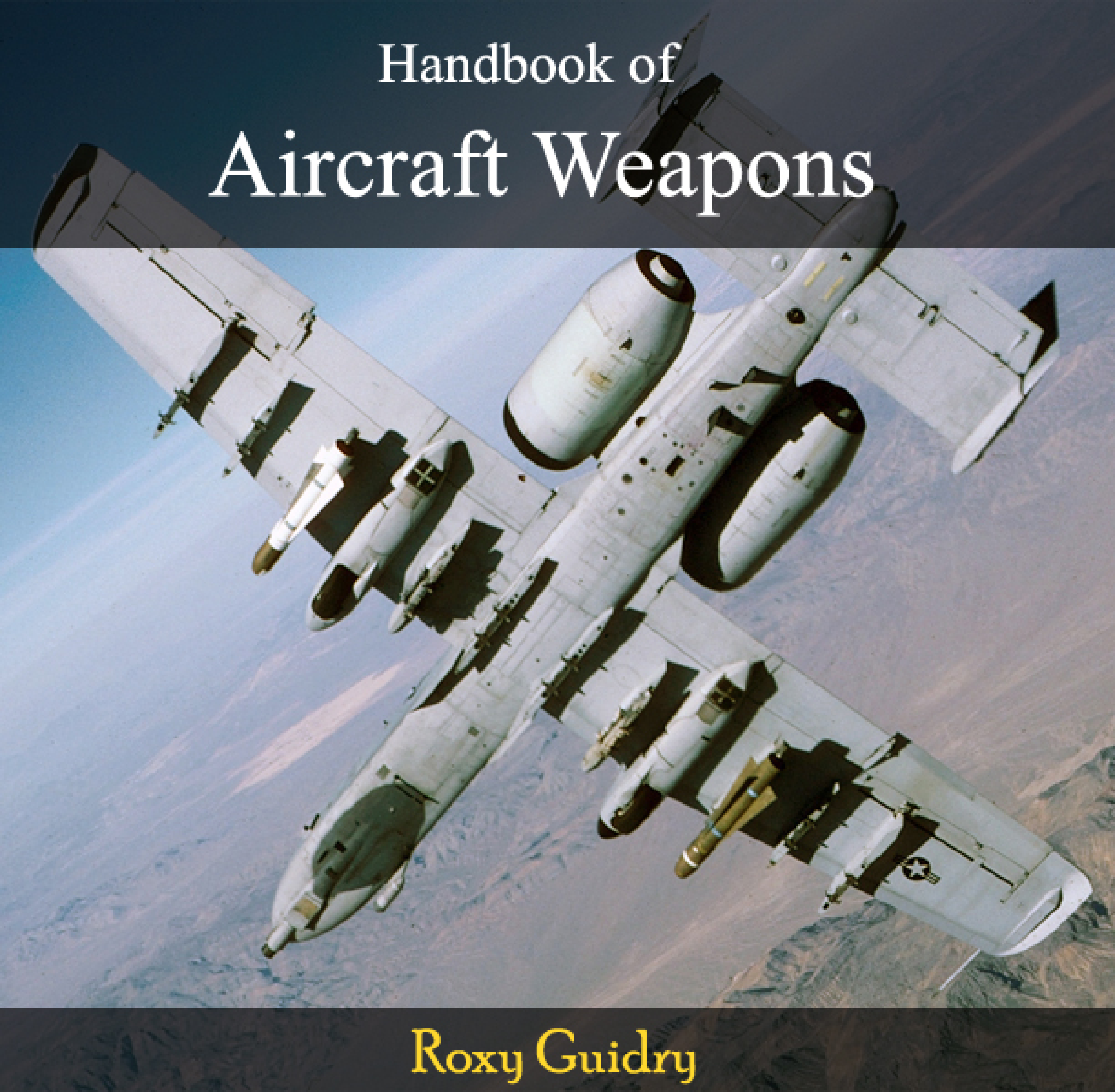
Handbook of Aircraft Weapons



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Aerial Bomb

An **aerial bomb** is a type of bomb intended to travel through the air with predictable trajectories, usually designed to be dropped from an aircraft. Aerial bombs include a vast range and complexity of designs, from "dumb" (gravity fall) to "smart" (remote or self guided), hand tossed from a vehicle, to needing a large specially built delivery vehicle; or perhaps *be* the vehicle itself such as a glide bomb, instant detonation or delay-action bomb. The act is termed aerial bombing.

Early history

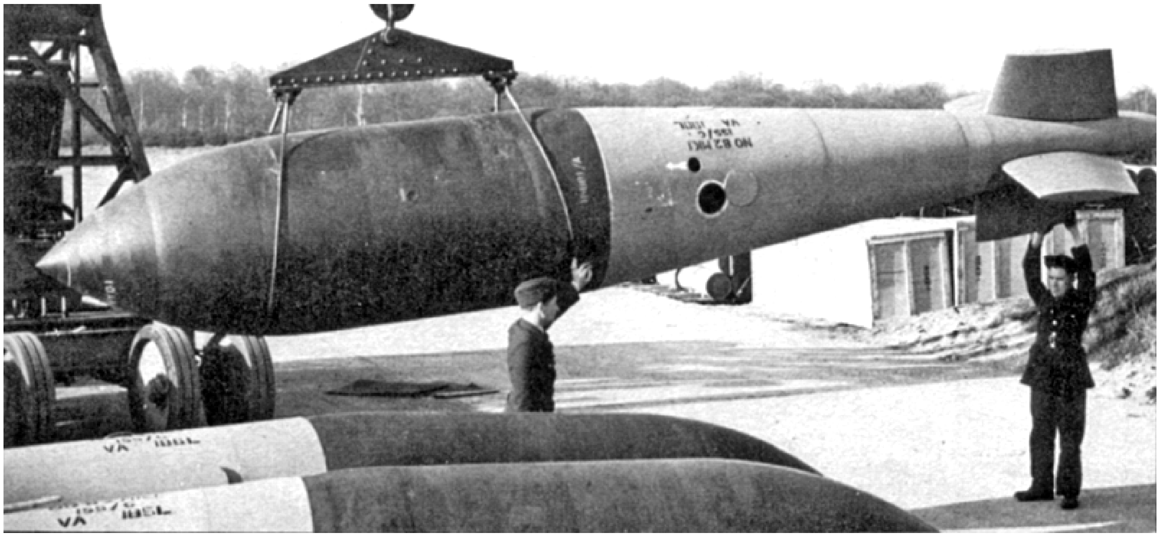
The first bombs delivered to their targets by air were launched on unmanned balloons, carrying a single bomb, by the Austrians against Venice in 1849. Prior to this the Napoleonic armies used balloons for reconnaissance. The **first air-dropped bomb** from a powered aircraft is recorded as when Lieutenant Giulio Gavotti of the Italian Army dropped four grenades from his Blériot XI aircraft onto an Ottoman military encampment at the Taguira oasis in Libya, on 1 November 1911.

Following Italy's bombing, a second bombing occurred in Mazatlán, Mexico during the Mexican Revolution. General Venustiano Carranza (later president of Mexico), intent on taking the city of Mazatlán, ordered a biplane to drop a crude bomb of nails and dynamite wrapped in leather on Neveria Hill adjacent to the city's downtown area. The bomb was crude, and the art of bombing was even cruder. The bomb did not land on the target but on the city streets. The bomb killed two citizens and wounded several others.

The dropping of bombs from balloons had been outlawed by the Hague Convention of 1899, but Italy argued that this ban did not extend to aircraft.

A British Cooper 20 pound bomb used during WWI

German WWII bombs: explosive to left, rest concrete practice bombs (250 kg and 50 kg)



Royal Air Force "Grand Slam" bomb, early 1945

An F-100 Super Sabre of the 308th TFS, being loaded with Mk 117 750 lb bombs at Tuy Hoa, South Vietnam in 1966

Modern JDAM guided GBU-31 bombs

Later bombings

In 1912, during the First Balkan War, Bulgarian Air Force pilot Christo Toprakchiev suggested the use of aircraft to drop "bombs" (called grenades in the Bulgarian army at this time) on Turkish positions.

Captain Simeon Petrov developed the idea and created several prototypes by adapting different types of grenades and increasing their payload.

On 16 October 1912, observer Prodan Tarakchiev dropped two of those bombs on the Turkish railway station of Karağaç (near the besieged Edirne) from an Albatros F.2 aircraft piloted by Radul Milkov. This was the first use of an aircraft as a bomber.

After a number of tests, Petrov created the final design, with improved aerodynamics, an X-shaped tail, and an impact detonator. This version was widely used by the Bulgarian Air Force during the siege of Edirne. A copy of the plans was later sold to Germany and the bomb, codenamed "Chataldzha" ("Чаталджа"), remained in mass production until the end of World War I. The weight of one of these bombs was 6 kilograms. On impact it created a crater 4-5 meters wide and about 1 meter deep.

In 1913, Greek naval aviation forces dropped four bombs on the Ottoman fleet in the Naval Battle of Lemnos.

The first bomb to be dropped by a German aircraft on the United Kingdom landed near Dover Castle on 24 December 1914.

Concrete bomb

German WWII bombs: explosive to left, rest concrete practice bombs (250 kg and 50 kg)

A **concrete bomb** is an aerial bomb which contains dense, inert material (typically concrete) instead of explosive. The target is destroyed using the kinetic energy of the falling bomb. Such weapons can only practically be deployed when configured as a laser-guided bomb or other form of smart bomb, as a direct hit on a small target is required to cause significant damage. They are typically used to destroy military vehicles and artillery pieces in urban areas, in order to minimise collateral damage and civilian casualties.

Guided or unguided concrete bombs may also be used for training pilots and ground personnel, due to the advantages of cost (no explosives or fusing), point of impact determination, minimised bombing range damage and safety. Concrete bombs are also used in testing and evaluation of aircraft and bombs.

Gravity bomb

An unguided 500 lb Mark 82 bomb.

A B-61 nuclear unguided bomb.

A F-111 dropping Mark 82 bombs with ballute type retardation systems (Mk82AIR / BSU49B)

A **gravity bomb**, also known as a **dumb bomb**, or **unguided bomb**, is a conventional aircraft-delivered bomb that does not contain a guidance system and hence, simply follows a ballistic trajectory.

This described all aircraft bombs in general service until the latter half of World War II, and the vast majority until the late 1980s.

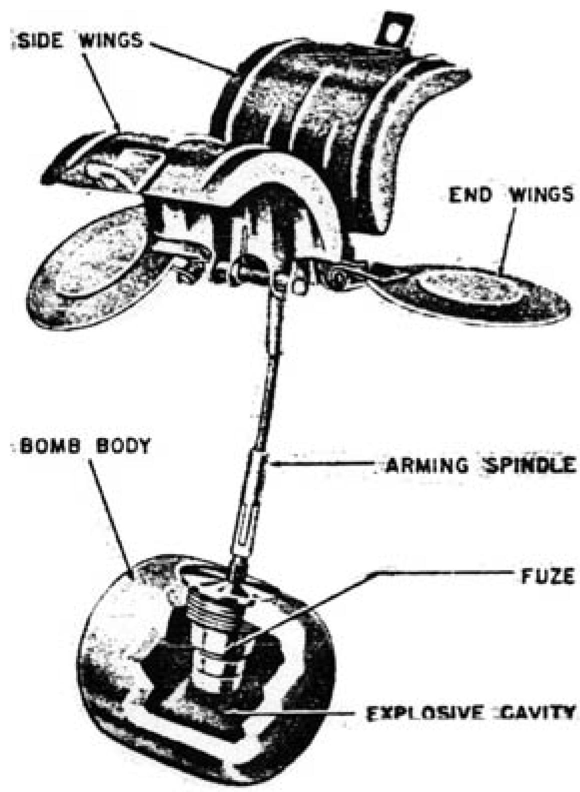
Then, with the dramatically increased use of precision-guided munitions, a retronym was needed to separate 'smart bombs' from free-fall bombs. 'Dumb bomb' was used for a time, but many military circles felt it sounded too trite, and eventually 'gravity bomb' gained currency. Previously, they were also referred to as 'iron bombs'.

Retarded bomb

A special type of gravity bomb is the retarded bomb, which uses a mechanical method of creating increased drag, such as a parachute, ballute, or drag-inducing petals. These deploy after the ordnance is released, slowing its fall and abbreviating its forward trajectory, giving the aircraft time to get clear of the blast zone when bombing from low altitudes or with nuclear ordnance. However, these bombs are less accurate than conventional free-fall bombs.

Chapter- 2

Cluster Bomb



SD2 Butterfly Bomb circa 1940 - wings rotate as bomb falls, unscrewing the arming spindle connected to the fuze

Cluster munitions, **cluster bombs** or **sub-munitions** are air-dropped or ground-launched explosive weapons that eject smaller munitions: a cluster of bomblets. The most common types are designed to kill enemy personnel and destroy vehicles. Other submunition-based weapons designed to destroy runways, electric power transmission lines, disperse chemical or biological weapons, or to scatter land mines have also been produced. Some submunition-based weapons can disperse non-munitions such as leaflets.

Because cluster bombs release many small bomblets over a wide area they pose risks to civilians both during attacks and afterwards. During attacks the weapons are prone to indiscriminate effects, especially in populated areas. Unexploded bomblets can kill or maim civilians long after a conflict has ended. Unexploded submunitions are costly to locate and remove.

Cluster munitions are prohibited for those nations that ratify the Convention on Cluster Munitions, adopted in Dublin, Ireland in May 2008. The Convention entered into force and became binding international law on 1 August 2010, six months after being ratified by 30 states; as of April 2010, a total of 105 states have signed the Convention.

