PSI. http://www.state.gov/secretary/rm/2005/46951.htm

84 CRS Report for Congress, « Proliferation Security Initiative », CRS Report for Congress, p. 3.

85 This is not necessarily true for illegal goods or substances with regard to the NPT, the CIAC or the CIAB.

86 Iran has the largest merchant fleet in the Middle East with 147 merchant ships (Saudi Arabia has 50); China has 1 627 ships flying under a Chinese flag. « Study of sea transports», Secretariat of the CNUCED, 2004, p. 34.

87 « Proliferation Security Initiative », CRS Report for Congress, p. 4.

« *decides that States must take and apply effective measures in order to set up internal control mechanisms to prevent proliferation of nuclear, chemical or biological weapons or vectors for these weapons, including setting up of appropriate control mechanisms for related elements and that for this purpose they must:*

- *(...)*
- *(…)*
- *Fix and set up appropriate and effective measures for frontier and police controls so as to detect, dissuade, prevent and combat traffic and brokering of these products, if necessary calling upon international cooperation, in agreement with the legal authorities of the country and respecting its legislation and international law.*
- *To set up, perfect, evaluate and institute appropriate and effective export and transfer control tools in the country for these products, including appropriate laws and regulations to control their export, transit, transfer and re-export (...)* ».

A monitoring committee set up for this resolution, responsible particularly for making an audit of national control means, identified disparities in control tools. Even if no measures are planned to make existing systems coherent, resolution 1540 does have the merit to encourage responsible States to align their national legislation onto minimum standards, particularly in setting up control of transit and transfer activities that are one of the bases of proliferation traffics. However, this initiative does nothing to solve the problem of a precise definition of goods and technologies to be controlled.

1.4 – *Theoretical control of intangible technology transfers*

The question of effective control over transfers of technology and know how remains a problem for the PSI and for supplier regimes. As we have seen, both material and immaterial goods (software) contributing to the acquisition of a cruise missile capacity have become commonplace in the 1980s and 1990s, although some are still difficult to access. The essential lock to be forced by a proliferating country that wishes to enter into the possessor’s club is now the capacity to integrate all the components concerned into a technically and militarily efficient operational system.

Know how and technologies can be accessed in several forms: cooperation programs, training (technical and operational), data transfers (tests, study or research results, work in a company, etc.), and may be in material or immaterial forms.

Due to progress with data transfers, some Americans consider, for example, that simply monitoring the presence of Russian technicians is clearly inadequate to evaluate the degree of help provided to the Chinese. A physical presence is no longer essential and technical assistance may be provided from elsewhere.

Control of these transfers is still in the very early stages, although several countries also officially apply export rules to technologies associated with sensitive goods.

The United States appears to have the best organized system on this subject based on the « *deemed export* »[88] concept. The rule consists of imposing an export license on every American company if it might be in a situation to transfer know how related to goods subject to control. For example, if an American company would like to engage a foreign worker to work on a sensitive product (manufacturing, design, etc.) it must obtain a license before it can do so. Checks on foreign trainees and students also form part of the range of means implemented by the United States. Washington strengthened its student visa control system in 2002, by submitting every new request to a prior checking system including a review of the possible consequences in the field of weapons of mass destruction and vectors[89].

Other States apply export controls to technology transfers in the same way as for material goods. This is the case for France for war and similar equipment according to article 3 of the October 2, 1992 Order. This text submits data that could be used to reproduce military equipment, and particularly cruise missiles and their specific components, to export authorization procedures.

Despite the existence of these legal mechanisms, the main difficulty in controlling intangible technologies is the efficiency of their application. This depends essentially on the capability and the will of the players concerned to set up internal systems to restrict illegal transfers. These systems can only be credible if the governments concerned maintain continuous control and encourage companies to set them up through counterparts, as is starting to become clear on the other side of the Atlantic, and also in Europe to a lesser extent.

2 – Dismantling anti-access strategies

There is no doubt that proliferation is continuing, despite the progressive setting up and reinforcement of control mechanisms for flows of goods and technologies associated with cruise missiles since the beginning of the 2000s. As we have seen, several countries that might be opposed to the United States and their allies in regional crises have made technical and financial efforts to obtain an arsenal that could be used in anti-access strategies. Some already have modern systems that pose a threat at regional entry points for western forces.

Therefore, it is essential to set up means, strategies and policies to assure access to potential theatres of conflict in scenarios involving the use of cruise missiles by the enemy.

The objective for western planners is firstly to assure the capacity of potential host countries to resist dissuasive logics that could make them withdraw their support from coalitions that wish to deploy their forces on their territory. The question of the degree of anti-cruise missile protection for these States and the need for the coalitions involved to reinforce it in case of crisis is at the heart of this problem.

[88] Karen Day, « The experience of one Nation that has implemented intangible transfer controls », Department of commerce, 2000. http://www.bis.doc.gov/News/Archive2000/DayOxfordSpeech.htm

[89] « Homeland Defense Could See Tighter Controls On University Education », AFP, April 10, 2002.

Protection against cruise missiles, as stated by the Department of Defense in the Inter-Armed Forces theatre defense doctrine[90], is based on three pillars:

- ⇨ Passive protection: designed to fortify forces, systems and critical infrastructures before an attack, including duplication of key capacities, development of recovery plans after an attack, dispersion of essential means and hardening of targets;
- ⇨ Active protection: based on anti-missile defense means and jamming and counter-measure means;
- ⇨ Counterforce / counterattack: includes all systems designed to neutralize missile-related infrastructures (launch sites and command-control)

Command and control networks are coordination tools common to the three pillars.

