State-of-the-art of ballistic missile defense systems in the World

Ing. Zdeněk Caha
University of Defence, Brno, Czech Republic
zdenek.caha@unob.cz

Abstract: *This review deals with state-of-the-art of ballistic missile defense development. Paper is directed on todays most comprehensive and used technologies most advanced ballistic missile defense systems all the world. Further on is described, introduces, applied progressive technologies and also mentioned now-a-days state of development, as well as expected time for such systems fielding in the Army.*

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The spread of ballistic missile technology has accelerated in recent years. This proliferation has been difficult to control, and more countries, some hostile to NATO interests, have developed sophisticated missile designs, including missiles capable of reaching the NATO members. Great danger also lies in the existence of chemical, biological, and nuclear weapons that can be paired with ballistic missiles for use against the NATO members, our troops abroad, our allies, and our friends. Ballistic missile defense is one of the most challenging missions in every democratic army. A ballistic missile's altitude, speed, and range leave a defender little room for error. To meet this challenge, lots of countries are developing a system capable of destroying a ballistic missile in each of three distinct phases of flight — boost, midcourse, and terminal. This requires accurate missile identification and tracking with advanced sensors; advanced interceptor missiles or directed energy weapons(e.g. lasers); and quick reaction time provided by reliable command and control, battle management, and communications.
In next part will be presented sumarized informations about state-of-art ballistic missile effence systems in the world.

A-135

System A-135, currently deployed by the Russians outside Moscow, is an anti-ballistic missile system designed to detect and target incoming ballistic missiles in their final descent, or terminal phase, and destroy them with long- and short-range interceptors.
Construction of the new facilities began in 1978 and were finished by November 1987. State acceptance tests of the system were completed by the end of 1989. That same year, the Soviets decided to modernize System A-135 even further to improve its combat performance. Thus, work continued on the new system during its period of experimental use, which lasted until the middle of 1994. At that point, System A-135 was placed on full combat alert.
System A-135 currently consists of three main components:
- long-range Gorgon (SH-11/ABM-4)
- short-range Gazelle (SH-08/ABM-3) interceptors
- new Pillbox multifunctional phased-array radar.

The long-range Gorgon is designed to intercept its targets just outside the Earth's atmosphere. Its three liquid-fueled boosters give it a range of approximately 350 kilometers. Each Gorgon initially carried a 1-megaton nuclear warhead. At present, 32 Gorgons are deployed around Moscow in four underground launch sites containing eight interceptors each.

By contrast, the short-range Gazelle is a quick-reaction, high-acceleration weapon designed to intercept its targets inside the Earth's atmosphere. It has two solid-fueled boosters, giving it a range of approximately 80 kilometers. Each Gazelle was initially armed with a 10-kiloton nuclear warhead.

A total of 68 Gazelles are currently deployed around Moscow in four underground launch sites containing 17 interceptors each.

Russia announced that, in the interest of safety, it had removed the original nuclear warheads from the short-range Gazelle interceptors. Many had warned that a low-altitude nuclear explosion would contaminate a 77-square-mile area, making Moscow virtually unlivable.

A-135's interceptors had been newly equipped with conventional high explosive warheads. It is unclear, however, whether all of System A-135's interceptors currently carry conventional warheads, or if some are still armed with nuclear warheads.

System A-135 includes the Pillbox multifunctional phased-array radar. The Pillbox was developed at the Central Scientific Research Radiotechnical Institute of the USSR Academy of Sciences in Moscow under the supervision of V. K. Sloka. It became operational in 1990 and is currently deployed at Pushkino, approximately 25 kilometers northeast of Moscow. The radar and its command center are both located inside a single four-sided 30-meter-high building that resembles a truncated pyramid. Described as "considerably advanced," the Pillbox is capable of detecting, tracking, and targeting incoming threats in a 360-degree radius, thus providing simultaneous observation of the entire upper hemisphere.