Development

The first cluster bomb used operationally was the German SD-2 or *Sprengbombe Dickwandig 2 kg*, commonly referred to as the Butterfly Bomb. It was used during the Second World War to attack both civilian and military targets. The technology was developed independently by the United States of America, Russia and Italy. The US used the M41 20 lbs fragmentation bomb wired together to clusters of 6 or 25 with highly sensitive or proximity fuzes.

From the 1970s to the 1990s cluster bombs became standard air-dropped munitions for many nations, in a wide variety of types. They have been produced by 34 countries and used in at least 23.

Artillery shells that employ similar principles have existed for decades. They are typically referred to as **ICM** (**Improved Conventional Munitions**) shells. The US military slang terms for them are "firecracker" or "popcorn" shells, for the many small explosions they cause in the target area.

Types of cluster bombs

A basic cluster bomb consists of a hollow shell and then two to more than 2,000 submunitions contained within it. Some types are dispensers that are designed to be retained by the aircraft after releasing their munitions. The submunitions themselves may be fitted with small parachute retarders or streamers to slow their descent (allowing the aircraft to escape the blast area in low-altitude attacks).

A US Vietnam era BLU-3 cluster bomblet

Modern cluster bombs and submunition dispensers are often multiple-purpose weapons, containing mixtures of anti-armor, anti-personnel, and anti-materiel munitions. The submunitions themselves may also be multi-purpose, such as combining a shaped charge, to attack armour, with a fragmenting case, to attack infantry, materiel, and light vehicles. Modern multipurpose munitions may have an incendiary effect.

Recently submunition-based weapons have been designed that deploy smart submunitions, using heat and visual sensors to locate and attack particular targets, usually armored vehicles. Weapons of this type include the U.S. CBU-97 sensor-fuzed weapon, first used in combat during Operation Iraqi Freedom, the 2003 invasion of Iraq. Munitions specifically intended for anti-tank use may be set to self-destruct if they reach the ground without locating a target, theoretically reducing the risk of unintended civilian deaths and injuries. Although smart submunition weapons are many times more expensive than standard cluster bombs, which are cheaper and simpler to manufacture, far fewer smart submunitions are required for defeating dispersed and mobile targets in an area, offsetting this cost. On the basis that they should not cause the indiscriminate area effects or unexploded ordnance risks of cluster munitions, these submunitions are not classified as cluster munitions under the widely accepted definition of the weapon enshrined in international law by the Convention on Cluster Munitions.

Incendiary

Incendiary cluster bombs are intended to start fires, just as conventional incendiary bombs (also called firebombs). They are specifically designed for this purpose, with submunitions of white phosphorus or napalm, and they often include anti-personnel and anti-tank submunitions to hamper firefighting efforts. When used in cities they have often been preceded by the use of conventional explosive bombs to break open the roofs and walls of buildings to expose flammable contents to the incendiaries. One of the earliest examples is the so-called Molotov bread basket first used by the Soviet Union in the Winter War of 1939-40. This type of munition was extensively used by both sides in the strategic bombings of World War II. Bombs of this type were used to start firestorms in cases such as the bombing of Dresden in World War II and the firebombing of Tokyo. In some modern bombs, submunitions are used to deliver a highly combustible thermobaric aerosol, which is subsequently ignited, resulting in a high pressure explosion.

During the Winter War of 1939–1940, the Soviet Union dropped Molotov bread baskets, which scattered incendiary bomblets, on Finland.

Anti-personnel

Anti-personnel cluster bombs use explosive fragmentation to kill troops and destroy soft (unarmored) targets. Along with incendiary cluster bombs, these were among the first forms of cluster bombs produced by Germany during World War II. They were famously used during the Blitz with delay and booby-trap fusing to prevent firefighting and other damage control efforts in the bombed areas. They were also used with a contact fuze when attacking entrenchments. These weapons were most widely used during the

Vietnam War when many thousands of tons of submunitions were dropped on Laos, Cambodia and Vietnam.

Anti-tank

Most anti-armor munitions contain shaped charge warheads to pierce the armor of tanks and armored fighting vehicles. In some cases, guidance is used to increase the likelihood of successfully hitting a vehicle. Modern guided submunitions, such as those found in the U.S. CBU-97 can use either a shaped charge warhead or an explosively formed penetrator. Unguided shaped-charge submunitions are designed to be effective against entrenchments that incorporate overhead cover. To simplify supply and increase battlefield effectiveness by allowing a single type of round to be used against nearly any target, submunitions that incorporate both fragmentation and shaped-charge effects are produced.

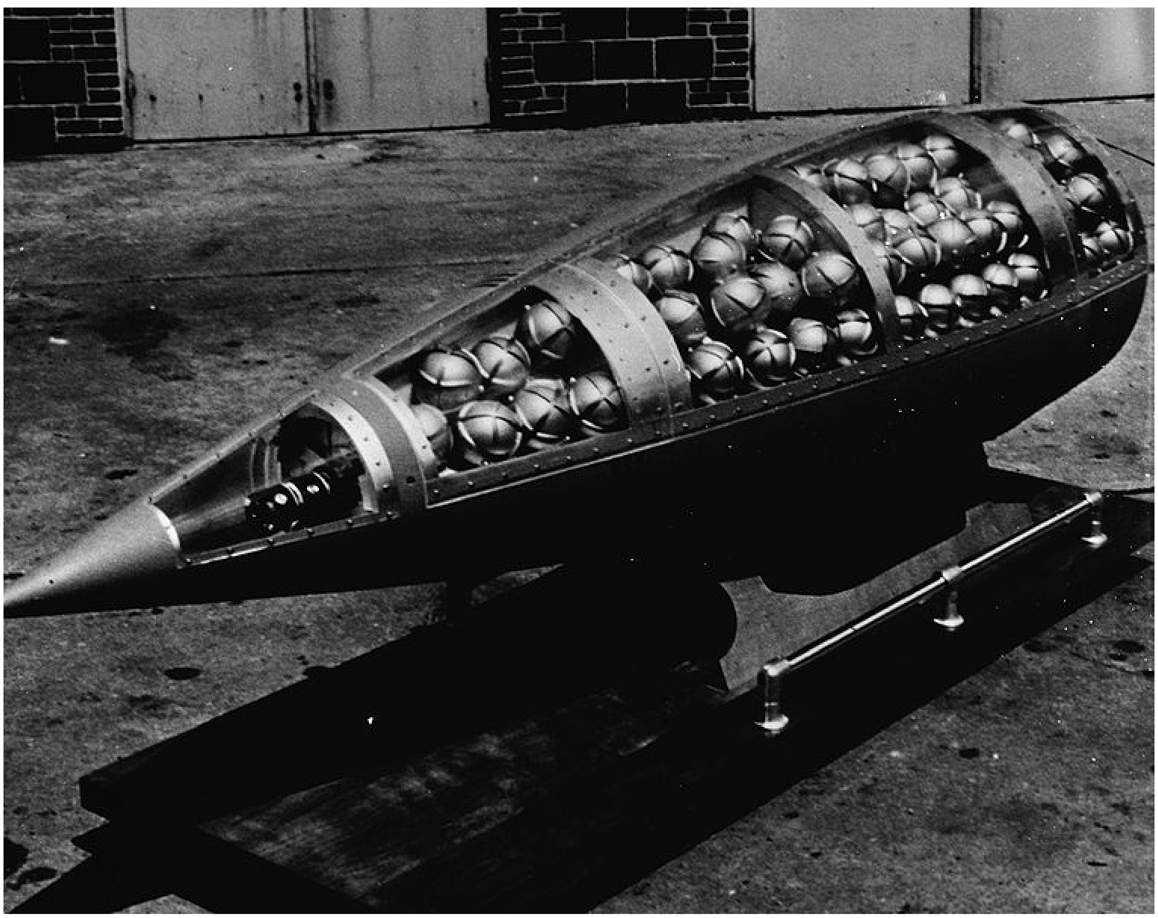
Modern Israeli anti-runway cluster bomb

Anti-runway

Anti-runway submunitions such as the British JP233 are designed to penetrate concrete before detonating, allowing them to shatter and crater runway surfaces. In the case of the JP233, the cratering effect is achieved through the use of a two-stage warhead that combines a shaped charge and conventional explosive. The shaped charge creates a small crater inside which the conventional explosive detonates to enlarge it. Anti-runway submunitions are usually used along with anti-personnel submunitions equipped with delay or booby-trap fuses that act as anti-personnel mines to make repair more difficult.

Mine-laying

When submunition-based weapons are used to disperse mines, their submunitions do not detonate immediately, but behave like conventional land mines that detonate later. The submunitions usually include a combination of anti-personnel and anti-tank mines. Since such mines usually lie on exposed surfaces, the anti-personnel forms, such as the US Area Denial Artillery Munition normally deploy tripwires automatically after landing to make clearing the minefield more difficult. In order to avoid rendering large portions of the battlefield permanently impassable, and to minimize the amount of mine-clearing needed after a conflict, scatterable mines used by the United States are designed to self-destruct after a period of time from 4–48 hours. The internationally agreed definition of cluster munitions being negotiated in the Oslo Process may not include this type of weapon, since landmines are already covered in other specific international instruments.



U.S. Honest John missile warhead cutaway, showing M134 Sarin bomblets (photo circa 1960)

Chemical weapons

During the 1950s and 1960s, the United States and Soviet Union developed cluster weapons designed to deliver chemical weapons. The Chemical Weapons Convention of 1993 banned their use. Six nations declared themselves in possession of chemical weapons. The US and Russia are in the process of destroying their stockpiles, although they have received extensions for the full destruction, not having completed the destruction of their Chemical Weapons stockpiles by 2007, as the Treaty had originally intended.

Anti-electrical

An anti-electrical weapon, the CBU-94/B, was first used by the U.S. in the Kosovo War in 1999. These consist of a TMD (Tactical Munitions Dispenser) filled with 202 BLU-114/B "Soft-Bomb" submunitions. Each submunition contains a small explosive charge that disperses 147 reels of fine conductive fiber, either carbon fiber or aluminum-coated glass fiber. Their purpose is to disrupt and damage electric power transmission systems by producing short circuits in high-voltage power lines and electrical substations. On the first attack, these knocked out 70% of the electrical power supply in Serbia. There are reports that it took 500 people 15 hours to get one transformer yard back on line after being hit with the conductive fibers.

Leaflet dispensing

The LBU-30 is designed for dropping large quantities of leaflets from aircraft. (Dispensing leaflets from the air is a common propaganda tactic in wartime.) Enclosing the leaflets within the bomblets ensures that the leaflets will fall on the intended area without being dispersed excessively by the wind. The LBU-30 consists of SUU-30 dispensers that have been adapted to leaflet dispersal. The dispensers are essentially recycled units from old bombs. The LBU-30 was tested at Eglin Air Force Base in 2000, by an F-16 flying at 20,000 feet (6,100 m).

History of use

First Chechen War

- Used by Russia

Croatia, 1995

- Used by Republic of Serbian Krajina,

Second Chechen War

- Russia repeatedly fired cluster munitions into Chechnya, many of them into civilian communities.

Afghanistan, 2001

- Used by the United States

Afghanistan joined 100 nations signing a treaty banning the use of cluster munitions. According to the New York Times newspaper, in a surprising last-minute change of policy, the government of President Hamid Karzai agreed to sign the Convention on Cluster Munitions in December 2008.

Lebanon, 1978, 1982 and 2006

- Extensively used by Israel during the 1978 Israeli invasion of Lebanon, the 1982-2000 occupation of Lebanon and in the 2006 Lebanon War.

During the Israeli-Lebanese conflict in 1982, Israel used cluster munitions, many of them American-made, on targets in southern Lebanon. Israel also used cluster bombs in the 2006 Lebanon War.

Two types of cluster munitions were transferred to Israel from the U.S. The first was the CBU-58 which uses the BLU-63 bomblet. This cluster bomb is no longer in production. The second was the MK-20 Rockeye, produced by Honeywell Incorporated in Minneapolis. The CBU-58 was used by Israel in Lebanon in both 1978 and 1982. The Israeli Defense company Israel Military Industries also manufactures the more up-to-date M-85 cluster bomb.

Hezbollah fired Chinese-manufactured cluster munitions into Israel using 122-mm rocket launchers during the 2006 war, hitting Kiryat Motzkin, Nahariya, Karmiel, Maghar, and Safsufa. A total of 113 rockets and 4,407 submunitions were fired into Israel during the war. The rockets killed one person and injured twelve.

The United Nations and human rights groups have accused Israel of dropping as many as 4 million cluster bomblets onto targets in Lebanon during the 2006 Lebanon war.

"Israel Defense Forces Chief of Staff Dan Halutz plans to appoint a major general to investigate the use of cluster bombs — some of which were fired against his order — during the Lebanon war. Halutz ordered the IDF to use cluster bombs with extreme caution and not to fire them into populated areas. Nonetheless, it did so anyway, primarily using artillery batteries and the Multiple Launch System (MRLS). IDF artillery, MLRS and aircraft are thought to have delivered thousands of cluster bombs, containing a total of some 4 million bomblets during the war."

Human Rights Watch said there was evidence that Israel had used cluster bombs very close to civilian areas and described them as "unacceptably inaccurate and unreliable weapons when used around civilians" and that "they should never be used in populated areas." Human Rights Watch has accused Israel of using cluster munitions in an attack on Bilda, a Lebanese village, on 19 July which killed 1 civilian and injured 12, including seven children. The Israeli "army defended ... the use of cluster munitions in its offensive with Lebanon, saying that using such munitions was 'legal under international law' and the army employed them 'in accordance with international standards.'" Foreign Ministry Spokesman Mark Regev added, "[I]f NATO countries stock these weapons and have used them in recent conflicts — in Yugoslavia, Afghanistan and Iraq — the world has no reason to point a finger at Israel."