2.1 – Command and control

Command and control systems are active at several levels in the defense against cruise missiles. They include both detection and tracking tools (including intelligence collection means) and networks used for transmission of data related to cruise missiles and coordination of defense actions.

Warning means are designed to detect and track missiles throughout the flight phase. This function includes discrimination of these missiles from the environment. The data obtained are then transmitted through the network(s) to active, passive and counter-force defense means.

Detection is particularly problematic faced with cruise missiles.

Infrared spatial warning means currently deployed or under development in the United States (*Defense Support Program* et *Space Based Infrared Sensor*) are incapable of detecting flying objects under cloud cover. In general, it can be assumed that these systems are incapable of detecting and tracking the path of cruise missiles reliably (in other words useful for the remainder of the defense architecture) due to their weak infrared signature[91]. Conversely, airborne infrared systems may be more suitable provided that they can move about under cloud cover (below an altitude of about 10 km). This final condition may limit detection because when traveling in this altitude, the endurance of existing drones is limited and they are vulnerable to the enemy's air defense. In summary, the use of infrared means is apparently not the best solution for the detection of cruise missiles at the moment[92].

Therefore, radar systems appear to be the main resource that could be used to detect this type of missile. Several technical obstacles can increase the difficulty of detection of cruise missiles:

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[90] « Doctrine for joint theater missile defense », US Joint Staff, Joint Pub. 3-01.5, February 1996.

[91] David Tanks, « Assessing the cruise missile puzzle », pp. 17-18.

[92] Ibid, p. 19.

- The radar cross-section for the most modern radar systems is small in some intervisibility configurations[93], and for most frequencies commonly used in the military field for flight path plotting[94].
- Detection of low altitude flying object requires the ability to differentiate the reemitted signal from parasites generated by various mobiles (birds, vehicles, etc.).

These factors influence the radar detection range for detecting cruise missiles. In particular, means based on the ground are affected by severe constraints due to masking due to relief and the curvature of the earth. Signature reduction techniques (absorbent materials or geometry) further increase detection difficulty.

Several technical solutions are now possible to facilitate detection of cruise missiles:

- Elevation of radar systems: the objective is to place radar systems at an altitude either on relief (mountains, cliffs, etc.) or on mobiles (aircraft, drones or balloons) so as to limit ground masking effects. However, this solution is only possible if the sensors concerned are capable of detecting a missile signal among parasites reflected by echoes on the ground;
- The use of bistatic or multistatic radar systems for which sources and the receiver are separate; a conventional radar operates by emitting a signal and receiving its echo that the system then classifies as a function of a library of threat data. Emission and reception functions for bistatic or multistatic radar systems are separate, with several emitters illuminating the target, and signals reemitted from the target are received by one or several receivers. This method can give better results when faced with stealth targets, by increasing the number of illumination angles. Non-military sources/emitters can also be used in this field, and this is referred to as passive detection[95].
- Integration of all available information into a network; networking provides a means of integrating several data sources to obtain a more precise air picture[96]. The sources are various available sensors (alert and firing control radar, infrared, optical) but also other elements such as friend-foe identification elements or data output from eavesdropping systems.

The United States has initiated several programs designed to improve the capability of forces to detect and track cruise missiles since the late 1990s.

Modernization of the radar in the AWACS E-3 airborne system began in 1994 as part of the *Radar System Improvement Program* (RSIP), with the declared objective of improving the detection capacity against stealth mobiles, particularly cruise missiles[97].

[93] In other words the position of the missile with respect to the radar. For example, this is the case when the missile front is facing radar waves.

[94] This is not the case for low frequency warning radar systems (HF, VHF bands). See Lee Upton and Lewis Thurman, « Radars for the detection and tracking of cruise missiles », *Lincoln Laboratory Journal*, 2000.

[95] For example, television, radio or telephone emitters as sources, using one or several receivers dedicated to processing signals reemitted by mobiles. David Tanks, « Assessing the cruise missile puzzle », p. 21.

[96] Concept of *Single Integrated Air Picture*.

[97] http://www.fas.org/man/dod-101/sys/ac/e-3.htm

Modifications made to processing software and radar increase the detection and positioning ranges of targets with weak signatures. One of the problems with the AWACS system is detection continuity. Although it is possible to maintain permanent detection of an area in theory[98], the cost of the operation is much too high for this solution to be used except in a crisis or conflict situation.

Several studies financed by the US Air Force and the US Navy were started in the 1970s and are still continuing to improve modeling of background noise and parasites affecting detection capabilities of mobiles flying at low altitude[99]. In particular, these models must be capable of improving the capacity of radars to detect targets flying at very low altitude. These studies enabled the US Air Force to continue with development and deployment of firing control radar systems on a small number of F-15 aircraft dedicated to missiles flying at low altitude[100].

The development of a system of sensors on Balloons, the *Joint Land Attack Cruise Missile Elevated Netted Sensor* (JLENS), was initiated in 1996 and awarded to Raytheon in 1998. The objective is to deploy radar systems designed to detect cruise missiles, participate in generation of the single integrated air picture, and assist interception systems for engagement, on static airborne platforms connected to the ground. Each system thus comprises two balloons (one 71 meters wide) the first being designed for detection and the second contributing to management of the engagement[101]. They will have to be integrated into air defense command and control networks, comprising the *Cooperative Engagement Capability* of the Navy or the Army's anti-missile defense command system and will thus be connected to the PAC-3 and AEGIS systems. The detection range of JLENS for missiles flying at an altitude of 100 m would be about 250 km, which would firstly make it possible to deploy them at a safe distance from areas in which they would be vulnerable, and secondly to significantly improve performances for intercepting cruise missiles of air defense systems such as the *Patriot Advanced Capability*-3.