In the event of a ballistic missile attack, the Russians hope that System A-135 will provide Moscow with two layers of defense. After the Pillbox radar spots an incoming missile, System A-135 will launch its Gorgon interceptors in hopes of destroying the threat in the upper reaches of the atmosphere, or even in outer space. If any incoming warheads penetrate this first layer, the Russians will launch a second wave of Gazelles.

The Russian military claims that this two-tiered "layered" defense is capable of protecting hundreds if not thousands of miles around Moscow, an area that encompasses the nation's capital, key military assets, and major industries.

Last year tests were completed on the modernized active parts of the system—the interceptor missiles, and the training-combat launch of one of these was successfully carried out at the southern Sary Shagan range.

S-400 (SA-20 Triumf)

In January 1999, the Russian Air Force formally announced that it had developed a new air defense system known as the S-400. But the S-400 was a thoroughly modernized version of the older S-300P system, versions of which dated back to the late 1960s.

The S-400, also known by its NATO designation, SA-20 Triumf, is an advanced Russian surface-to-air missile system. Once operational, it will be able to destroy aircraft, cruise missiles, and short- and medium-range ballistic missiles at ranges of up to 400 kilometers.

In addition to the new long-range missile, the Russians revealed that the S-400 would be armed with lightweight 9M96 missiles to counter low-flying targets. Each 9M96 interceptor would have a range of approximately 120 kilometers and feature a gas-dynamic control system that would allow it to perform intricate low-altitude maneuvers.

The Triumf interceptor is reported to have a range of 400km, and is to be used against both ballistic and cruise missiles such as the American Tomahawk—as well as against early

warning, tactical, and strategic aircraft. In terms of its ballistic missile defense capabilities, it is said to be able to intercept warheads traveling at a speed of 4,800 km per hour (1.3km/sec).
At year 2004 the system launched the upgraded 48N6DM long-range missile. The missile was guided to the target with precision, while the tasks set have been fulfilled.
Last variant of the S-400 is Russia's newest missile defense systém the Samoderzhets . The Samoderzhets or "Autocrat" system is said to be "fifth-generation," one step beyond the "fourth-generation," and currently state-of-the-art S-400 interceptor. The Samoderzhets is apparently not Russia's most advanced system coming—another system is expected in 2012—but may rather be for export.
Specifically, the Samoderzherts system may use the same 9M96 and 9M96/2 missile interceptors currently deployed on the S-400, as well as the logner range 9M82M interceptor used by the S-300VM. The 9M82M interceptor is said to have a maximum range of 200km and can intercept ballistic missiles with a reentry speed of 4.5km per second.

S-500

S-500 is a Russian surface-to-air missile system that, if developed, will be able to track and destroy ballistic missiles with ranges of up to 3,500 kilometers. At present, however, reports indicate that Russia has not yet started building the S-500, apparently due to a lack of funds.
There was information that Russia can build it together with U.S too.
At present, however, there is no evidence that Russia plans to collaborate with the U.S. on the S-500.

SA-11

Russia continues to market new form of missile defense system to the Mideast, the Buk-1M1-2 (SA-11).New version of the Buk defense system (also known as Gadfly) is capable of intercepting aircraft, cruise missiles, and some short range ballistic missiles. In a statement by Buk's manufacturer, the Russian Rosoboronexport company, said that this is the only anti-aircraft missile system of medium range in the world, which is capable of destroying in unfriendly environment of radio and fire countermeasures not only aircraft of strategic and tactical aviation, helicopters and cruise missiles, but also tactical ballistic and aircraft missiles, including antiradar, destroying elements of high-precision weapons as well as surface and ground targets.