Georgia, 2008

- Used by Georgia, Russia denies use of such equipment

Russia and Georgia both used cluster munitions during the 2008 South Ossetia war. According to the Human Rights Watch, the Russian Air Force dropped RBK-250 cluster bombs in populated areas, killing at least 11 civilians (including Dutch journalist Stan Storimans) and injuring dozens: "this is the first known use of cluster munitions since 2006, during Israel’s war with Hezbollah in Lebanon" - the group said. Russian Colonel-General Anatoly Nogovitsyn, answering question about the topic said: "We never use cluster bombs. There is no need to do so." Human Rights Watch said on September 1 that Georgia had admitted to using cluster bombs during the war, The Associated Press and AFP reported. The Georgian military used LAR-160 multiple rocket launchers to fire MK4 LAR 160 type rockets (with M-85 bomblets) with a range of 45 kilometers the Georgian MoD said. The Dutch government investigated the death of Storimans and concluded based on footage and materials found on location that the cluster bomb responsible for Storimans had been propelled by an SS-26 tactical missile. The SS-26 (though not been a cluster bomb) is used by Russia, but not Georgia forces, hence the Dutch government concluded that the attack was Russian.

Threat to civilians

Sergeant First Class Furl A. Krebs loads a munition with 22,500 Korean language leaflets in 1950 for use as psychological warfare during the Korean War

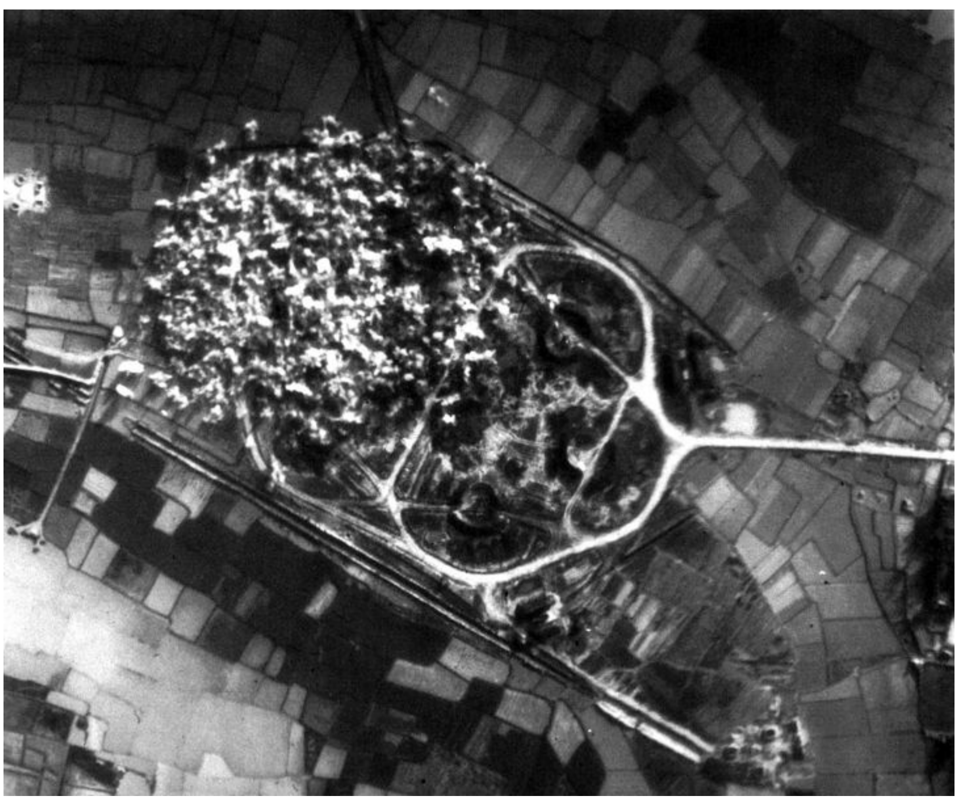
While all weapons are dangerous, cluster bombs pose a particular threat to civilians for two reasons: they have a wide area of effect, and they have consistently left behind a large number of unexploded bomblets. The unexploded bomblets can remain dangerous for decades after the end of a conflict.

Cluster munitions are opposed by many individuals and hundreds of groups, such as the Red Cross, the Cluster Munition Coalition and the United Nations, because of the high number of civilians that have fallen victim to the weapon. Since February 2005, Handicap International called for cluster munitions to be prohibited and collected hundreds of thousands of signatures to support its call. 98% of 13,306 recorded cluster munitions casualties that are registered with Handicap International are civilians, while 27% are children.

The area affected by a single cluster munition, known as its footprint, can be as large as two or three American football fields. A single unguided M26 MLRS rocket can effectively cover an area of 0.23 km^2. In US and most allied services, the M26 has been replaced by the M30 guided missile fired from the MLRS. The M30 has greater range and accuracy but a smaller area of coverage. It is worth noting that for reasons including both danger to civilians and changing tactical requirements, the non-cluster unitary warhead XM31 missile is, in many cases, replacing even the M30.

Because of the weapon's broad area of effect which is characteristic of all explosive weapons, they have often been documented as striking both civilian and military objects in the target area. This characteristic of the weapon is particularly problematic for civilians when cluster munitions are used in or near populated areas and has been documented by research reports from groups such as Human Rights Watch, Landmine Action, Mines Action Canada and Handicap International. In some cases, like the Zagreb rocket attack, civilians were deliberately targeted by such weapons.

Unexploded ordnance



Half of a surface-to-air missile site in North Vietnam blanketed in exploding bomblets dispersed by a U.S. cluster munition, Vietnam War

The other serious problem, also common to explosive weapons is unexploded ordnance (UXO) of cluster bomblets left behind after a strike. These bomblets may be duds or in some cases the weapons are designed to detonate at a later stage. In both cases, the surviving bomblets are live and can explode when handled, making them a serious threat to civilians and military personnel entering the area. In effect, the UXOs can function like land mines.

Even though cluster bombs are designed to explode prior to or on impact, there are always some individual submunitions that do not explode on impact. The US-made MLRS with M26 warhead and M77 submunitions are supposed to have a 5% dud rate but studies have shown that some have a much higher rate. The rate in acceptance tests prior to the Gulf War for this type ranged from 2% to a high of 23% for rockets cooled to −25 °F (−32 °C) before testing. The M483A1 DPICM artillery-delivered cluster bombs have a reported dud rate of 14%.

Given that each cluster bomb can contain hundreds of bomblets and be fired in volleys, even a small failure rate can lead each strike to leave behind hundreds or thousands of UXOs scattered randomly across the strike area. For example, after the 2006 Israel-Lebanon conflict, UN experts have estimated that as many as one million unexploded bomblets may contaminate the hundreds of cluster munition strike sites in Lebanon.

M77 submunition of type fired against Lebanon in 1986. Each MLRS rocket has 644 M77 packed in the warhead

In addition, some cluster bomblets, such as the BLU-97/B used in the CBU-87, are brightly colored to increase their visibility and warn off civilians. However, the yellow color, coupled with their small and nonthreatening appearance, is attractive to young children who wrongly believe them to be toys. This problem was exacerbated in the War in Afghanistan (2001–present), when US forces dropped humanitarian rations from airplanes with similar yellow-colored packaging as the BLU-97/B, yellow being the NATO standard colour for high explosive filler in air weapons. The rations packaging was later changed first to blue and then to clear in the hope of avoiding such hazardous confusion.

The US military is developing new cluster bombs that it claims could have a much lower (less than 1%) dud rate. Sensor-fused weapons that contain a limited number of submunitions that are capable of autonomously engaging armored targets may provide a viable, if costly, alternative to cluster munitions that will allow multiple target engagement with one shell or bomb while avoiding the civilian deaths and injuries consistently documented from the use of cluster munitions. Certain such weapons may be allowed under the recently adopted Convention on Cluster Munitions, provided they do not have the indiscriminate area effects or pose the unexploded ordnance risks of cluster munitions.

In the 1980s the Spanish firm Esperanza y Cia developed a 120mm caliber mortar bomb which contained 21 anti-armor submunitions. What made the 120mm "Espin" unique was the electrical impact fusing system which totally eliminated dangerous duds. The system operates on a capacitor in each submunition which charged by a wind generator in the nose of the projectile after being fired. If for what ever reason the electrical fuse fails to function on impact, approximately 5 minutes later the capacitor bleeds out, therefore neutralizing the submunition's electronic fuse system. Later a similar mortar round was offered in the 81mm caliber and equipped some Spanish Marine units. But on signing the Wellington Declaration on Cluster Munitions, Spain withdrew both the 81mm and 120mm "Espin" rounds from its military units.

Civilian deaths from unexploded cluster bomblets

- In Vietnam, people are still being killed as a result of cluster bombs and other objects left by the US and Vietnamese military forces. Estimates range up to 300 people killed annually by unexploded ordnance.
- Some 270 million cluster submunitions were dropped on Laos in the 1960s and 1970s; approximately one third of these submunitions failed to explode and continue to pose a threat today.
- During the 1999 NATO war against Yugoslavia U.S. and Britain dropped 1,400 cluster bombs in Kosovo. Within the first year after the end of the war more than 100 civilians died from unexploded British and American bombs. Unexploded cluster bomblets caused more civilian deaths than landmines.
- Israel used cluster bombs in Lebanon in 1978 and in the 1980s. Those weapons used more than two decades ago by Israel continue to affect Lebanon. During the 2006 war in Lebanon Israel fired large numbers of cluster bombs in Lebanon,

containing an estimated more than 4 million cluster submunitions. In the first month following the ceasefire, unexploded cluster munitions killed or injured an average of 3-4 people per day.

Areas with significant unexploded cluster bomb submunitions

Ban Advocates from Afghanistan and Ethiopia demonstrating outside of the Dublin conference

- Nagorno Karabakh
- Lebanon
- Indochina, especially in Laos and central Vietnam's former demilitarized zone.
- Serbia
- Afghanistan
- Iraq
- Western Sahara

Countries that have been affected by cluster munitions include:

- Afghanistan
- Albania
- Bosnia & Herzegovina
- Cambodia
- Chad
- Iraq
- Israel
- Kuwait
- Laos
- Lebanon
- Montenegro
- Serbia (mainly south Serbia and Kosovo)
- Sierra Leone
- South Ossetia
- Sudan
- Syria

- Croatia
- Eritrea
- Ethiopia
- Georgia (including South Ossetia)
- Pakistan
- Russia (Chechnya)
- Saudi Arabia
- Tajikistan
- Vietnam
- Western Sahara
- United Kingdom - The Falkland Islands

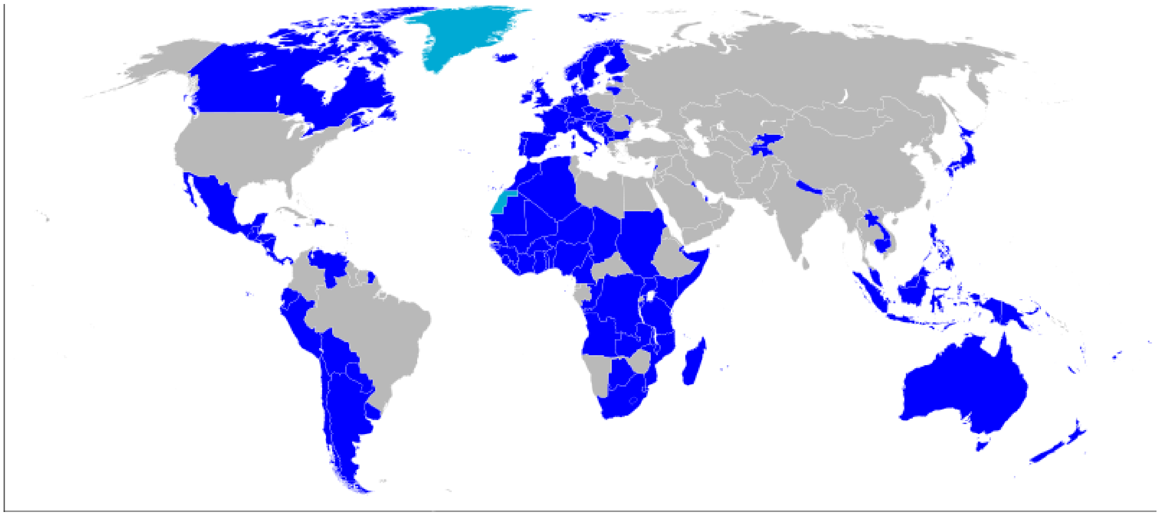
International legislation

Cluster bombs fall under the general rules of international humanitarian law, but were not specifically covered by any currently binding international legal instrument until the signature of the Convention on Cluster Munitions in December 2008. This international treaty stemmed from an initiative by the Government of Norway known as the Oslo Process which was launched in February 2007 to prohibit cluster munitions. More than 100 countries agreed to the text of the resulting Convention on Cluster Munitions in May 2008 which sets out a comprehensive ban on these weapons. This treaty was signed by 94 states in Oslo on 3–4 December. The Oslo Process was launched largely in response to the failure of the Convention on Certain Conventional Weapons (CCW) where five years of discussions failed to find an adequate response to these weapons. The Cluster Munition Coalition (CMC) is campaigning for the widespread accession to and ratification of the Convention on Cluster Munitions.

A number of sections of the Protocol on explosive remnants of war (Protocol V to the 1980 Convention), 28 November 2003 occasionally address some of the problems associated with the use of cluster munitions, in particular Article 9, which mandates States Parties to "take generic preventive measures aimed at minimising the occurrence of explosive remnants of war". In June 2006, Belgium was the first country to issue a ban on the use (carrying), transportation, export, stockpiling, trade and production of cluster munitions, and Austria followed suit on 2007-12-07.