JLENS systems can be deployed on a permanent basis at relatively low cost compared with the cost of AWACS[102] type airborne systems. Thus, development of the JLENS that in the long term includes acquisition of 12 complete systems[103], should make it possible to complete detection capabilities already provided by the AWACS fleet. However, the JLENS system has several disadvantages:

- ⇨ it is vulnerable to terrorist actions and special operations, because it requires a permanent operations base on the ground;

[98] As a reminder, the US Air Force has a fleet of 33 AWACS, Japan and South Korea each have 4 air surveillance aircraft.

[99] Lee Upton and Lewis Thurman, « Radars for the detection and tracking of cruise missiles », *Lincoln Laboratory Journal*, 2000.

[100] Adam Hebert, « Cruise Control », *Air Force Magazine*, February 2002.

[101] http://www.globalsecurity.org/space/systems/jlens.htm

[102] David Tanks, « Assessing the cruise missile puzzle », p. 26.

[103] For an estimated cost of 1.6 billion dollars. http://www.fas.org/spp/starwars/program/jlens.htm

- ⇨ its performances are influenced by weather conditions; in particular performances and operational availability would appear to be degraded particularly under unfavorable conditions (for example like those that occur in Asia)[104].

Cruise missile sensors and defense systems have to be integrated into the command network to take the maximum benefit from modernization of systems. The creation of a precise single integrated air picture[105] (including ballistic and cruise missiles, aircraft and helicopters) is based on collection and merging of data originating from all sensors. Based on this information, the command network can determine which defense means should be used to counter threatening mobiles (interceptors, counter-force or even passive protection). However, there are genuine difficulties with the principle of a single command network. It assumes a strong level of operational and technical interoperability between the armed forces concerned, each of which has organizational detection / tracking and defense means. In technical terms, it is necessary to be able to use systems capable of transmitting and processing a large quantity of information. American forces have not yet set up such a network, as is clearly illustrated by the use of anti-missile systems during the *Iraqi Freedom* operation[106].

Apart from detection, it is also important to take account of management of the discrimination function. Once a mobile has been detected, it has to be decided whether it is friend or foe, so as to set up interception and protection measures. Discrimination parameters differ depending on the political situation (peace, crisis, war) and the nature of the theater. Discrimination in wartime becomes easier by the fact that every detected unidentified mobile is generally considered to be enemy. Conversely, discrimination in peace time becomes more difficult due to the freedom of air traffic.

Development of the Air Command and Control System (ACCS) by the Atlantic Alliance based on the principle of organizing a network between defensive and offensive sensors and means to be able to manage all air operations[107], is a significant effort engaged by western forces to increase the overall air defense efficiency of Member States[108].

The US Navy *Cooperative Engagement Capability* (CEC) program is aimed at enabling all ships within a single group to use a single integrated air picture generated from all available ship and air sensors and to engage defense means more quickly and coordinate firing from the various available platforms. The CEC system that entered a production phase in 2003, should be fitted on the entire American fleet in 2008[109]. Exercises were carried out in the early 2000s in order to demonstrate the possibility of extending the CEC to land means, and particularly anti-missile defense means[110].

[104] Lockheed was awarded the development contract for a balloon flying at high altitude (20 000 m) in 2003, which would solve weather problems. http://www.globalsecurity.org/intell/systems/haa.htm

[105] *Single Integrated Air Picture*.

[106] D. Gormley, « Missile defense myopia: lessons from Iraqi War », 2003-2004.

[107] http://www.nato.int/issues/accs/

[108] The disparity of the Allies' means within the framework of a unified air defense, has obliged NATO to choose the solution of a network of networks, but apparently the selected architecture is perfectly satisfactory for the particular constraints of processing for several types of threats: ballistic, cruise, aircraft.

[109] http://www.jhuapl.edu/newscenter/pressreleases/2002/020624.htm

[110] David Tanks, « Assessing the cruise missile puzzle », p. 25.

Work, studies and programs initiated in the United States since the late 1980s in order to improve cruise missile detection capabilities and to coordinate air defense means are beginning to lead to specific products. However, financial investments are small compared with the reality of the threat, and in comparison with anti-ballistic missile defense. Moreover, the absence of an authority to federate technical and industrial efforts in the subject prevents the development of a system of systems integrating a set of disparate means into a single network.

2.2 – Passive protection

The special feature of passive protection is related to the variety of means and infrastructures to be protected, including mobiles (ships at sea); aircraft on the ground, men in transit or waiting areas, storage areas, command centers, economic or civil infrastructures.

Several complementary types of logic may be used to satisfy the need to guarantee survivability of elements necessary for an operation and access to theaters of operation.

The development of host infrastructures includes construction of additional bases (for example ports or airports) and also reorganization of logistic flows (flexbasing). Construction of bases is a long and expensive process. For example the development cost of American bases in Saudi Arabia is estimated at about 30 billion dollars[111]. Furthermore, since available construction sites have to be made available before the work can be started, the process depends very much on the political will of the host countries. At the moment, the trend appears to be towards a reduction in the number of regional locations[112].

Furthermore, the costs of hardening infrastructures are very high, although hardening is an ideal solution for protection against a cruise missile threat[113]. For example, the cost of a hardened aircraft shelter is of the order of 4 million dollars[114]. Thus it would appear to be impossible to effectively protect a large number of critical infrastructures to be deployed within range of enemy missiles, even for the United States. In this respect, note that the number of available hardened hangars for air means is small. Half of the US 1 400 hangars[115] are in South Korea and only about a hundred are located in Japan[116].