Ground-based Midcourse Defense (GMD)

GMD is the system to detect and track long-range ballistic missiles in their boost phase, and destroy them during their midcourse phase, i.e. while the missiles are outside the atmosphere and at their highest trajectory.
Today ground-based missile defense base is located at Fort Greely, Alaska and at Vandenberg Air Force Base, California (total of 28 Ground-based Interceptors). Two Navy Aegis warships are on patrol near North Korea and would be among the first sensors that could trigger the use of the ground-based interceptors.
U.S. plans place parts off GMD to Europe and to reach it began confidential talks with Poland and the Czech Republic.
GMD will consist of an complex array of synchronized components: Air Force Defense Support Program (DSP) satellites; Space Based Infrared System-High (SBIRS-High) satellites; the Space Tracking and Surveillance System (STSS); Upgraded Early Warning Radars (UEWRs); a Battle Management, Command, Control and Communications (BMC3)

unit; the Sea-Based X-Band Radar (SBX); and Ground-Based Interceptor (GBI) missiles.

Defense Support Program (DSP)

The Defense Support Program (DSP) is a system of satellites that detect and track ballistic missile launches, space launches, and nuclear detonations worldwide. It uses infrared detectors that are capable of sensing heat from missile plumes against the cooler background of the earth. Since 1970, the DSP has been a critical component of the North American Aerospace Defense Command's (NORAD) Tactical Warning and Attack Assessment System. At present, five DSP satellites are operational. Three provide primary service: DSP F-6R, launched in 1984; DSP F-5R, launched in 1987; and DSP-I F-14, launched in 1989. An additional two serve as backups: DSP F-15, launched in 1982; and DSP F-12, launched in 1984. These five satellites transfer warning data via communications links to NORAD and U.S. Space Command early warning centers within the Cheyenne Mountain Complex outside Colorado Springs, Colorado.

Space-Based Infrared System-High SBIRS-High

The Pentagon plans to eventually replace the DSP with a new satellite system known as the Space-Based Infrared System-High (SBIRS-High) that is better suited for U.S. missile defense. The new system would consist of five satellites in geosynchronous earth orbit, two sensors on host satellites in highly elliptical orbit, and associated fixed and mobile ground stations. SBIRS-High will provide missile warning information and to support the missile defense, technical intelligence, and battle space characterization missions.

Space Tracking and Surveillance System (STSS)

The Space Tracking and Surveillance System (STSS) will consist of low-orbiting infrared satellites designed to detect and track ballistic missiles in all stages of flight. Data from STSS will allow U.S. interceptors to engage enemy missiles as early as possible in their trajectories and discriminate between warheads and decoys.
STSS will have the responsibility of tracking enemy missiles against the cold background of space, one of the biggest challenges of ballistic missile defense. Not only will STSS succeed at this task, it will observe its targets with great detail. To accomplish this mission, each satellite will consist of three main components: a wide-view acquisition sensor, a narrow-view tracking sensor, and a signal and data processor subsystem.

Upgraded Early Warning Radar (UEWR)

Early Warning Radars (EWRs) are phased-array surveillance radars that the U.S. military uses to detect incoming ballistic missiles and will be able to search for different types of incoming missiles, distinguish hostile warheads from non-hostile objects, and transfer this data to other missile defense elements via improved communications software. UEWRs will be responsible for locating enemy missiles as they clear the horizon line. After the incoming threats have been detected, the UEWRs will hand them over to new X-Band Radars (XBRs) for "target refinement"--tracking, imaging, and discrimination. Information from the UEWRs and XBRs will be constantly fed to the Battle Management/Command, Control and Communications (BMC3) system, which will launch ground-based interceptor missiles or other defensive devices against the incoming threats.

Sea-Based X-Band Radar (SBX)

The Sea-Based X-Band Radar (SBX) consists of an advanced radar system mounted on a floating platform and is able to track, discriminate, and assess long-range ballistic missiles as part of Ground-Based Midcourse Defense (GMD) system.