There has been parliamentary activity on cluster munitions in several countries, including Austria, Australia, Denmark, France, Germany, Luxembourg, Netherlands, Norway, Sweden, Switzerland, United Kingdom and United States. In some of these countries, ongoing discussions concerning draft legislation banning cluster munitions, along the lines of the legislation adopted in Belgium and Austria will now turn to ratification of the global ban treaty. Norway and Ireland have national legislation prohibiting cluster munitions and were able to deposit their instruments of ratification to the Convention on Cluster Munitions immediately after signing it in Oslo on 3 December.

International treaties



Nations subscribing to the Wellington Declaration, which led to the Convention on Cluster Munitions

Other weapons, such as land mines, have been banned in many countries under specific legal instruments for several years, notably the Ottawa Treaty to ban land mines, and some of the Protocols in the Convention on Certain Conventional Weapons that also help clearing the lands contaminated by left munitions after the end of conflicts and provides international assistance to the affected populations. However, until the recent adoption of the Convention on Cluster Munitions in Dublin in May 2008 cluster bombs were not banned by any international treaty and were considered legitimate weapons by some governments.

To increase pressure for governments to come to an international treaty on November 13, 2003, the Cluster Munition Coalition (CMC) was established with the goal of addressing the impact of cluster munitions on civilians. At the launch, organised by Pax Christi Netherlands, the then Minister of Foreign Affairs, the later Secretary General of NATO, Jaap de Hoop Scheffer, addressed the crowd of gathered government, NGO, and press representatives.

International governmental deliberations in the Convention on Certain Conventional Weapons turned on the broader problem of explosive remnants of war, a problem to which cluster munitions have contributed in a significant way. However, despite calls from the Cluster Munition Coalition and a range of humanitarian organizations - notably the International Committee of the Red Cross (ICRC) and Handicap International - and approximately 30 governments, international governmental negotiations to develop specific measures that would address the humanitarian problems cluster munitions pose did not prove possible in the conventional multilateral forum. Because of its consensus decision making practices, current deliberations in the CCW face serious challenges in developing meaningful outcomes.

In February 2006, Belgium announced its decision to ban the weapon by law. Then Norway announced a national moratorium in June and Austria announced its decision in July to work for an international instrument on the weapon. The international controversy over the use and impact of cluster munitions during the war between Lebanon and Israel in July and August 2006 added weight to the global campaign for a ban treaty.

Ugandan demonstrator at the May 2008 Dublin conference for the Convention on Cluster Munitions

Against this background, a new flexible multilateral process similar to the process that led to the ban on anti-personnel land mines in 1997 (the Ottawa Treaty) began with an announcement in November 2006 in Geneva as well at the same time by the Government of Norway that it would convene an international meeting in early 2007 in Oslo to work towards a new treaty prohibiting cluster munitions. 49 governments attended the meeting in Oslo February 22–23, 2007 in order to reaffirm their commitment to a new international ban on the weapon. During the meeting Austria announced an immediate moratorium on the use, production and transfer of cluster munitions until a new international treaty banning the weapons is in place.

A follow-up meeting in this process was held in Lima in May where around 70 states discussed the outline of a new treaty, Hungary became the latest country to announce a moratorium and Peru launched an initiative to make Latin America a cluster munition free zone.

In addition, the ICRC held an experts meeting on cluster munitions in April 2007 which helped clarify technical, legal, military and humanitarian aspects of the weapon with a view to developing an international response.

Further meetings took place in Vienna from 4–7 December 2007, and in Wellington from 18–22 February 2008 where a declaration in favor of negotiations on a draft convention was adopted by more than 80 countries. In May 2008 after around 120 countries had subscribed to the Wellington Declaration and participated in the Dublin Diplomatic Conference from 19 to 30 May 2008. At the end of this Conference, 107 countries agreed to adopt the Convention on Cluster Munitions, that bans cluster munitions and was opened for signature in Oslo on December 3–4, 2008 where it was signed by 94 countries.

In July 2008, United States Defense Secretary Robert M. Gates implemented a policy to eliminate by 2018 all cluster bombs that do not meet new safety standards.

In November 2008, ahead of the signing Conference in Oslo, the European Parliament passed a resolution calling on all European Union governments to sign and ratify the Convention.

On 16 February 2010 Burkina Faso became the 30th State to deposit its instrument of ratification for the Convention on Cluster Munitions. This means that the number of States required for the Convention to enter into force had been reached. The treaty's obligations became legally binding on the 30 ratifying States on 1 August 2010 and subsequently for other ratifying States.

Convention on Cluster Munitions

Taking affect on August 1, 2010, the "*Convention on Cluster Munitions*" bans the stockpiling, use and transfer of virtually all existing cluster bombs and provides for the clearing up of unexploded munitions. It has been adopted by 108 countries, of which 38 have ratified it, but many of the world's major military powers including the United States, Russia and China are not signatories to the treaty.

Countries that have used cluster munitions

At least fourteen countries have used cluster munitions in recent history (since the creation of the United Nations). All of these nations still have stocks of these munitions. Countries that have subscribed to the Wellington Declaration, agreeing in principle to ban cluster bombs, are listed in bold.

- Eritrea
- Ethiopia
- **France**
- Georgia
- Israel
- **Morocco**
- **Netherlands**
- **Nigeria**
- Russia
- Saudi Arabia
- **South Africa**
- **Tajikistan**
- **United Kingdom**
- United States

- **Sudan**

In addition, at least three countries that no longer exist (the Soviet Union, Yugoslavia and Rhodesia) have used cluster bombs.

Countries that have produced cluster munitions

At least 28 nations have produced cluster munitions in recent history (since the creation of the United Nations). All of these nations still have stocks of these munitions. Most (but not all) of them are involved in recent wars or long unsolved international conflicts; however most of them did not use the munitions they produced. Countries that have subscribed to the Wellington Declaration, agreeing in principle to ban cluster bombs, are listed in bold.

- Argentina
- Brazil
- **Bulgaria**
- **Chile**
- People's Republic of China
- Republic of China
- Egypt
- **France**
- **Germany**
- Greece
- India
- Iran
- Iraq
- Israel
- **Italy**
- **Japan**
- North Korea
- South Korea
- Pakistan
- Poland
- Romania
- Russia
- **Serbia**
- Singapore
- **Slovakia**
- **South Africa**
- **Spain**
- **Sweden**
- Turkey
- **United Kingdom**
- United States

Countries that have stocks of cluster munitions

As of 2008, at least 76 countries have stockpiles of cluster munitions (including all the countries above, that have produced them). Countries listed in bold have subscribed to the Wellington Declaration, agreeing in principle that their stockpiles should be destroyed.

- **Algeria**
- **Angola**
- **Austria**
- Azerbaijan
- **Bahrain**
- Belarus
- **Bosnia and Herzegovina**
- Brazil
- **Bulgaria**
- **Chile**
- China
- **Croatia**
- Cuba
- **Czech Republic**
- **Denmark**
- Ecuador
- Egypt
- Estonia
- Eritrea
- Ethiopia
- **Finland**
- **France**
- Georgia
- **Germany**
- Greece
- **Guinea**
- **Guinea-Bissau**
- **Hungary**
- India
- **Indonesia**
- Israel
- **Italy**
- **Japan**
- Jordan
- Kazakhstan
- North Korea
- South Korea
- **Kuwait**
- Libya
- **Moldova**
- Mongolia
- **Montenegro**
- **Morocco**
- **Netherlands**
- **Nigeria**
- Oman
- Pakistan
- **Peru**
- Poland
- **Portugal**
- Romania
- Russia
- Saudi Arabia
- **Serbia**
- Singapore
- **Slovakia**
- **South Africa**
- **Spain**
- **Sudan**
- **Slovenia**
- **Sweden**
- **Switzerland**
- Syria
- Turkey
- Turkmenistan
- **Uganda**
- Ukraine
- United Arab Emirates
- **United Kingdom**
- United States
- Uzbekistan
- Yemen
- Zimbabwe

Countries that have ratified the Convention on Cluster Munitions

The Convention on Cluster Munitions entered into force on 1 August 2010, six months after it was ratified by 30 states. As of November 2010, 43 states have ratified the convention:

- Albania
- Antigua and Barbuda
- Austria
- Belgium
- Bosnia and Herzegovina
- Burkina Faso
- Burundi
- Cape Verde
- Comoros
- Croatia
- Denmark
- Guatemala
- Holy See
- Ireland
- Japan
- Laos
- Lebanon
- Luxembourg
- Republic of Macedonia
- Malawi
- Mali
- Malta
- Mexico
- Moldova
- New Zealand
- Nicaragua
- Niger
- Norway
- St. Vincent and the Grenadines
- Samoa
- Sierra Leone
- San Marino
- Seychelles
- Slovenia
- Tunisia
- United

- Ecuador
- Fiji
- France
- Germany
- Monaco
- Montenegro

Kingdom

- Uruguay

Chapter- 3

Aircraft Mounted Guns

ADEN cannon

A quad 30 mm ADEN cannon package from the pictured Hawker Hunter.

The **Royal Small Arms Factory ADEN** is a 30 mm revolver cannon used on many military aircraft, particularly those of the British Royal Air Force and Fleet Air Arm.

Development

The ADEN (named for the Armament Development Establishment, where it was designed, and Enfield, where it was produced) was developed in the late 1940s as a replacement for the older Hispano-Suiza HS.404 20 mm cannon used in British aircraft of World War II. It is based (as are the French DEFA cannon and American M39 cannon) on the mechanism of the German Mauser MG 213C, an experimental revolver cannon designed for the *Luftwaffe*, but never used in combat. The ADEN entered service on the Hawker Hunter in 1954, and subsequently used on every British gun-armed aircraft until the advent of the Panavia Tornado in the 1980s.

The current version is the **ADEN Mk 4**. Although its muzzle velocity of 2,430 ft/s (741 m/s) is considerably lower than the Hispano's 2,789 ft/s (850 m/s), the substantially larger and heavier projectile makes the ADEN more lethal, and it has a higher rate of fire of about 1,300 rounds per minute.

An improved version, the **ADEN Mk 5**, incorporates a multitude of small changes to improve reliability and increase rate of fire slightly to 1,500–1,700 rounds per minute. No new Mk 5s were built, but many older weapons were converted, being redesignated **Mk 5 Straden**.

Aircraft using the ADEN 30 as in-built armament have included the A-4SU Super Skyhawk, English Electric Lightning, Folland Gnat (and HAL Ajeet), Hawker Hunter, Gloster Javelin, Saab Lansen, Saab Draken, SEPECAT Jaguar, Supermarine Scimitar, and CAC Sabre. Several podded versions exist, including the installations scabbed below the fuselage of British Hawker Siddeley Harrier (and USMC AV-8A/Cs) and Sea Harriers and the Swedish **FFV Aden**, which is used (among others) on the BAe Hawk. The FFV Aden contains the weapon and 150 rounds of ammunition, is 151.57 in (3.85 m) long, and weighs 802.5 lb (364 kg) fully loaded.

The ADEN is very similar to the French DEFA cannon, and the two weapons use the same range of 30 mm ammunition.

ADEN 25

The ADEN Mk 5 became the basis for the planned **ADEN 25**, which was to be a somewhat larger weapon (90 in / 2.29 m long, 203 lb / 92 kg) firing the new range of NATO 25 mm ammunition (as in the American GAU-12 Equalizer) at a much higher muzzle velocity of 3,445 ft/s (1,050 m/s). The lighter ammunition was also to produce a higher rate of fire, 1,650 to 1,850 rounds per minute. Unfortunately, severe development problems plagued the ADEN 25, which proved unable to meet its design weight target. It was finally cancelled in 1999. As a result, RAF Harrier GR.7 and GR.9 aircraft currently have no cannon, no attempt apparently having been made to retrofit the older ADEN 30 mm pods. Fleet Air Arm Sea Harriers retained the 30 mm weapon until their retirement in 2006.

Specifications

- **Type**: single-barrel automatic cannon
- **Caliber**: 30 mm (1.18 in) × 113 mm
- **Operation**: revolver chamber
- **Length**: 1.59 m (62.6 in)
- **Weight (complete)**: 87.1 kg (192 lb)
- **Rate of fire**: 1,200 - 1,700 rpm
- **Muzzle velocity**: 741 m/s (2,430 ft/s)
- **Projectile weight**: 220 g (7.76 oz)

20 mm Becker

The **20 mm Becker** was a German automatic cannon developed for aircraft use during World War I. It was first mass produced in 1916 and was installed in a variety of aircraft; the only German autocannon to actually see service in the air during the war.

Development commenced in 1913 and was therefore already advanced when the War Ministry issued a specification in June 1915 calling for an aircraft cannon of under 37 mm caliber and 70 kg weight capable of firing a 10-round burst. Tests commenced shortly thereafter with the weapon mounted in a Gotha G.I, but proved unsatisfactory. Despite this, the potential of the gun was such that the arsenal at Spandau was engaged to help develop and fine-tune the design, leading to a production contract for 120 Becker Type M2 guns in June 1916. In addition to the orders for aircraft guns placed with Becker, Spandau and MAN also received a contract to build Becker cannon for the Army.

The 20-mm Becker was a slim weapon working on the principle of advanced primer ignition blowback. It weighed only 30 kg. It was fed by a somewhat awkward, curved box magazine, available in versions that held 10 or 15 rounds; the latter weighed another 5 kg. As the rate of fire was 325 rounds per minute, this magazine could be emptied very quickly. The muzzle velocity was 490 m/s, which was low compared to the rifle-calibre machine guns of the period such as the German MG 08, but a respectable performance compared to other automatic cannon of the period, such as the Vickers "pom-pom".