The number of key-equipment or infrastructures based in the area close to the theater of operation should be minimized, to help overcome this difficulty. Reducing logistics and support functions on site could be one solution to reduce this volume, however provided that routing times to advanced bases are compatible with operations times[117]. The concept of *flexbasing* is apparently applied to the Asian theater with the use of Guam as the

[111] C. Bowie, « The Anti-access threat and theater air bases », p. 55.

[112] For example, see the movement of American forces from the Prince Sultan base in Saudi Arabia to Al Udeid in Qatar, in 2003.

[113] John Stillion and John Orletsky, « Air Bases vulnerability to conventional cruise and ballistic missiles », pp. 30-31.

[114] Ibid, p. 31.

[115] Each can hold one aircraft.

[116] Others in Pakistan, India and Taiwan. C. Bowie, « The Anti-access Threat and theater air bases », pp. 25-26.

[117] In the field of air operations, the *flexbasing* concept developed by the RAND for the benefit of USAF forms part of this logic. http://www.rand.org/publications/MR/MR1113/

advanced logistic base for the Asia-Pacific theater[118]. Similarly, networking of command and control means could locate essential control centers further from potential threats.

The United States has also studied the development of mobile logistic platforms. The first project would be to assemble fixed platforms at sea in potential conflict areas that could act as a logistics, air and transit/grouping base for land forces. In particular, each base would include a 2 000 m long runway, and would be capable of accommodating 3 000 men and acting as a dock for ships[119]. The project, managed by the *Office of Naval Research* is still in the research phase and forms part of the *sea basing* concept. However this solution remains expensive[120] and questions are still being asked about the added value that it offers compared with existing means. Other technical solutions are being studied, such as the use of fleets of small ships that could be assembled at sea to form bases. As emphasized by Art Cebrowsky, the debate should concentrate on the question of operational utility at the moment, rather than programming type questions[121].

Dispersion on several bases or areas is another method for limiting the vulnerability specific to concentrations of men or equipment. Such a method requires the existence of zones and infrastructures in which personnel and displaced equipment could be accommodated. It also has an operational and financial cost because it globally increases support and maintenance needs of means deployed in the theater[122].

Putting resources and men at a safe distance consists of placing all or some of the means out of range of potential threats. In particular, this method can be used for part of air or naval resources, the limit being the efficient range of systems. Bowie estimates that the maximum separation distance for fighter aircraft is 2 700 kilometers[123]. Similarly, the range of onboard aviation makes it possible to keep aircraft carriers at a distance from potentially dangerous areas. However, there are several limits to this reasoning. Naval forces will need to get closer and closer to the coast in order to support land operations, while minimizing transit times of onboard resources. Therefore a balance has to be found between the evolution of the threat created by cruise missiles (in terms of range and carriers) and safety distances. In terms of onboard anti-missile defense means (AEGIS type), their efficiency depends predominantly on their position, and consequently there is a risk that they might be within range of the most efficient anti-ship missiles, particularly in Asian scenarios.

Camouflage for cruise missiles is designed to conceal objects from enemy intelligence in order to hinder the production of strike plans. The use of decoys is one possible solution, for example for stationary land or air means[124]. For naval systems, apart from the use of counter-measures, a reduction of radar and infrared signatures is the preferred method for reducing detectability and assuring passive protection of ships that might approach the

[118] « Guam emerging as potential strategic hub for US Pacific Forces », East-Asia Intel.com, November 2005.

[119] http://www.globalsecurity.org/military/systems/ship/mob.htm

[120] Several billion dollars per platform.

[121] « Sea Basing: poised for take-off », Office of Force Transformation.
http://www.oft.osd.mil/library/library_files/trends_372_Transformation_Trends_15_February_2005%20Issue.pdf

[122] C. Bowie, « The Anti-access Threat and theater air bases », pp. 56-57.

[123] Ibid, p. 63.

[124] For example, see Serbian use of this type of decoy to limit the efficiency of Alliance strikes during the *Allied Force* operation. However, the effectiveness of this type of means needs to be treated with caution. http://www.afa.org/magazine/June2000/0600kosovo.asp

coast to perform their missions. The Swedish Navy will have VISBY class corvettes starting from 2005, with hulls made entirely of composite materials and with a shape optimized to reduce signatures[125]. In 1998, France developed and deployed *La Fayette* class destroyers with a low radar signature, and superstructures made from composite materials. Other countries, including the United States with the DD(X) program and the United Kingdom with their TYPE 45 destroyers[126], have initiated developments to obtain more stealthy ships. However, these programs continue to be based on steel structures that are considered to be more reliable and resistant, and signature reductions are based on design skills[127].

Furthermore the DD(X) program, for which the first copies should be deployed starting from 2007, appears to be threatened by budget cuts envisaged by Congress. Although pure and simple cancellation of the program is not likely, a reduction in the number of units[128] or capacities[129] are possible options.

Military solutions for passive protection of civil populations and infrastructures appear to be too expensive to become widespread. However, some key sites can still be hardened. Fast dissemination of warning data is crucial for civil populations who are most directly concerned by the risks of the use of unconventional weapons, so that emergency dispositions to reduce the effect of this type of attack can be implemented[130].

2.3 – Active protection

Active protection consists of neutralizing attacking missiles so that they do not reach their objective.

The main method of passive protection is physical interception of attacking missiles to destroy them (or at least to damage them sufficiently to neutralize them). It may also consist of causing a malfunction of a critical part of the missile sufficient to compromise its mission (counter-measures).