Ground-Based Interceptor (GBI)

The Ground-Based Interceptor (GBI) is a multi-stage silo-launched booster rocket and kill vehicle that will track and destroy high-speed ballistic missiles in their midcourse phase, i.e. while the missiles are still outside the atmosphere and at their highest trajectory. Each GBI missile will consist of two main components: a three-stage booster rocket and the Exoatmospheric Kill Vehicle (EKV).

Exoatmospheric Kill Vehicle (EKV) and Multiple Kill Vehicle (MKV)

The Exoatmospheric Kill Vehicle (EKV) is a small flying device located in the tip of a Ground-Based Interceptor (GBI) missile. It is designed to separate from the GBI in flight, punch through the Earth's atmosphere, and smash into an incoming ballistic missile in its midcourse phase, i.e. while the missile is at its highest trajectory.
Nexts using what is known as the many-on-many strategy, the Multiple Kill Vehicle system deploys several exoatmospheric kill vehicles from each interceptor missile (as opposed to the previous designs which include only one EKV), which are then able to destroy the enemy missile itself as well as any countermeasures.

Cobra Dane radar

The Cobra Dane radar is deployed at Eareckson Air Station in Shemya, Alaska, located on the western end of the Aleutian chain.
Its close proximity to Russia allows Cobra Dane collect data on Russian intercontinental ballistic missiles (ICBMs) and submarine launched ballistic missiles (SLBMs) which are frequently fired to the Kura testing range on the Kamchatka peninsula.
Cobra Dane is an AN/FPS-108 radar that operates in the 1215-1400 MHz band using a 29m phased array antenna. System is also capable of tracking targets in space at 40,000 km.

Terminal High Altitude Area Defense (THAAD)

The Terminal High Altitude Area Defense (THAAD) system is a mobile, land-based weapons program designed to destroy short- and medium-range ballistic missiles in their terminal phases. THAAD will be able to intercept incoming missiles both inside and just outside of the Earth's atmosphere at a range of 200 kilometers.
THAAD will consist of four principal components: an X-band radar; a Command & Control and Battle Management Communications (C2BMC) unit; mobile launchers; and the THAAD interceptor missiles themselves.
In a typical combat scenario, THAAD's X-band, phased array, solid-state radar will scan the horizont for hostile missiles. It will be capable of detecting threats at a range of 1,000 kilometers. Once an incoming missile has been detected, the X-band radar will relay this information to the C2BMC unit, a mobile command center installed on Humvees that

manages and integrates all THAAD components. C2BMC units are capable of linking THAAD with other missile defense layers to strengthen the overall Ballistic Missile Defense System. C2BMC is also responsible for determining friend from foe.
Following the launch, the interceptor will receive targeting information from the ground-based X-band radar. After its burnout stage, the interceptor's kill vehicle (KV) will separate from the booster. The KV is equipped with a liquid Divert and Attitude Control System (DAVS) which will maneuver the KV toward the target interception point. An infrared seeker in the KV's nose will home in on the target. At the point of impact, the KV will collide with the incoming missile (like a bullet hitting a bullet), causing complete destruction of the warhead including any nuclear, chemical, or biological agents.
State of art: testing at White Sands Missile Range in New Mexico and the Pacific Missile Range in Hawai. Plans for year 2008 are 24 missiles.

PAC-3

Patriot Advanced Capability-3 (PAC-3) is a surface-to-air guided missile defense system that builds upon the existing Patriot air defense infrastructure. The new fully operational PAC-3 provides advanced capability against enemy cruise missiles, aircraft, and unlike previous systems, tactical ballistic missiles.
State of art: Today 512 PATRIOT Advanced Capability-3 missile in inventory Planes for 2008: 712 PAC-3 Missiles.