The main types to utilise the Becker were large aircraft - the Friedrichshafen G.III bomber and AEG G.IVk ground-attack machine. Tests in smaller, single-engined aircraft were not so successful, but were carried out extensively through the rest of the war, commencing with an Albatros J.I in December 1917. Due to the gun's operating principles, it could not be synchronised, and this posed an immediate problem for its installation in this type of plane. The solution adopted after the tests with the Albatros J.I was to fit it to fire downwards through the floor. Fitting the gun to a fighter with a pusher configuration was another obvious solution, and trials were carried out with an Albatros D.VI. Other intended installations were for an AGO C.I and the Hansa D.I, but these were not carried out before the Armistice.

Total production figures are not known, but were in excess of 539. A total of 362 were surrendered to the Allies.

The patent for the gun was bought by SEMAG in 1921, who continued development with a more powerful cartridge, and then by Oerlikon in 1924, who marketed improved versions as the Oerlikon F, L and S.

BK 5 cannon

BK-5 cannon

rear view of a BK-5 in the National Museum of the United States Air Force, Dayton, Ohio, showing the semi-circular magazine

Type	Cannon
Place of origin	Germany
Service history	
In service	1944–1945
Wars	World War II
Production history	
Designer	Rheinmetall
Designed	1943
Manufacturer	Rheinmetall
Produced	1943–1945
Number built	approx. 300
Specifications	
Weight	540 kilograms (1,200 lb)

Cartridge	50 mm
Rate of fire	45 rounds per minute.

The **Bordkanone 5**, or **BK 5** for short, was a 50 mm autocannon intended primarily for use against Allied heavy bombers, especially the USAAF's combat box heavy bomber flight formations, so that defending *Luftwaffe* fighter aircraft could fire from a great enough distance to make the USAAF bomber's heavy defensive firepower ineffective against defending German fighter aircraft. Rheinmetall was given a contract in 1943 to adapt the 50 mm KwK 39 tank gun, from the Panzer III tank, for aerial use in the twin-engined Me 410 *Hornisse* bomber destroyer. They were installed as *Umrüst-Bausätze* (Factory Modification) 4 in the Me 410A-1/U4, and experimentally, in two Me 262A-1a/U4 jet fighter prototypes (though these were not used operationally) , as the MK 214 cannon of similar caliber was not yet available. The semi-circular magazine held 22 rounds. Approximately 300 were produced and it saw only limited action, most notably in the Me 410A-1/U4 *Hornissen* aircraft that served with the II. Gruppe of Zerstörergeschwader 26. It was also mounted on the Junkers Ju 88P-4 night attack aircraft. Intended for long-range shots, the cannon was given a telescopic sight in addition to the Me 410's standard Revi C12C gunsight. This proved to be more of a hindrance than a help in the turning fights in which the Me 410s often found themselves, as the maneuvering targets easily escaped from the telescopic sight's small field of view.

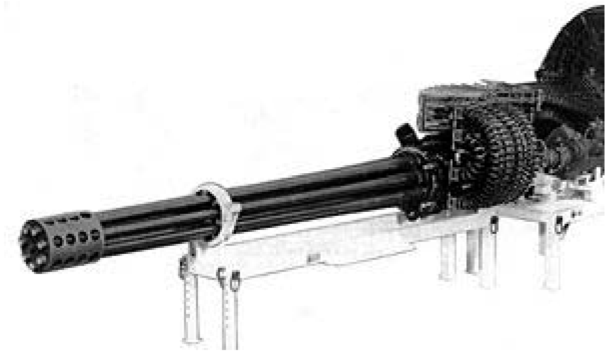
As installed in the Me 262, the cannon was found to be prone to jamming, and if fired at night tended to temporarily blind the pilot's night vision.

According to the account of the engagements against the USAAF by II/ZG 26 from late February through mid-April 1944 mentioned at a German language website , the 53 *Hornissen* of that Zerstörergruppe equipped with the BK 5 were said to have to shot down a staggering total of 129 B-17 Flying Fortress and four B-24 Liberator heavy bomber aircraft, distributed over a series of five or six interceptions, all while losing only nine of their own Me 410s.

Specifications for the BK 5 as given on the National Museum of the United States Air Force's website was previously identical to the entry for with the 30 mm MK 108 cannon, but this has since been corrected.

GAU-8 Avenger

GAU-8 Avenger



The GAU-8/A Avenger's barrel and breech assembly (ammunition drum off edge of photo).

Type	Gatling-style autocannon
Place of origin	United States
Service history	
In service	1977–present
Used by	United States
Production history	
Manufacturer	General Electric
Number built	Approx. 715
Variants	GAU-12/U Equalizer GAU-13/A
Specifications	
Weight	619.5 lb (281 kg)
Length	19 ft 10.5 in (6.06 m) (total system) 112.28 in (2.85 m) (barrel only)
Barrel length	90.5 in (2.30 m)
Width	17.2 in (0.437 m) (barrel only)
Cartridge	30 × 173 mm
Caliber	30 mm caliber
Barrels	7
Action	Electric-Motor, Hydraulic-Driven
Rate of fire	4,200 rpm (rounds per minute)
Muzzle velocity	3,500 ft/s (1,070 m/s)
Maximum range	Over 4,000 feet (1,220 m)
Feed system	Linkless feed system

The General Electric **GAU-8/A Avenger** is a 30 mm, hydraulically-driven seven-barrel Gatling-type rotary cannon that is mounted on the United States Air Force's Fairchild Republic A-10 Thunderbolt II. It is among the largest, heaviest and most powerful aircraft cannons in the United States military. Designed specifically for the anti-tank role, the Avenger delivers very powerful rounds at a high rate of fire.

History

The GAU-8 was created as a parallel program with the *A-X* (or Attack Experimental) competition that produced the A-10. The specification for the cannon was laid out in 1970, with General Electric and Philco-Ford offering competing designs. Both of the A-X prototypes, the YA-10 and the Northrop YA-9, were designed to incorporate the weapon, although it was not available during the initial competition, and the M61 Vulcan was used as a temporary replacement. Once completed, the entire GAU-8 assembly (correctly referred to as the A/A 49E-6 Gun System) represents about 16% of the A-10 aircraft's unladen weight.

The gun is placed slightly off center in the nose of the plane with the front landing gear positioned to the right of the center line, so that the actively firing cannon barrel is directly on the aircraft's center line. The Russian Gryazev-Shipunov GSh-6-30 is a similar class of weapon, although it is lighter with a higher fire rate, but has a lower muzzle velocity and overheats more quickly.

GAU-8 closeup

The A-10 and its GAU-8/A gun entered service in 1977. It was produced by General Electric, though General Dynamics Armament and Technical Products has been responsible for production and support since 1997 when the division was sold by Lockheed Martin to General Dynamics.

The gun is loaded using Syn-Tech's linked tube carrier GFU-8/E 30 mm Ammunition Loading Assembly cart. This vehicle is unique to the A-10 and the GAU-8.

Design

The GAU-8 itself weighs 620 pounds (280 kg), but the complete weapon, with feed system and drum, weighs 4,029 pounds (1,828 kg) with a maximum ammunition load. It measures 19 ft 5½ in (5.931 m) from the muzzle to the rearmost point of the ammunition system, and the ammunition drum alone is 34.5 inches (88 cm) in diameter and 71.5 inches (1.82 m) long. The magazine can hold 1,174 rounds, although 1,150 is the typical load-out. Muzzle velocity when firing Armor-Piercing Incendiary rounds is 3,250 feet per second (990 m/s), almost the same as the substantially lighter M61 Vulcan's 20 mm round.

GAU-8 inside A-10

The standard ammunition mixture for anti-armor use is a four-to-one mix of PGU-14/B Armor Piercing Incendiary, with a projectile weight of about 15.0 oz (425 grams or 6,560 grains) and PGU-13/B High Explosive Incendiary (HEI) rounds, with a projectile weight of about 12.7 oz (360 grams or 5,556.25 grains). The PGU-14/B's projectile incorporates a lightweight aluminum body, cast around a smaller caliber depleted uranium penetrating core. The Avenger is lethal against tanks and all other armored vehicles.

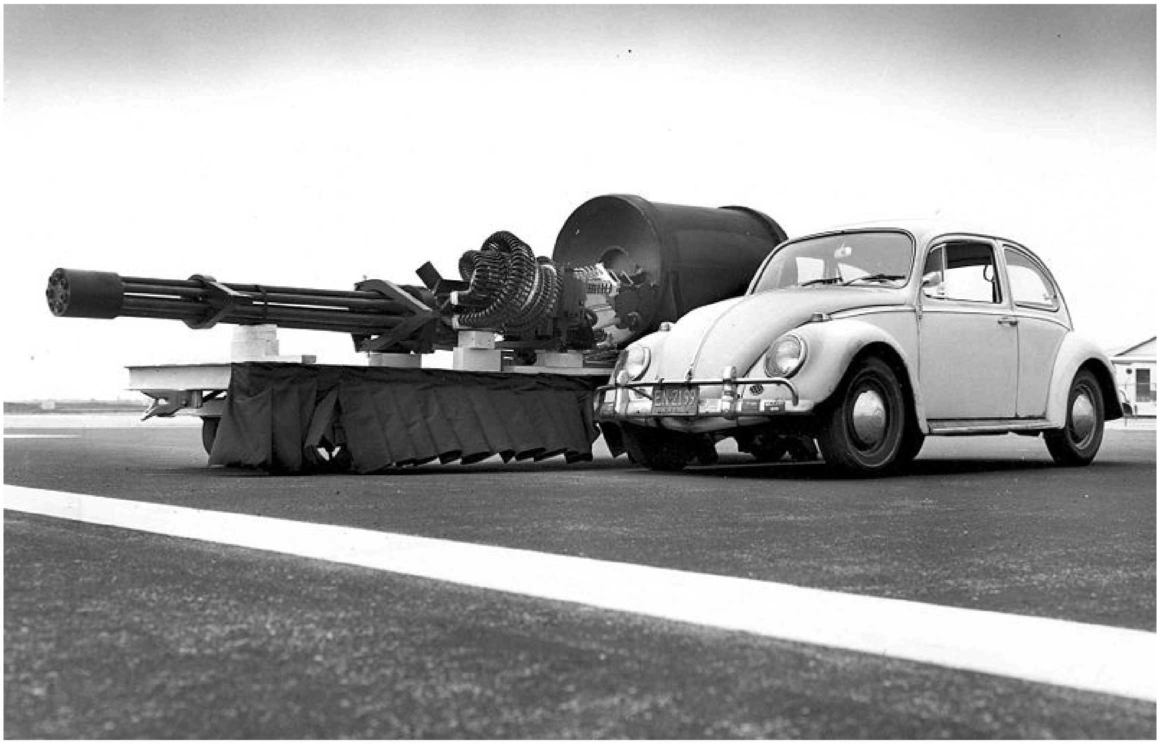
A very important innovation in the design of the GAU-8/A shells is the use of aluminum alloy cases in place of the traditional steel or brass. This alone adds 30% to ammunition capacity for a given weight. The shells also have plastic driving bands to improve barrel life. They are imposing to examine and handle, measuring 11.4 inches (290 mm) in length and weighing 1.53 pounds (0.69 kg) or more.

The Avenger's rate of fire was originally selectable, 2,100 rounds per minute (rpm) in the low setting, or 4,200 rpm in the high setting. Later this was changed to a fixed rate of 3,900 rpm. In practice, the cannon is limited to one and two-second bursts to avoid overheating and conserve ammunition; barrel life is also a factor, since the USAF has specified a minimum life of at least 20,000 rounds for each set of barrels. There is no technical limitation on the duration the gun may be continuously fired, and a pilot could potentially expend the entire ammunition load in a single burst with no damage or ill effects to the weapons system itself. However, this constant rate of fire would shorten the barrel life considerably and require added barrel inspections and result in shorter intervals between replacement.

Each barrel is a very simple non-automatic design having its own breech and bolt. Like the original Gatling gun, the entire firing cycle is actuated by cams and powered by the rotation of the barrels. The barrels themselves are driven by the aircraft's dual hydraulic system.

The GAU-8/A ammunition is linkless, reducing weight and avoiding a great deal of potential for jamming. The feed system is double-ended, allowing the spent casings to be recycled back into the ammunition drum, instead of ejected from the aircraft, which would require considerable force to eliminate potential airframe damage. The feed system is based on that developed for later M61 installations, but uses more advanced design techniques and materials throughout, to save weight.

Firing system



The GAU-8/A Avenger Gatling gun next to a VW Type 1. Removing an installed GAU-8 from an A-10 requires first installing a jack under the aircraft's tail as the cannon comprises most of the aircraft's forward weight.

Accuracy

The GAU-8/A is extremely accurate and can fire from 2100 to 4200 shells per minute without complications. The 30-mm shell has twice the range, half the time to target, and three times the mass of projectiles carried by comparable Close Air Support aircraft.

The muzzle velocity of the GAU-8/A is about the same as that of the M61 Vulcan cannon, but its improved ammunition is more destructive and has superior ballistic properties. Its time of flight to 4,000 feet (1,200 m) is 30 percent less than that of an M61 round, the projectile decelerates much less rapidly after leaving the barrel, and it drops a negligible amount, about 10 feet (3.0 m) over the distance. The GAU-8/A accuracy when installed in the A-10 is rated at "5 mil, 80 percent", meaning that 80 percent of rounds fired at 4,000 feet (1,200 m) will hit the target within a 20 feet (6.1 m) radius circle. By comparison, the M61 is rated at 8 milliradians.