Interception of subsonic cruise missiles is not difficult provided that the detection-discrimination-tracking system has performed its role. There is a variety of available solutions including air-air interceptors carried by fighters, medium or even short range ground-air systems[131], or close-up self-defense systems[132]. The interception range may cause a problem when faced with cruise missiles carrying unconventional loads against targets with a low level of passive protection. In this case, the use of short-range interception systems cannot assure non-dissemination of substances close to the target area. Conversely, this type of system is suitable for the protection of ships for which the

[125] http://www.naval-technology.com/projects/visby/

[126] Note also that hull sizes differ: about 200 m for DD(X), 150 m for TYPE 45 and 73 m for VISBYs. http://news.bbc.co.uk/1/hi/technology/3724219.stm

[127] Reduction of the emerged part, hull geometry, use of absorbent paints.

[128] Megan Scully, « Pentagon budget request swells to $419.3 billion, but procurement falls », *The Hill*, November 2005.

[129] « Pentagon may scale back US Navy DD(X) destroyer », Reuters, November 2005.

[130] Particularly in the case of a crisis, populations and emergency structures are equipped and prepared to face unconventional events (distributed protective suits, first respondent in alert).

[131] Air defense and anti-missile defense interceptors are suitable for intercepting subsonic cruise missiles.

[132] In general, large caliber guns with a high firing rate or very short range ground-air missiles.

feared event is a hit on the target by an anti-ship missile. It may also be suitable to complement the protection of air bases[133].

Options against supersonic missiles are much more limited. Systems that would be the most capable of interception are very agile supersonic ground-air systems capable of flying at low altitude. The ASTER French-Italian interceptor family was designed to counter stealth targets flying at low altitude, and satisfies these constraints. Future British TYPE 45 destroyers and HORIZON type frigates will be equipped with them[134]. The United States is working on modifications to the Standard missile (SM-2) for interception of supersonic mobiles flying at low altitude. The SM-6 ERAM (*Extended Range Active Missile*) could be deployed on future DDX destroyers to handle the threat of modern cruise missiles[135].

Finally, the placement of an active protection by layers, like antiballistic missile defense, appears the best means of responding to operational scenarios including firing of different types of cruise missiles (supersonic, low altitude, stealth, unsophisticated) in salvos. The layers must provide in-depth protection by engaging attacking missiles as quickly as possible (far layer), but giving priority to a significant close-up self-defense capacity to handle missile detected late or that managed to penetrate the first layers.

As emphasized by many authors[136], the ratio between development and acquisition cost of defense against cruise missiles and development and acquisition costs of cruise missiles is high. However, although it is worth trying to reduce the cost of anti-cruise missile defense to make it affordable, it would be absurd if the main reason for not developing it was to be financial. It is indeed essential to obtain the most efficient possible defense against cruise missiles during a war, considering the operational, economic and political effects related to their successful use.

The use of counter-measures is another active protection mode. Infrared or radar system decoys installed on surface ships are designed to mislead the terminal guidance of anti-ship missiles.

Less specific, the use of techniques for jamming signals from satellite navigation systems appears to be an attractive possibility for countering most cruise missiles. As we have seen, the dissemination of precise satellite guidance technologies is a factor that would a priori reinforce the threatening nature of proliferation of cruise missiles. Precise updating of the missile flight path through unauthorized use of the American GPS system, the only genuinely operational satellite system at the moment accessible to the general public, is a major factor in improvements to military performances of this type of missile.

The uncrypted civil signal (called the *coarse/acquisition* signal) is sensitive to relatively simple counter-measures :

- ⇨ Firstly, noise interference that consists of emitting a continuous signal designed to saturate the signal from satellites within an area[137]. This technique would

[133] John Stillion and John Orletsky, « Airbase vulnerability to conventional cruise and ballistic missiles », p. 46.

[134] http://www.royal-navy.mod.uk/static/pages/1973.html

[135] Patricia Kime, « Navy Pursues SM-6 as Defense Against Cruise Missile Threats », *Sea Power*, November 2004.

[136] D. Gormley, « Dealing with the threat of cruise missile », p. 73. Tanks, « Assessing the cruise missile puzzle », p. 28.

[137] http://www.computerworld.com/mobiletopics/mobile/story/0,10801,65096,00.html

make receivers integrated into enemy systems completely unusable, resulting in an important degradation in the precision of these systems[138]. Due to the low power of civil GPS signals, a relatively low intensity jammer could cover fairly wide areas[139]. This method could possibly be used to jam signals from other satellite navigation means (GLONASS, BEIDU).

⇨ Furthermore, management of the GPS constellation by the US enabled them to deliberately deteriorate the integrity of the time message sent by the satellites, which is an essential component of the positioning precision on the ground. By inducing an error in the time message on a few satellites at a given moment with respect to the reference time produced by the atomic clocks on the said satellites, the American authorities are capable of degrading positioning information across an entire country. Obviously, the consequences, if any, of such a decision on all human activities is a crucial element that would be taken into account.

A more complex technical solution could also be envisaged[140]. This would be to create "intelligent" jamming of the signal consisting of providing false positioning data to a system using satellite navigation means. There would appear to be severe technical difficulties with this solution, particularly the need to know the position and destination of the missile[141]. In particular, the detection and tracking loop would have to operate perfectly. A priori, this method is still infrequently used, but it would apparently be the most suitable for use against cruise missiles. It could be used to direct cruise missiles to areas with no particular vulnerability.

2.4 – Counter force operations

Destruction of launchers before they were able to fire cruise missiles is undoubtedly the best solution for defense against cruise missiles. However, the mobility of launchers (submarines, aircraft or vehicles) is such that the detection – decision – engagement loop would have to operate extremely quickly to enable firing on the launchers before they move, or protect or camouflage themselves.