Aegis Ship-Based BMD

The system will integrate the U.S. Navy's existing fleet of Aegis cruisers (Ticonderoga class) and Aegis destroyers (Arleigh Burke class) with the Standard Missile-3 (SM-3) interceptor.
At present, each Aegis cruiser and destroyer is outfitted with the Aegis Weapon System--the heart of which is the AN/SPY-1 radar system. AN/SPY-1 sends out beams of electromagnetic energy in all directions, thus allowing Aegis ships to track up to 100 targets simultaneously, while still retaining the ability to counter other air, surface, and submarine threats. AN/SPY-1 will be able to detect ballistic missiles as they rise above the horizon.
Once a hostile missile has been detected, Aegis BMD will launch its Standard Missile-3 interceptor from its MK41 Vertical Launching System (currently deployed on Aegis cruisers and destroyers). An evolution of the SM-2 Block IV interceptor, the SM-3 is a hit-to-kill missile comprised of a three-stage booster with a kill vehicle. As the SM-3 burns through its three stages, its GPS-Aided Inertial Navigation System will set it on an intercept trajectory with the hostile missile. SM-3 will also receive target updates from the Aegis destroyer.
Once close enough to the ballistic missile, the SM-3 will fire its kill vehicle, the Kinetic Warhead (KW), from its nosecone. The KW will immediately begin to search for its target. It will acquire the ballistic missile using a high-resolution seeker, and maintain an accurate trajectory using its internal navigational system. As it closes on its target, the KW will identify the missile's payload, and shift its aimpoint to ensure a lethal hit. When the KW finally slams into the enemy warhead, the kinetic energy of the high velocity impact will ensure complete destruction of the threat.
In 2006, the Navyl deployed nine Aegis ships outfitted with SM-3 missiles and configured to carry out ballistic missile defense operations from almost anywhere in the world.

Space-Based Laser (SBL)

The Space-Based Laser (SBL) is space based anti-missile system. As envisioned, it would consist of a 20-satellite(It is estimated that a 20-satellite constellation would destroy almost all threats, while a 12-satellite constellation would eliminate 94 percent)constellation orbiting the globe at altitudes of 1,300 kilometers, each satellite equipped with a high-energy chemical laser that would detect, track, target, and destroy hostile ballistic missiles at the speed of light.
The SBL high-powered beam would rush into the vacuum of space at the speed of light, penetrate the earth's atmosphere, and destroy the missile just above the clouds. The entire process, from detection to elimination, would take seconds. Each SBL would carry enough fuel for about one hundred shots.
Space-Based Laser Integrated Flight Experiment (SBL-IFX)--that included Boeing, Lockheed Martin, and TRW. SBL-IFX initially planned to perform a complete demonstration of SBL's capabilities by 2012

Airborne Laser (ABL)

The Airborne Laser (ABL) is the largest and most complex of the Missile Defense Agency's high-energy laser projects. Once operational, ABL will consist of a chemical laser integrated into the fuselage of a modified Boeing 747-400F freighter aircraft. The system will be capable of eliminating ballistic missiles in their boost phase just seconds after they have been launched.
Controlled by a four-man team, each 747 will operate at altitudes of 40,000 feet or higher. Six infrared sensors positioned on the outside of the 747 (one each on the front and rear and two on each side) will give ABL the ability to scan the horizon for threats. Once a hostile missile has been detected, ABL's three tracking lasers will illuminate the target and calculate its course and direction. The first laser will lock on to the missile and provide detailed tracking information. The second will determine the aimpoint of the target. The third will measure the amount of atmospheric disturbance between the 747 and the missile so that computers and deformable mirrors can compensate for the amount of refraction the laser beam will encounter on its way to the target.
Finally, the ABL will fire its high-energy Chemical Oxygen Iodine Laser (COIL) from a turret located in the 747's nose. The COIL will combine common industrial chemicals (hydrogen peroxide, potassium hydroxide, chlorine gas, water) to create its lethal beam. ABL's beam control/fire control system will maintain the strength and direction of the beam as it travels through the atmosphere. A three- to five-second burst will heat the missile's metal skin until it cracks. Since the missile's interior is pressurized during launch, the crack will expand rapidly into a tear and the fuel will explode, causing the missile to disintegrate over its launch site.
The ABL project is currently moving forward in two-year development "blocks." On 2002, the prototype 747, known as YAL-1A, made its first test flight. The 2004 phase will lead up to a demonstration of ABL's ability to intercept a short-range ballistic missile, most likely over the Pacific Ocean. Block 2006 involve the deployment of the Block 2004 aircraft, which will be analyzed for integration with the overall Ballistic Missile Defense System and tested for emergency capability. In the Block 2008 period, the program will build a second 747 and focus its efforts on upgrades and affordability.