Recoil

Each barrel fires when it reaches roughly the 9 o'clock position, when viewed from the front of the plane. Because the gun's recoil forces could push the entire plane off target during firing, the weapon itself is mounted off-center in the other direction, toward the 3 o'clock position, so that the firing barrel lies directly on the aircraft's center line. The firing barrel also lies just below the aircraft's center of gravity, being bore sighted along a line 2 degrees below the aircraft's line of flight. This arrangement accurately centers the recoil forces, preventing changes in pitch and/or yaw when fired. This configuration also provides space for the front landing gear, which are mounted slight off-center on the right side of the nose.

The GAU-8/A utilizes recoil adapters. They are the interface between the gun housing and the gun mount. By absorbing (in compression) the recoil forces, they spread the time of the recoil impulse and counter recoil energy transmitted to the supporting structure when the gun is fired.

The A-10 engines were initially susceptible to flameout when subjected to gases generated in the firing of the gun. When the GAU-8 is being fired, the smoke from the gun can make the engines stop, and this did occur during initial flight testing. Gun exhaust is essentially oxygen-free, and is certainly capable of causing flame-outs of gas turbines. The A-10 engines now have a self sustaining combustion section. When the gun is fired the igniters come on to reduce the possibility of a flame-out.

The recoil force of the GAU-8/A is 10,000 pounds-force (45 kN), which is slightly more than the output of one of the A-10's two TF34 engines (9,065 lbf / 40.3 kN each). While this recoil force is significant, in practice cannon fire only slows the aircraft a few miles per hour.

Variants

Some of the GAU-8/A technology has been transferred into the smaller 25 mm GAU-12/U Equalizer developed for the AV-8B Harrier II aircraft, which is about the same size as the M61 but is considerably more lethal. GE has also developed the GAU-13/A, a four-barreled weapon using GAU-8/A components, which has been tested in podded form as the GPU-5/A, and the Avenger forms the basis for the Dutch-developed Goalkeeper naval air-defence gun. No current or contemplated aircraft other than the A-10, however, carries the full-up Avenger system.

Specifications

- Accuracy: 80% of rounds fired at 4,000 feet (1,200 m) range hit within a 20 feet (6.1 m) radius
    - PGU-14/B API Armor Piercing Incendiary (DU)
    - PGU-13/B HEI High explosive incendiary
    - PGU-15/B TP Target Practice
- Armor penetration:
    - 69 mm at 500 meters
    - 38 mm at 1000 meters
    -

Chapter- 4

Air-Dropped Bombs

AASM

Armement Air-Sol Modulaire (Air-to-Ground Modular Weapon)	

AASM family of weapons

Type	Precision-Guided Munition
Place of origin	France
Service history	
In service	2007
Used by	French Air Force French Naval Aviation
Wars	War in Afghanistan
Production history	
Manufacturer	Sagem Défense Sécurité
Specifications (250 kg (550 lb) version)	
Weight	340 kg (750 lb)
Length	3.1 m (10 ft 2 in)
Warhead	250 kg (550 lb) bomb body (Mk82, BLU 111 or CBEMS/BANG)

Engine	Solid rocket motor
Operational range	15 km (9 mi) at very low altitude 50 km (31 mi) at high altitude
Guidance system	Hybrid inertial/GPS in decametric all-weather version Hybrid inertial/GPS + IIR or SALH in metric day/night version
Accuracy	10 m (32 ft 10 in) CEP decametric version 1 m (3 ft 3 in) CEP metric version
Launch platform	Mirage 2000D Rafale

The **Armement Air-Sol Modulaire** (Air-to-Ground Modular Weapon) (AASM) is a French Precision-Guided Munition developed by Sagem Défense Sécurité. AASM comprises a frontal guidance kit and a rear-mounted range extension kit matched to a dumb bomb. The weapon is modular because it can integrate different types of guidance units and different types of bombs. The basic version features a 250-kilogram (550 lb) bomb plus hybrid inertial navigation system (INS) / Global Positioning System (GPS) guidance. Other variants add imaging infrared (IIR) or semi-active laser homing (SALH) to increase accuracy; there are also versions with 125-kilogram (280 lb) or 1,000-kilogram (2,200 lb) bomb bodies. It entered service in 2007 with the French Air Force and Naval Aviation.

Development

The program started in 1997, when the Délégation Générale pour l'Armement (DGA), the French defense procurement agency, launched an international competition on the design for the weapon. In 2000, a contract was awarded to SAGEM for an initial lot of AASM GPS/INS bomb kits, expected at the time to be delivered from 2004 and to enter service the following year. A test campaign to validate in flight the main performances of this AASM variant started on December 6, 2004 and ended on July 26, 2005. While demonstrating excellent results, this campaign showed the need to change some of the aerodynamic features of the weapon. To compensate for delays in AASM deliveries in 2008 France ordered dual-mode (laser- and GPS/INS-guided) GBU-49 Enhanced Paveway II kits for integration with Mirage 2000D and Rafale fighter-bombers. The GPS/INS + IIR guided version completed its qualification tests on July 9, 2008 after three firings at the DGA's missile test range in Biscarosse. This 250 kg IR version performed a night launch from a Rafale fighter-bomber at DGA's Biscarosse test range in December 2010. According to Sagem, the weapon was launched at a range of more than 50km from the target, which was hit within one meter. A 125 kg version was successfully test fired on January 27, 2009, and a laser guided variant was air-launched for the first time on

June 17, 2010. According to French Senate's Comité des Prix de Revient des fabrications d'Armement (CPRA) cited by the daily La Tribune, the total cost of the AASM program including development costs and the delivery of 2348 kits is 846 millions euros.

Variants

AASM comes in several variants according to its size and the type of guidance used. The current model features a 250 kg bomb matched to a nose-mounted guidance kit and a rear-mounted range extension kit, containing a rocket booster and enlarged fins. There is also a 125 kg, first tested in 2009, and a proposed 1000 kg version. As for guidance, the basic version combines data from a Global Positioning System (GPS) receiver and an inertial navigation system (INS) unit through Kalman filtering, achieving a 10 metres (32 ft 10 in) circular error probability (CEP). This "decametric" all-weather variant is complemented by a "metric" day/night fair weather version which adds imaging infrared (IIR) guidance that matches the target area with a target model stored in its memory for a 1 metre (3 ft 3 in) CEP. A third version, currently under testing, uses semi-active laser homing instead of IIR allowing it to hit moving targets with more precision. On October 2010, these versions were given alphanumeric designations with the INS/GPS version becoming the SBU-38 (SBU=Smart Bomb Unit), the INS/GPS/IIR version becoming the SBU-54 and the INS/GPS/SALH version becoming the SBU-64; the system as a whole was renamed Hammer to make it more appealing to export customers.

Operational use

The first order for AASM was placed by the DGA in 2000 for a total of 744 units; deliveries started in 2007 after a two year delay in development. In 2009 a second order for 680 units was placed, by the end of that year deliveries had reached 334. AASM made its combat debut on April 20, 2008, during the War in Afghanistan when a Rafale fighter fired two in support of ground troops.

B28 nuclear bomb

B28RE

B28FI

The **B28** (originally **Mk 28**) was a thermonuclear bomb carried by U.S. tactical fighter bombers and bomber aircraft. From 1962 to 1972 under the NATO nuclear weapons sharing program, American B28s also equipped six Europe-based Canadian CF-104 squadrons known as the RCAF Nuclear Strike Force. It was also supplied for delivery by UK-based Royal Air Force Valiant and Canberra aircraft assigned to NATO under the command of SACEUR.

Production history

The **Mk 28** was produced from 1958 through 1966. It used the W28 lightweight, Class D warhead (also shared with the TM-76 Mace surface-to-surface missile and the GAM-77 Hound Dog air-launched cruise missile). After 1968 it was redesignated **B28**.

20 different versions were offered, distinguished by their yield and safety features. The B28 used the "building block" principle, allowing various combinations of components for different aircraft and roles. The principal configurations were as follows:

- **B28EX** — streamlined external-carriage version for free-fall delivery; no parachute.
- **B28RE** — streamlined external-carriage version with parachute retarder
- **B28IN** — unstreamlined internal-carriage version for free-fall delivery; no parachute.
- **B28RI** — unstreamlined internal-carriage version with parachute retarder
- **B28FI** — unstreamlined internal-carriage version with parachute for laydown delivery; used only by SAC B-52s.

The B28 had a diameter of about 22 in (58 cm), with a length varying between 96 in (2.44 m) and 170 in (4.32 m) and weight of 1,700 lb (771 kg) to 2,320 lb (1,053 kg), depending on the model type and whether a parachute retard pack was fitted. The range of explosive yields was as follows:

- **Mod 1** — 1.1 megaton TNT equivalent
- **Mod 2** — 350 kiloton TNT equivalent
- **Mod 3** — 70 kiloton
- **Mod 5** — 1.45 megaton

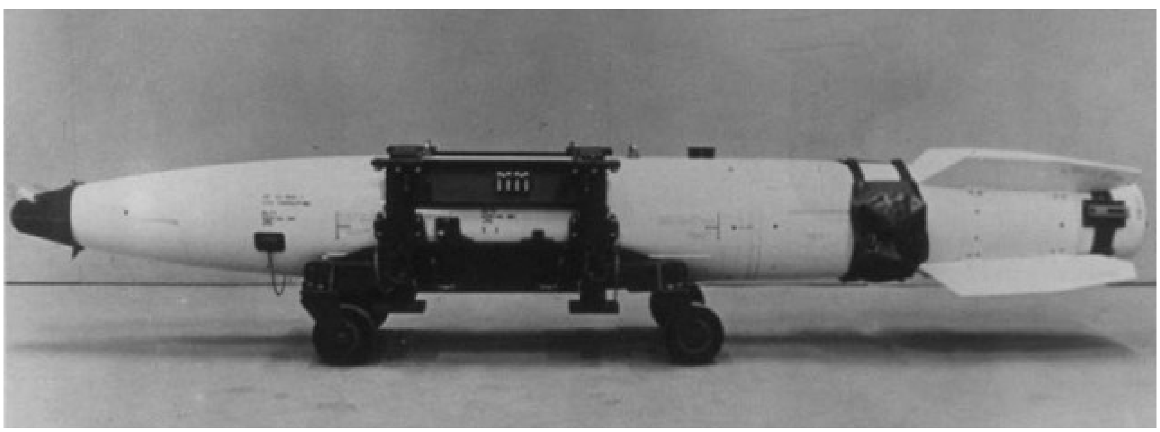
The fuze mechanism on a B28 could be set for an air burst or ground burst detonation. A total of 4,500 B28s were produced. The last examples were retired in 1991.

Related designs

The B28 bomb design has been described as the origin of a series of related nuclear warheads. The nuclear fission first stage or primary, code-named the Python primary, was reused in several subsequent weapons.

Nuclear researcher Chuck Hansen's research indicates that the Python primary was used in the US B28 nuclear bomb and the W28, W40, and W49 nuclear warheads.

B43 nuclear bomb



The B43 nuclear bomb

The **B43** was a United States air-dropped nuclear weapon used by a wide variety of fighter bomber and bomber aircraft.

The B43 was developed from 1956 by Los Alamos National Laboratory, entering production in 1959. It entered service in April 1961. Total production was 2,000 weapons, ending in 1965. Some variants were parachute-retarded and featured a ribbon parachute.

The B43 was built in two variants, **Mod 1** and **Mod 2**, each with five yield options. Depending on version, the B43 was 18 inches (45 cm) in diameter, and length was between 12 ft 6 in and 13 ft 8 in (3.81 m and 4.15 m). The various versions weighed between 2,060 lb and 2,125 lb (935 kg to 960 kg). It could be delivered at altitudes as low as 300 ft (90 m), with fusing options for airburst, ground burst, free fall, contact, or laydown delivery. Explosive yield varied from 70 kilotons of TNT to 1 megaton of TNT.

The B43 used the Tsetse primary design for its first fission stage, along with several mid and late 1950s designs.

Delivery systems

Carrier aircraft included most USAF, USN and USMC fighters, bombers and attack aircraft, including the A-3 Skywarrior, A-4 Skyhawk, A-5 Vigilante, A-6 Intruder, A-7 Corsair II, B-47 Stratojet, B-52 Stratofortress, F-100 Super Sabre, F-105 Thunderchief, F-4 Phantom II, F-111 Aardvark and its FB-111A strategic bomber variant, F-15E Strike Eagle, F-16 Fighting Falcon, and the F/A-18 Hornet. The B-1B Lancer was also intended to carry the B43, though it remains unclear whether this particular aircraft was ever type-approved to carry the B43 prior to the B-1's reassignment to conventional strike roles. The B43 was also supplied for delivery by Royal Air Force Canberra and Valiant aircraft assigned to NATO under the command of SACEUR.

Broken Arrow

The B43 was never used in anger, but it was involved in a nuclear accident when an A-4E Skyhawk, BuNo *151022*, of the USS Ticonderoga (CVA-14) (from Attack Squadron VA-56), was lost off the coast of Japan on 5 December 1965 when it rolled off an elevator of aircraft carrier USS *Ticonderoga* (CVA-14), in 16,000 feet of water in the Pacific Ocean, 80 miles from one of the Ryukyu Islands, Okinawa. The Skyhawk was being rolled from the number 2 hangar bay to the number 2 elevator when it was lost. Airframe, pilot, Lt. J.G. D. M. Webster, and the bomb were never found. No public mention was made of the incident at the time and it would not come to light until a 1981 Pentagon report revealed that a one-megaton bomb had been lost. Japan then asked for details of the incident.

Withdrawn

The B43 was phased out in the 1980s, and the last B43 weapons were retired in 1991 in favor of the newer B61 and B83 weapons.