Obviously, most of these launchers could be tracked by local detection assets, which in theory would mean that they could be targeted after they have launched their missiles[142]. But such sensors have several limits, the main of which is that it is impossible for some of them to operate above or inside unsafe areas. Therefore, placement of complementary means for example such as satellites should be envisaged that would be integrated into the command and control loop of counter-force and air defense operations. This integration is necessary to obtain a seamless system compiling detection-warning information, and data from sensors dedicated to tracking of launchers and activating the neutralization means. These neutralization means could be precision munitions (guided bombs, missiles), or special operations within enemy territory.

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138 For a cruise missile using a hybrid inertial GPS navigation system, the loss of the GPS signal could reduce the precision from a few meters to several kilometers.

139 According to Orletsky, a jammer with a power of 1 Watt could jam an area of about 16 km^2. J. Orletsky, « Airbase vulnerability to conventional cruise and ballistic missile attacks », p. 43.

140 J. Orletsky, « Airbase vulnerability to conventional cruise and ballistic missile attacks », p. 43.

141 J. Orletsky, op. cit., p. 44.

142 For example, using the JSTARS system. D. Gormley, « Dealing with the threat of cruise missile », p. 73 ; Tanks, « Assessing the cruise missile puzzle », p. 73.

In the same way as interceptions, counter-force operations depend on the capability to detect enemy missile firing as early as possible, and success of the coordination process between the different elements participating in the defense.

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Defending against cruise missiles, begins with the objective of setting up a system of systems structured around a command and control network capable of merging information from various sources and using these data to efficiently activate tools present on the operation theater. Setting up a defense architecture against cruise missiles requires prior production of special joint operation concepts to face this threat. This approach must tend to integrate the different components of air defense (anti-cruise and anti-ballistic missiles, anti-aircraft) to prevent friction due to the coexistence of several systems covering a common air space from becoming unmanageable.

Conclusion

Several modern cruise missile programs engaged in the early 1990s are now reaching maturity and could be deployed in the armies of several proliferating States in the short term.

This is the case for China which, with the support of Russian institutes specialized in the field and through direct acquisitions from Russia, has succeeded in developing several ground attack and anti-ship strike systems. In turn, China's usual partners could also benefit from the transfer of technologies, know-how or complete systems. The development of the Pakistani Babur ground attack missile is one source of concern because this missile, presented in Islamabad as being a nuclear warhead carrier, has obvious similarities with missiles possessed by Peking. Another concern is that Iran could obtain the know how necessary to develop such a weapon, through direct transfers or through an acquisition network, the existence of which has been known since the purchase of the AS-15 airframes.

Proliferation of cruise missiles is particularly worrying because their use in modern conflicts could affect existing balances. Anti-access strategies that could be adopted by States possessing these missiles, particularly in conflicts involving American forces, could significantly slow down military preparation, or even in the worst cases, deny western forces deployment.

The case of the Straits of Formosa provides an illustration. Performances of Chinese missiles are such that they create a real risk for American fleets and deployments in the region. In the case of a conflict, fast access of American forces to the theater is essential to counter a Chinese strategy aimed at the conquest of the island of Taiwan. The intervention that would be necessary within a few days to prevent the massive use of ballistic missiles against Taiwan from leading to fast capitulation of Taipei will be made more difficult by the use of cruise missiles by the Chinese Navy and Air Force.

On another scale, by providing its forces with modern anti-ship and ground attack missiles, Teheran would have the ability to deny a usable area to reduce the resolution of countries that could host American deployments in the Gulf region.

The effectiveness of existing non-proliferation means appears to be marginal in several respects. The missile technology control regime (MTCR), the main tool for control of flows of goods and know how, is a non-binding instrument based on the good will of its member countries. Even if the annex covers the spectrum of the technologies concerned relatively well, the only guarantee of its efficiency is the will of the members not to supply these goods to potentially proliferating countries. While communist China has become the main outlet for Russian weapon systems, questions may be asked about Moscow's real determination not to supply any more cruise missile to its client. Furthermore, the MTCR cannot prevent all flows of cruise missile goods and technologies, regardless of its efficiency. As was demonstrated in the affair of the sale of the AS-15 missiles to China and Iran, there are genuine underground proliferation networks, comparable to those that might exist for nuclear weapons. In this respect, the proliferation security initiative (PSI) is designed to complement supplier regimes. However, the PSI has not yet demonstrated its worth and, in particular, it needs to be able to manage situations resulting from intercepted loads. Furthermore, the PSI needs to adapt to deal with the situation by which proliferating countries use their own fleet for transfers of sensitive equipment. Although a change in international law would appear to be the right way to solve this problem, the adoption of resolution 1540 in April 2004 is nothing more than a first but still insufficient general framework .

Despite the existence of these non-proliferation tools, western forces are genuinely faced with the possibility of seeing cruise missiles used against them in anti-access and zone denial strategies. Defense tools must be developed to face this. These tools should be organized about a command and control system including detection, active protection and counter-force means. At this stage, it is clear that efforts made by Western States in terms of defense against cruise missiles have only been minimal when compared with efforts made for ballistic missiles. The high cost and long times associated with the design and production of a defense system apparently explain this lack of action faced with a threat still considered to be marginal. Although technical and operational solutions are starting to emerge, it is still necessary to create a precise definition of methods by which an anti-cruise missile defense system would be integrated into a more general protection against air threats from aircraft to ballistic missiles. Furthermore, systems currently being developed or deployed were only designed to provide protection to forces and are insufficient to satisfy the need to efficiently defend the public and host countries of such deployments against cruise missiles.