Medium Extended Air Defense System (MEADS)

The Medium Extended Air Defense System (MEADS) is a tri-national project of the United States, Germany, and Italy. Once operational, it will use the new Patriot Advanced Capability-3 (PAC-3) missiles to protect ground forces and fixed military positions against attack from

tactical ballistic missiles, low and high altitude cruise missiles, aircraft, and unmanned aerial vehicles.

Arrow

Arrow is a joint project of Israel and the United States. It consists of high-altitude interceptors, deployed in Israel, able to seek and destroy incoming ballistic missiles in their terminal phase, i.e. during the final minutes of descent.

Although the recent U.S. invasion eliminated the Iraqi menace, Israel is still threatened by Syria's Scuds and Iran's longer-range Shabab-3 missiles. Arrow now gives Israel the ability to defend itself against these weapons of mass destruction.

Arrow consists of three main components: a phased array radar, a fire control center, and a high-altitude interceptor missile. The phased array radar, known as "Green Pine," is capable of detecting incoming warheads at a distance of 500 kilometers. This provides adequate radar coverage, since missiles launched at Israel from other Middle Eastern nations will not appear over the horizon before this distance.

The system is designed to work quickly and efficiently. As soon as Green Pine detects an incoming missile, the fire control center, called "Citron Tree," launches its interceptor missile. The interceptor shoots toward the threat at nine times the speed of sound, and reaches a height of 30 miles in less than three minutes. Once it gets within two seconds of its target, Arrow's optical detectors aims for the incoming missile's warhead.

The interceptor's own explosive warhead detonates within 40 to 50 yards of the missile, allowing Arrow to miss its target and still neutralize the threat. In this manner, Arrow differs from U.S. interceptors like the Patriot Advanced Capability-3 (PAC-3) and the Theater High Altitude Area Defense (THAAD), which rely on hit-to-kill technology in which the kinetic force of a precise impact causes the destruction of the threat.

Israel presently has two Arrow batteries deployed on its soil, one at Palmachim to protect Tel Aviv and the other at Ein Shemer near Hadera. The Israeli Defense Force plans to procure 200 interceptors; 100 for each battery. A third battery is in development in the south.

Tactical High Energy Laser/ Advanced Concept Technology Demonstrator (THEL/ACTD)

The Tactical High Energy Laser (THEL) is a joint project of the United States and Israel designed to destroy short-range ballistic missiles, cruise missiles, ground- and air-launched rockets, unmanned aerial vehicles, mortar shells, and artillery projectiles. It consists of an advanced radar that detects and tracks incoming rockets, and a high-energy laser beam that destroys them.

Israel army equipe this system to protect Israeli towns faced a constant threat from Hezbollah guerillas along its northern border. During eighteen years of fighting, the guerrillas wreaked havoc by firing numerous small, unguided Katyusha rockets at Israeli towns. The rockets were fast and low-flying and caused considerable damage. Hezbollah's attacks were so numerous that Israel could not use interceptor missiles. In addition, since the Katyushas flew on ballistic trajectories and landed on Israeli towns unless completely destroyed.

THEL will consist of four main components: a command center, a fire control radar, a pointer-tracker, and the high energy laser itself. The command center, known as Command, Control, Communications, and Intelligence (C3I), will manage all aspects of the system, including detecting, tracking, and destroying incoming targets within THEL's range. C3I will be operated by a two-man crew: a commander and a gunner.