BLU-116

The **BLU-116** is a United States Air Force bomb, designed as an enhanced *Bunker buster* penetration weapon, designed to penetrate deep into rock or concrete and destroy hard targets.

The BLU-116 is the same shape, size, and weight (1,927 lb / 874 kg) as the BLU-109 penetration bomb first deployed in the 1980s. The BLU-116 has a lightweight outer shell around a dense, heavy metal penetrator core. The shape and size mean that the BLU-116 could be used by unmodified existing aircraft and bomb guidance units such as the GPS guided GBU-31 Joint Direct Attack Munition and GBU-24 Paveway III laser guided bomb.

Specifications

From:

- Length: 2.4 m
- Width: 0.37 m
- Weight: 874 kg
- Explosives: 109 kg PBXN

Controversy

Some organizations have linked the BLU-116 design to Depleted uranium, with evidence including references to a DU penetrator option in US Patent 6,389,977 ***"Shrouded Aerial Bomb"*** which describes the weapon which became the BLU-116. Two of the claims make reference to the use of tungsten or depleted uranium to make the casing of the bomb however these claims do not constitute evidence that either material was used in the actual weapon.

Mark 81 bomb

Mark 81 General Purpose (GP) Bomb	

Crewmen upload three Mark 81 general purpose high explosive bombs, with Mark 14 TRD (Tail Retarding Device) attached, aboard an A-4F Skyhawk aircraft from Marine Attack Squadron 133 (VMA-133).

Type	Low-drag general purpose bomb
Place of origin	United States
Specifications	
Weight	262 lb (119 kg)
Length	74 in (1880 mm)
Diameter	9 in (229 mm)
Filling	Tritonal, Minol or Composition H6
Filling weight	96 lb (44 kg)

The **Mark 81** (Mk 81) 250 lb (113 kg) general purpose bomb (nicknamed "**Firecracker**") was the smallest of the Mark 80 series of low-drag general-purpose bombs.

Development & deployment

Developed for United States military forces in the 1950s, it was first used during the Vietnam War. The bomb consists of a cast steel case with 96 lb (44 kg) of Composition H6, Minol or Tritonal explosive. The power of the Mk 81 was found to be inadequate for U.S. military tactical use, and it was quickly discontinued, although license-built copies or duplicates of this weapon remain in service with various other nations.

Development of a precision guided variant of the Mk 81 bomb (GBU-29) was started due to its potential to reduce collateral damage compared to larger bombs, but this program has now been cancelled in favor of the Small Diameter Bomb.

Variants

- **Mark 81 Snakeye** fitted with a Mark 14 TRD (Tail Retarding Device) to increase the bomb's drag after release. The bomb's increased air-time, coupled with its (relatively) forgiving safe drop envelope, allowed for very low-level bombing runs at slower speed. Used commonly in the close air support (CAS) role in Vietnam (prior to wider availability of GBU precision ordnance). Nicknamed "snake", as in the typical Vietnam CAS loadout of "snake and nape" (250-lb. Mk-81 Snakeye bombs and 500-lb. M-47 napalm canisters).

- **GBU-29** Joint Direct Attack Munition, a precision guided version of the Mark 81 (cancelled).

Mark 77 bomb

A Mark 77 bomb being loaded on an F/A-18 Hornet, 1993

The **Mark 77 bomb** (MK-77) is a US 750-lb (340 kg) air-dropped incendiary bomb carrying 110 U.S. gallons (416 L; 92 imp gal) of a fuel gel mix which is the direct successor to napalm.

The MK-77 is the primary incendiary weapon currently in use by the United States military. Instead of the gasoline, polystyrene, and benzene mixture used in napalm bombs, the MK-77 uses kerosene-based fuel with a lower concentration of benzene. The Pentagon has claimed that the MK-77 has less impact on the environment than napalm. The mixture reportedly also contains an oxidizing agent, making it more difficult to put out once ignited, as well as white phosphorus.

The effects of MK-77 bombs are so similar to those of napalm that even many members of the U.S. military continue to refer to them as "napalm" bombs in informal situations. The official designation of Vietnam-era napalm bombs was the Mark 47.

Use of aerial incendiary bombs against civilian populations, including against military targets in civilian areas, was banned in the 1980 United Nations Convention on Certain Conventional Weapons Protocol III. However the United States reserved the right to use incendiary weapons against military objectives located in concentrations of civilians where it is judged that such use would cause fewer casualties and/or less collateral damage than alternative weapons.

Use in Iraq and Afghanistan

MK-77s were used by the United States Marine Corps during Operation Desert Storm and Operation Iraqi Freedom. Approximately 500 were dropped, reportedly mostly on Iraqi-constructed oil filled trenches. They were also used at Tora Bora, in Afghanistan.

At least thirty MK-77s were also used by Marine Corps aviators over a three-day period during the 2003 invasion of Iraq, according to a June 2005 letter from the UK Ministry of Defense to former Labour MP Alice Mahon. This letter stated:

"The U.S. destroyed its remaining Vietnam era napalm in 2001 but, according to the reports for I Marine Expeditionary Force (I MEF) serving in Iraq in 2003, they used a total of 30 MK 77 weapons in Iraq between 31 March and 2 April 2003, against military targets away from civilian areas. The MK 77 firebomb does not have the same composition as napalm, although it has similar destructive characteristics. The Pentagon has told us that owing to the limited accuracy of the MK 77, it is not generally used in urban terrain or in areas where civilians are congregated."

This confirmed previous reports by U.S. Marine pilots and their commanders saying they had used Mark 77 firebombs on military targets:

Then the Marine howitzers, with a range of 30 kilometres, opened a sustained barrage over the next eight hours. They were supported by U.S. Navy aircraft which dropped 40,000 pounds of explosives and napalm, a US officer told the *Herald*.

"We napalmed both those [bridge] approaches," said Colonel James Alles, commander of Marine Aircraft Group 11. "Unfortunately there were people there ... you could see them in the cockpit video. They were Iraqi soldiers."

According to the Italian public service broadcaster RAI's documentary, MK 77 had been used in Baghdad in 2003 in civilian-populated areas. However, there were never any confirmed reports of the use of incendiaries specifically against civilians.

In some cases where journalists reported that the U.S. military has used napalm, military spokesmen denied the use of "napalm" without making it clear that MK-77 bombs had actually been deployed instead.

U.S. officials incorrectly informed UK Ministry of Defence officials that MK-77s had not been used by the U.S. in Iraq, leading to Defence Minister Adam Ingram making inaccurate statements to the UK Parliament in January 2005. Later both Adam Ingram and Secretary of State for Defence John Reid apologized for these inaccurate statements being made to Members of Parliament.

Variants

Later variants of the bomb were modified to carry a reduced load of 75 U.S. gallons (284 L; 62 imp gal) of fuel, which resulted in the total weight decreasing to around 552 pounds (230 kg).

- Mk 77 Mod 0 - 750 lb (340 kg) total weight with 110 U.S. gallons (416 L; 92 imp gal) of petroleum oil.
- Mk 77 Mod 1 - 500 lb (230 kg) total weight with 75 U.S. gallons (284 L; 62 imp gal) of petroleum oil.
- Mk 77 Mod 2
- Mk 77 Mod 3
- Mk 77 Mod 4 - Approx 507 lb (230 kg) total weight with 75 U.S. gallons (284 L; 62 imp gal) of fuel (Used during the 1991 Gulf War)
- Mk 77 Mod 5 - Approx 507 lb (230 kg) kg total weight with 75 U.S. gallons (284 L; 62 imp gal) of JP-4/JP-5 fuel and thickener (Used during the 2003 invasion of Iraq)
- Mk 78 - 750 lb (340 kg) total weight with 110 U.S. gallons (416 L; 92 imp gal) of petroleum oil. No longer in service.
- Mk 79 - 1,000 lb (450 kg) total weight with 112 U.S. gallons (424 L; 93 imp gal) of napalm and petrol. No longer in service.

Mark 82 bomb

Mark 82 General Purpose (GP) Bomb	
	
Mk 82 bomb as displayed on USAF website.	
Type	Low-drag general purpose bomb
Place of origin	United States
Unit cost	$268.50 (in 2000)
Specifications	
Weight	500 lb (241 kg)
Length	87.4 in (2220 mm)
Diameter	10.75 in (273 mm)
Filling	Tritonal, Minol or H6
Filling weight	192 lb (89 kg)

The **Mark 82** (Mk 82) is an unguided, low-drag general-purpose bomb (unguided bomb), part of the U.S. Mark 80 series. The explosive filling is tritonal.

Development and deployment

A B-2 Spirit dropping Mk 82 bombs into the Pacific Ocean in a 1994 training exercise off Point Mugu, California.

With a nominal weight of 500 lb (227 kg), it is the smallest of those bombs in current service, and one of the most common air-dropped weapons in the world. Although the Mk 82's *nominal* weight is 500 lb (227 kg), its actual weight varies considerably depending on its configuration, from 510 lb (232 kg) to 570 lb (259 kg). It is a streamlined steel casing containing 192 lb (87 kg) of Tritonal high explosive. The Mk 82 is offered with a variety of fin kits, fuzes, and retarders for different purposes.

The Mk 82 is the warhead for the GBU-12 laser-guided bombs and for the GBU-38 JDAM.

Currently only the General Dynamics plant in Garland, Texas is DoD certified to manufacture bombs for the US Armed Forces.

The Mk 82 is currently undergoing a minor redesign to allow it to meet the insensitive munitions requirements set by Congress.

Mk. 82 bomb with Tail Retarding Device – this photograph shows an unfuzed, museum display Mk 82 with its usual combat paint scheme. For display purposes, the optional high-drag "Snakeye" tailfins used for low-altitude release are shown.

According to a test report conducted by the United States Navy's Weapon System Explosives Safety Review Board (WSESRB) established in the wake of the tragic 1967 USS Forrestal fire, the cooking off time for a Mk 82 is approximately 2 minutes 30 seconds.

Low-level delivery

In low-level bombing, it is easy for the delivering aircraft to sustain damage from the blast and fragmentation effects of its own munitions because the aircraft and ordnance arrive at the target at the same time. To combat this, the standard Mk-82 General Purpose bomb can be fitted with a special high-drag tail fin unit. In this configuration, it is referred to as the Mk-82 Snakeye.

The tail unit has 4 folded fins which spring open into a cruciform shape when the bomb is released. The fins increase the drag of the bomb, slowing its forward progress and allowing the delivery aircraft to safely pass over the target before the bomb explodes.

Variants

- **BLU-111/B** – Mk 82 loaded with PBXN-109 (vs H-6); item weighs 480 lbs. PBXN-109 is a less sensitive explosive filler. The BLU-111/B also is the warhead of the A-1 version of the Joint Stand-Off Weapon JSOW.

- **BLU-111A/B** – Used by the U.S. Navy, this is the BLU-111/B with a thermal-protective coating added to reduce cook-off in (fuel-related) fires.

- **BLU-126/B** – Designed following a U.S. Navy request to lower collateral damage in air strikes. Delivery of this type will start no later than March 2007. Also known as the Low Collateral Damage Bomb (LCDB), it is a BLU-111 with a smaller explosive charge. Non-explosive filler is added to retain the weight of the BLU-111 so as to give it the same trajectory when dropped.

- **Mark 62 Quickstrike mine** – A naval mine, which is a conversion of Mark 82 bomb.

Chapter- 5

Air-Launched Missiles

PL-12

PL-12 SD-10	
 A model of an export version of the PL-12, SD-10A, (bottom-left corner) with JF-17 on display at the Farnborough Airshow 2010.	
Type	Air-to-air missile Surface-to-air missile
Place of origin	People's Republic of China
Service history	
In service	2007
Used by	People's Liberation Army Air Force People's Liberation Army Ground Force People's Liberation Army Navy Pakistan Air Force
Production history	
Manufacturer	CATIC
Unit cost	$84,000 USD
Produced	2002

Specifications	
Weight	438 lbs (199 kg)
Length	12.89 ft (3.93 m)
Diameter	203 mm (8 in)
Warhead	High explosive fragmentation warhead
Detonation mechanism	Proximity fuse
Engine	Solid fuel dual-thrust rocket motor
Wingspan	670 mm
Propellant	Solid fuel
Operational range	100+ km
Flight ceiling	21 km
Flight altitude	0-21 km
Speed	Mach 4
Guidance system	Inertial / Data-link (mid-course) Active radar homing (terminal phase)
Launch platform	Shenyang J-15 J-11B / J-11BS / J-11BH / J-11BSH J-10A / J-10S / J-10B J-8II JF-17 Type 054, Type 054A frigates

The **PL-12** (*PiLi-12*, 霹雳-12), also designated **SD-10** (*ShanDian-10*, 闪电-10), is a radar-guided air-to-air missile developed by China's Luoyang Electro-Optical Technology Development Center. PL-12 is in service with the People's Liberation Army Air Force (PLAAF) and its export version, SD-10, is expected to enter service with the Pakistan Air Force.

Development history

The PL-12 active-radar BVR air-to-air missile became the highest priority air-to-air weapons programme for China's military industry during 2002, and supplanted several previous developmental projects (such as the PL-10 and PL-11) in terms of effort and importance. It provides the People's Liberation Army Air Force with a sophisticated, domestic airborne weapon on par with mainstream Western Airforces around the world. It will equip the mainstream of future modern Chinese fighters, and current compatible fighters.

The PL-12 is listed as part of CATIC's current 'Thunder-Lightning' family of air-to-air missiles, that includes the PL-5E, PL- 9C and TY-90 systems (all developed by the Luoyang Electro-Optical Technology Development Center). The chief designer of PL-12 is Fan Huitao (樊会涛) of AVIC I.