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Annexe 1 -
Technology of cruise missiles

Historical aspects

The V-1 was the first operational « cruise missile ». Navigation was based on an inertial system that could not be used for low altitude flight. The result was a high attrition rate due to the British detection capability and interception by piloted aircraft. V-1s were short range, imprecise, had predicted flight paths, were easily decoyed and their flight altitude was too high for them to be undetected. The result was a low penetration ratio (<50 %) and low efficiency (4 deaths/missile)[143]. More than 20 000 V-1s were launched onto London and the United Kingdom causing 39 000 victims.

Until the 1970s, the United States and Soviet Union continued to develop and deploy cruise missiles using the same technologies as the V-1. Their lack of precision and their low penetration capacity limited them to carrying nuclear warheads. With the arrival of intercontinental ballistic missiles near the end of the 1960s, the advantages of cruise missiles became less important and most programs were abandoned. However, this was the period during which turbo-engines were developed to achieve greater ranges for cruise missiles.

Three fundamental technologies appeared starting from the 1970s and 1980s, introducing a new advantage of cruise missiles by improving their flight capacity at low altitude and their precision:

- ⇨ In the navigation field: TERCOM (Terrain Contour Matching/navigation by comparison between a radar image of the ground and an image in the missile memory) and DSMAC (*Digital Scene-Matching Correlation*) improve the precision of the missile and its low altitude flight capacity by completing the inertial navigation system. However, the use of these technologies requires access to expensive means for taking and digitizing geographic images that are still under stringent export control. However, TERCOM and DSMAC will revolutionize the use of cruise missiles for the United States by making them efficient in carrying conventional warheads (the Tomahawk is a direct application of these technologies).
- ⇨ In the navigation field: the arrival of the *global positioning system* (GPS) in the 1980s and its intensive use in weapons starting from the Gulf war has a greater impact in terms of proliferation. Making this technology commonplace (decision by Reagan in 1983) for use in civil applications facilitates *de facto* access of potentially proliferating countries to

[143] Obviously, this is an average efficiency, since the number of missiles launched was very large; See Nicholls, pp. 32-33.

navigation technologies capable of giving precisions of the order of about ten meters at the target and (complementary to standardization of satellite imagery), a certain flight capacity at low altitude. However, access to GPS alone is not sufficient to make modern cruise missiles affordable, particularly because possibilities of jamming signals above some regions in time of crisis may affect the precision of missiles that depend on them.

- ⇨ In the navigation field: standardization of access to high definition satellite images makes it possible to obtain precise positioning scenes and data. Furthermore, possibilities in terms of geographic digitization are widespread and facilitate mission planning operations. These technologies are essential to produce navigation data for missiles using GPS systems or terrain comparison systems (TERCOM/DSMAC).
- ⇨ In the penetration field: development of stealth techniques – optimization of the shape (to reduce reflected signals) and absorbent materials – to reduce the detectability of modern cruise missiles and complement flight capacity at very low altitude to increase the penetration performances of these missiles. Although state-of-the-art techniques appear to be well controlled, ingenious engineering can significantly reduce radar and infrared signatures of missiles (air inlet location, shape of the head part).

New entrants appeared during the 1990s. Some European countries (United Kingdom and France on the SCALP program, Germany and Sweden on the Taurus) then China and Israel and finally India and South Africa are developing their own cruise systems (within the framework of a Russian-Indian cooperation on the supersonic Brahmos).

Structure of a cruise missile

A cruise missile contains the following subassemblies:

- ⇨ Propulsion:

1. – By an anaerobic system – solid or liquid propellant similar to those used for ballistic missiles – that can achieve high speeds but relatively low ranges (a few tens of kilometers – see the Chinese C-801 anti-ship missile with an effective range of 42 km or EXOCET). This type of propulsion is systematically used for launching turbopropelled cruise missiles (that have to be accelerated to a certain speed before the main engine can start operation) from the ground or the sea.
2. – By a turbojet system, that can achieve relatively high speeds (transonic and possibly supersonic) but that consumes an enormous amount of fuel which consequently limits the range of the missile. Cruise missiles with a range of between 300 and 500 km use turbojets. The SCALP is fitted with a turbojet.
3. – By a turbofan system, much more economic in fuel but that can only achieve subsonic speeds. This type of system is used on Tomahawk or Russian AS-15 missiles.

4. – By a ramjet system that operates at supersonic speeds (and has to be accelerated beyond the speed of sound before it can operate). The Russian SS-N-22 anti-ship missile is based on a ramjet. Heat generated during combustion can be easily detected.

⇨ Aerostructures: the missile casing, its control surfaces (fins) and its lift surfaces (wings) make up the aerostructures. The choice of materials (aluminum or special steel alloys, composite, wood, etc.) will influence the detectability of the missile. The chosen shapes will also participate in reduction of signatures. However, since the missile must continue to be able to fly, stealth choices are the result of a technical compromise that is difficult to achieve[144].

⇨ Navigation: the navigation system is used to guide a missile from its launcher to the area in which the target is located[145]. Diagrammatically, a cruise missile relies on a relatively simple navigation system sufficient to obtain satisfactory precision over relatively short distances (case of anti-ship missiles):

5. – an inertial control unit: which gives the position and attitude of the missile by integration of data obtained by accelerometers and gyroscopes;

6. – a radioaltimeter: to calculate the altitude of the missile;

7. – an automatic pilot, to pilot the missile along the planned flight path.

However, other means are necessary for low altitude and/or long-range flight paths, to improve both the positioning precision and the final precision. The use of satellite positioning means (GPS, GLONASS or GALILEO) or terrain comparison systems (TERCOM, DSMAC) is called hybridizing.