Positioned near the hostile zone, the fire control radar will continuously scan the horizon for threats. Once an incoming rocket has been detected, the radar will calculate the target's

trajectory and enable the pointer-tracker to lock on to the target. THEL will be mounted on a large gimbaled assembly that will allow the pointer-tracker to swivel when tracking the rockets.
Once the target is within range, the pointer-tracker will focus THEL's high-energy deuterium-fluoride (DF) laser beam on the incoming rocket. The DF laser beam is created by mixing fluorine atoms with helium and deuterium to generate DF in an excited state. A resonator extracts the DF and transforms it into a beam of coherent, monochromatic light. The beam itself is only a few inches in diameter, but is powerful enough to heat steel at 200 yards or more. The pointer-tracker will keep the laser beam focused on the incoming rocket until the intense heat causes the warhead to explode. Debris from the blast will fall short of the rocket's intended target, thus effectively neutralizing the threat. Once deployed, THEL will be capable of firing 60 shots before reloading. The system will operate at a per-kill cost of approximately $3,000, making it one of the most inexpensive anti-missile systems in existence.
To date, THEL has destroyed 28 Katyusha test rockets and five test artillery shells. On May 4, 2004, THEL's new transportable version, known as the Mobile Tactical High Energy Laser (MTHEL), tracked and destroyed a large-caliber test rocket at the U.S. Army's White Sands Missile Ranch in New Mexico. The rocket flew faster and higher than the Katyushas, and carried a live warhead. The U.S. and Israel expect MTHEL to be operational and ready for deployment by 2007.

HQ-15

Chinese balistic missile defence system Hongqi-15 (HQ-15) is a long-range, high-altitude, upgraded version of the Russian-made S-300PMU-1 (SA-10D Grumble). Currently manufactured and deployed by China, the system is designed to detect, track, and destroy incoming ballistic missiles, cruise missiles, and low-flying aircraft.
A typical S-300PMU-1 battery contains 48 missiles on 12 mobile launchers. The missiles are guided by the 36N85 vehicle-mounted engagement radar, which is capable of detecting incoming ballistic missiles at 40 kilometers, and aircraft between 3 and 150.
China might be attempting to upgrade the HQ-15 to the level of the Russian S-400 (SA-20 Triumf), a next-generation missile with a reported range of 400 kilometers, giving it increased capability against aircraft, cruise missiles, and ballistic missiles.

Sources:

Military News Agency (Moscow), 2002, 2004, 2005, 2006, *Press release by Russian Ministry of Defense*, Forecast International Defense Intelligence Newsletters, 2004, 2005, *Geostrategy-Direct, 2003*, *Vremya Novostei* Russian newspaper 2004, 2005, *United Press International, 2000*, Agence France-Presse, 2000, 2003, *Insight Magazine, 2001*, Albuquerque Journal, 2004, *Aerospace Daily, 2004 – 2006*, Inside the Air Force, 2004, *Air Force Magazine, 2004 – 2006*, Flight International, 2003, 2005, *Press - Reuters 2005, 2006*, Fairbanks daily news 2005, *Bloomberg 2006*, *Aerospace Daily & Defense Report 2005, 2006, Inside Missile Defense, 2004, 2005*, Roosevelt, Ann. "MEADS Demonstration This Month In Italy." Defense Daily, 2004, *Forecast International Defense Intelligence Newsletters, 2004, 2005, 2006*, Lockheed Martin Corporation, Press Releases, 2001-2006, *Missile Defense Agency, Press Releases, 2003-2006*, MTHEL Press Releases, 2003 – 2005, *Jane's International Defence Reviews, 2000, 2005, 2006*.

Web pages:

miisilethread.org, fas.org, defenselink.mil, missilesandfirecontrol.com, mda.mil, defencetalk.com, spacedaily.com, astronautix.com, globalsecurity.org, forum.valka.cz