⇨ Terminal guidance: once in the area in which the target is located, this subsystem guides the missile as far as the target assigned to it. It involves a comparison of a precise image of the target (radar or optical image) and the image taken by an imager integrated into the missile. Terminal guidance technologies are essential to enable precise firing on predetermined targets (for example aircraft carriers).

⇨ Warheads: unit, with submunition or non-conventional, they may be integrated onto a cruise missile, but this technical operation in itself introduces particular engineering problems (in terms of dynamic balancing of the missile during flight in order to guarantee its stability).

The question of system integration is essential to handle the real difficulty in designing a cruise missile: limited internal space in the missile, electrical power supply (compactness, weight), dynamic balancing, programming of the onboard computer. Components may be individually accessible, but the challenge is still to

[144] See the article by Steven Zaloga, « The cruise missile threat, exaggerated or premature? ».

[145] In fact, a navigation system may be sufficient for firing on coordinates for which a particular area is aimed at, without the need to hit a particular target.

assemble them into a complete and operational system with repeatable performances. All new entrants, for example including Germany, have been or are still faced with this difficulty.

The associated infrastructure includes

- The carrier and the definition of the carrier-warhead interface. Note that some of the advantage of cruise missiles is due to the range of carriers from which they can be fired: aircraft, warships, commercial ships, submarines, launching from ground.
- Mission planning: the objective is to define the path that each missile will take as far as its target (avoiding natural objects such as ground-air batteries or radar systems), characterization of the said target for terminal guidance (radar image - even if this characterization is not necessary when firing on coordinates).
- Operational planning/intelligence: coordination of raids/attacks, choice of targets.
- Digital models: it is absolutely necessary to obtain digitized geographic models for some guidance systems (case of TERCOM or TERPROM).

Annexe 2 -
Summary table of cruise missile controls

SUBSYSTEM OR TECHNOLOGY	MTCR	WASSENAAR
Complete missile	**Category 1** • Item 1.A.2: Missile with more than 300 km range and more than 500 kg payload • Item 1.B: Associated production means • Item 1.D: Technologies for development, production and use of category 1.A missiles **Category 2 :** • Item 19.A.2: Missile with more than 300 km range • Item 19.A.3: Missiles designed or modified for spreading missions (decontrol note: apart from model aircraft) • Item 19.D: Software for coordinating subsystems • Item 19.E: Associated technologies	**Munitions list:** • ML.4: Missiles, equipment and associated accessories (including launching device) • ML.10: Drones designed or modified for military use, equipment and associated accessories
Propulsion	**Category 1** • No control **Category 2 :** • Item 3.A.1: turbomachines with more than 400 N thrust and a specific consumption of less than 0.15 $kg.N^{-1}$;h^{-1} (decontrol note: apart from aircraft engines) • Item 3.A.2: ramjets and their components • Item 3.D: associated software • Item 3.E: associated technologies	**Munitions list:** • ML.10: Aerobic propulsion means designed or modified for military use **Dual-use list:** • Category 9.A.1: aircraft turbomachines except for those designed for civil aviation • Category 9.A.11: ramjets and associated components
IN navigation	**Category 1** • Item 2.A.1: dedicated guidance systems capable of obtaining a precision of less than 3.33 % of the maximum range (note except for systems dedicated to aircraft) • Item 2.D.3: associated software • Item 2.E: associated technologies **Category 2 :** • Item 9.A.1: autopilot systems for category 1 missiles • Item 9.A .3: Accelerometers with a sensitivity less than or equal to 0.05g • Item 9.A.4: rate gyros with a bias of less than 0.5 degrees/h • Item 9.A.6: Systems using accelerometers or rate gyros designed for use in category 1 missiles • Item 9.B: Calibration and test means for inertial control units • Item 9.D: navigation software	**Double-use list:** • Category 7.A.3: inertial guidance systems with drift less than 0.8 nautical miles/h • Category 7.A.3: inertial systems updated by satellite navigation means

SUBSYSTEM OR TECHNOLOGY	**MTCR**	**WASSENAAR**
GNS navigation	**Category 2 :** - Item 11.A.3: receiver of satellite navigation systems : o Designed for category 1 missiles or o Designed for airborne applications and capable of providing navigation information at speeds greater than Ma 0.6 - Item 11.E: Hardening technologies	**Dual-use list:** - Category 7.A.5: receivers of satellite navigation systems
Navigation (other)	**Category 2:** - Item 11.A.1; Altimeters designed for category 1 missiles - Item 11.A.4: Electronic navigation means designed for category 1 missiles (digital imager, doppler radar, etc.)	**Dual-use list:** - Category 7.A.6: altimeters
Structures	**Category 2:** - Item 17.A.1: signature reduction means designed for category 1 missiles - Item 17.C.1: signature reduction materials (e.g. paint) - Item 17.E.1: associated technologies - Item 6.A: composite materials and alloys designed for category 1 missiles	**Dual-use list:** - Category 1: composite materials, aeronautical alloys, signature reduction materials **Note:** The category concerned includes an extended spectrum of materials that can be used for aeronautical applications. The list given above is given for guidance.
Space observation	No entry	**Dual-use list:** - Category 6.A.4: optical sensors for spatial observation and associated components
Digital mapping / Mission preparation	No entry	**Munitions list:** - ML.5: Acquisition, reconnaissance, identification and information merging means
Integration	**Category 2:** - Item 12.A.1: launching means for category 1 and 2 cruise missiles - Item 12.D.1: associated software - Item 12.E.1: associated technologies	No entry (?)
Comments	The MTCR generally combines technologies with the goods considered. However, the regime's directives are still fairly general on control of intangible transfers.	