Prior to the emergence of the PL-12, China's active radar seeker AAM development programme was sometimes identified as the 'AMR-1'. During Air Show China 1996, held during November in Zhuhai, the China Leihua Electronic Technology Research Institute/No 607 Research Institute exhibited a newly-developed active radar seeker, the AMR-1. This seeker was, in turn, believed to have been applied to a new air- to-air missile design, derived from the LY-60 surface-to-air missile, and dubbed the 'PL-12'. This active radar missile, and the earlier semi-active radar homing PL-11, seemed to have a common design heritage with the Italian Aspide missile, supplied to China during the late 1980s. The status of the PL-11 and 'LY-60/PL-12' development programmes is unclear, but sources within CATIC say these earlier programmes have all been abandoned in favor of the PL-12.

The existence of the PL-12 programme was acknowledged by Chinese officials for the first time in early 2002 (the first pictures of the new missile appeared from Chinese sources during 2001). According to CATIC sources the missile has a range of 80 km. Earlier speculation around the AMR-1/LY-60 programme suggested that a ramjet engine was being developed for it, and such a powerplant would allow a missile to be effective at such long ranges.

An article from the PLA Newspaper of 2nd December 2008 reveals that SD-10 has more than 100 km effective range.

Description

SD-10A on display with the JF-17 light-weight fighter at the Farnborough International Airshow 2010.

The new PL-12 active guided air-launched anti-aircraft missile uses the radar and data link from Russia's very capable Vympel R-77, combined with a Chinese missile motor. Some sources claim the resulting combination has a greater range than the Russian missile, and a fire-and-forget active guidance (from R-77) capability comparable to the modern U.S. AIM-120 AMRAAM.

The PL-12 is outwardly very similar to the US-designed AIM-120 AMRAAM. The two share a comparable aerodynamic configuration, although the PL-12 is a little longer, wider and heavier than the AMRAAM. The PL-12 has four rear-mounted control fins that each have a very distinctive notch cut into their base. These fins are longer and more prominent than those of the AMRAAM and are cropped at an angle (rather than in line with the missile body). Four larger triangular fins are fixed to the mid-section of the missile. Internally, the leading edge of the centrebody fins is in line with the start of the missile's rocket motor. That motor is a variable-thrust solid rocket booster, that offers two levels of motive power for different sections of the flight envelope.

CATIC is known to be developing X-band and Ku-band active radar seekers, which may be intended for the PL-12. However the latest reports confirm that China has been co-operating closely with Russia's AGAT Research Institute, based in Moscow, and that AGAT is the source of the PL-12's essential active seeker. This joint development effort (perhaps with the name 'Project 129') has reportedly seen the supply of AGAT's 9B-1348 active-radar seeker (developed for the Vympel R-77, AA-12 'Adder') to China for integration with the Chinese-developed missile. Alternatively, technology from AGAT's 9B-1103M seeker family may be offered to China. Russia is also the source for the missile's inertial navigation system and datalink.

The PL-12 has four engagement modes. To take the greatest advantage of its maximum range it will use a mix of command guidance (via a datalink) plus its own inertial guidance before entering the active radar terminal guidance phase. The missile can also be launched to a pre-selected point, using its strap-down inertial system, before switching on its own seeker for a terminal search. Over short ranges the missile can be launched in a 'fire-and-forget' mode using its own active seeker from the outset. Finally, the PL-12 has a 'home-on-jam' mode that allows it to passively track and engage an emitting target, without ever using its own active radar or a radar from the launch aircraft. This capability is the foundation on which the capability of anti-radiation missile is developed. The seeker is connected to a digital flight control system that uses signal processing techniques to track a target. The missile's warhead is linked to a laser proximity fuse.

The PL-12 is claimed to have an operational ceiling of at least 21 km, with a maximum effective range of 100 km and a minimum engagement range of 1,000 m. The missile has a 38+ g manoeuvering limit and, according to CATIC, it has been tested for a 100-hour captive 'live flight' life. According to Chinese claims, PL-12 is more capable than the American AIM-120 A/B, but slightly inferior than the AIM-120C.

The PL-12 can be deployed by the Chengdu J-10, Shenyang J-8F, Shenyang J-11 and JF-17 combat aircraft..

Surface launched version

Like the AIM-120 AMRAAM, PL-12 is also used as SAM, and tests have already successfully completed as the possible replacement of LY-60, but such system has not entered service because China has already been developing the vertical launched version. The vertical launching system is developed by the Luoyang Optronic Technological Development Center in Henan, and the system is called **CCL**, short for **C**oncentric **C**ylindrical **L**auncher, which is similar to American Mk 48 VLS in appearance, but due to the very limited information publicized, it is difficult to tell if the Chinese VLS is a "cold launch" system or a "hot launch" system like that of American Mk 48 VLS.

LS-II ADS

At the 7th Zhuhai Airshow held at the end of 2008, a mobile air defense system (ADS) based on PL-12/SD-10 were revealed to the public. The weapon system is designated as LS-II ADS, with LS stands for Lie Shou, meaning Hunter in Chinese (猎手). The launching system does not incorporate VLS technology, but is very similar to Raytheon SL-AMRAAM (Surface Launched - Advanced Air-to-Air Missile).

The launching platform is Dongfeng (东风, East Wind) EQ2050 Iron Armor (Tiejia, 铁甲) or other Chinese High Mobility Multipurpose Wheeled Vehicle (HMMWV), and like SL-AMRAAM, both the short-range IR guided AAM and medium-range AAM are included. The Chinese LS-II ADS launching platform differs from its Raytheon counterpart in that the latter has a total of 6 missiles, while former only has four. LS-II ADS only contains two short-range IR guided AAMs (PL-9) and two medium-range AAMs (PL-12/SD-10), with PL-12/SD-10 missiles mounted in the center, and the PL-9 missiles mounted on the outside. The second pair of medium-range AAMs of Raytheon SL-AMRAAM system outside the short-range IR guided AAMs does not exist on the Chinese LS-II ADS.

In addition to the launching vehicle, LS-II ADS also include two other vehicles, which is also often based on the Dongfeng (东风, East Wind) EQ2050 Iron Armor (Tiejia, 铁甲) or other Chinese High Mobility Multipurpose Wheeled Vehicle (HMMWV), for the purpose to simplify logistics, though chassis of other vehicles are also available. One of the two other vehicle is for power source, and LS-II ADS can be fully functional without it, though on a shorter continuous operation. When engaging targets, PL-9/DK-9 would engage targets at lower altitude while PL-12/SD-10 would engage targets at higher altitude, and multiple missiles can be fired together to simultaneously engage multiple targets.

Another vehicle of LS-II ADS carries a passive-phased array radar for fire control. The new radar is based on the anti-stealth radar shown a year earlier at defense exhibition at Abu Dhabi in 2007, and appears to be a scaled-down version of the former. However, the developer dubbed the radar as *Anti-low radar cross section early warning radar*, though some capability against stealth target do exist. Electro-optical fire control system is mounted separately on the roof of the driver's cabin of the launching vehicle, and can function independently in the absence of the radar. LS-II ADS is integrated to the larger air defense network via LIN87 data link.

Ruhrstahl X-4

A Ruhrstahl X-4 at the US National Airforce Museum.

The **Ruhrstahl X-4** was a wire guided air-to-air missile designed by Germany during World War II. The X-4 did not see operational service and thus was not proven in combat. The X-4 was the basis for the development of experimental, ground launched anti-tank missiles that became the basis for considerable post-war work around the world, including the Malkara missile.

History

Kramer X4 (Deutsches Museum in Munich)

During 1943, the USAAF's Eighth Air Force mounted a series of heavy raids against Germany. Despite disastrous bomber losses, these prompted *Luftwaffe* research into considerably more powerful anti-bomber weaponry in order to reduce the cost in lost fighter aircraft and aircrew. A massive development effort resulted in a number of heavy-calibre 30mm to 75mm autocannon designs, air-to-air rockets, SAMs and the X-4.

Work on the X-4 began in June 1943, by Dr Max Kramer at Ruhrstahl. The idea was to build a missile with enough range to allow it to be fired from outside the range of the bombers' guns (what is now called a stand-off weapon), while being guided with enough accuracy to guarantee a "kill". The X-4 met these specifications and more; its BMW 109-448 rocket motor accelerated the missile to over 1,150 km/h (715 mph) and kept it there during its "cruise", between 1.5 and 4 km (0.9-2.5 mi), while the defensive guns had a maximum effective range of about 1000 m (1,094 yd). The rocket burned a hypergolic mixture of **S-Stoff** (nitric acid with 5% iron(III) chloride) and **R-Stoff** (an organic amine-mixture of 50% dimethylaminobenzene and 50% triethylamine called **Tonka 250**) as propellant, delivering 140 kg (310 lb) thrust initially, declining to 30 kg (66 lb) over the 17 second burn. There was no room for a fuel pump, so instead the fuels were forced into the engine by pistons inside long tubes, the tubes being coiled (as with a coil spring) to fit inside the airframe. S-Stoff was so corrosive, it dissolved all base metals and was extremely difficult and dangerous to handle. The Germans planned to replace the engine with a solid fuel design as soon as possible.

The missile was stabilized by spinning it slowly in flight, at about 60 rpm. This meant any asymmetrical thrust from the engine, or inaccuracies in the control surfaces, would be evened out as the missile spun. Signals were sent to the missile over two wires wound onto spools on the missile body, and corrected the direction of flight by operating control surfaces on the tail. A gyroscope kept track of "up" so that the control inputs from the pilot's joystick in the launch aircraft would be translated into yaw and pitch even as the missile rolled. Flares attached to two of the mid-section wings were used to keep the missile visible through the smoke of its engine.

The warhead consisted of a 20 kg (45 lb) fragmentation device that had a lethal radius of about 25 feet (8 m). It was thought that the guidance system would allow the pilot to get the missile into this range in terms of pitch and yaw, but at the ranges that the missile could operate at it would be almost impossible to judge range to anywhere near this accuracy. For this reason the missile mounted a proximity fuze known as **Kranich**, an acoustical system that was tuned to the 200 Hz sound of the B-17's engines in cruise. The trigger range was 7 m (23 ft). While approaching at high speed from the rear the Doppler effect would mean that the sound would be shifted to a higher frequency, but as the missile passed the bomber the shift would suddenly drop to zero and the warhead would be triggered.

The first flight test occurred on August 11, 1944 using a Focke-Wulf Fw 190 to as the launch platform. Subsequent tests used the Junkers Ju 88 and Messerschmitt Me 262, although they were not launched from the latter. The X-4 had originally been intended for use by single-seat fighters, but the problems in guiding both the missile and the aircraft at the same time proved this to be unworkable. Instead the X-4 was re-directed to multi-seat aircraft like the Ju 88, while the R4M rocket was to be used on the single-seaters.

The X-4 was designed to be easily assembled by unskilled labour. By early 1945, Ruhrstahl's Brackwede factory had produced over 1,000 airframes (the number 1,300 is typically quoted), and were waiting for the rocket motors when BMW's Stargard factory, which produced them, was bombed. It is possible some X-4s were used in the closing weeks of World War II, although it was never delivered to the *Luftwaffe*. The fighter-interceptor designed to use this missile as its primary weapon was the Focke-Wulf Ta 183 Huckebein, which was just a "paper" and wind tunnel prototype.

After the war, French engineers tried to develop a domestic version of the X-4, called **AA-10**. 200 units were manufactured between 1947 and 1950. However, the program was disbanded due to the dangerous pre-flight refuelling involved (the nitric acid and Tonka combination was highly explosive).

R-77 (missile)

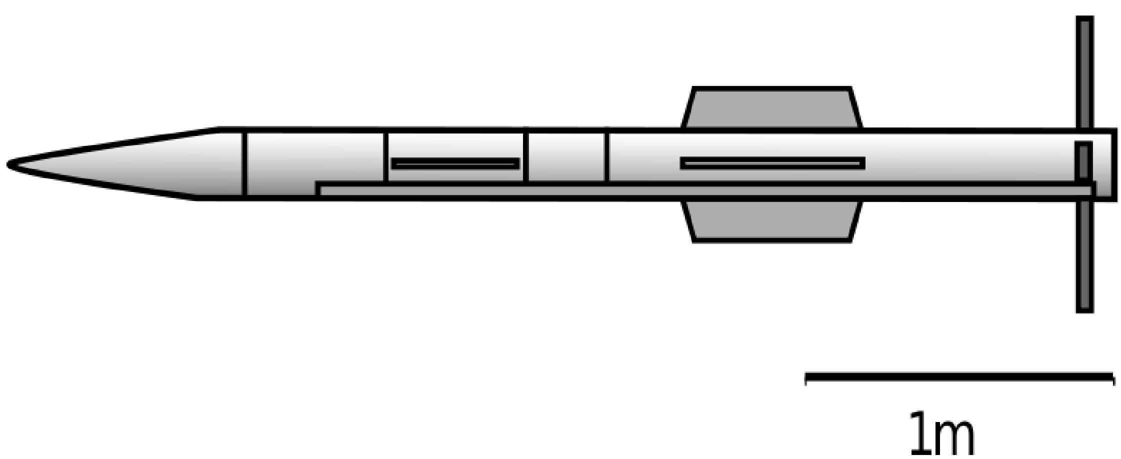
R-77/RVV-AE
(NATO reporting name: AA-12 Adder)

Type	Medium-Range Active-Radar Homing Air-to-Air Missile
Service history	
In service	1994 (R-77)
Production history	
Manufacturer	Vympel
Specifications	
Weight	175 kg (R-77), 226 kg (R-77M1)
Length	3.6 m (R-77)
Diameter	200 mm
Warhead	22 kg HE, fragmenting
Detonation mechanism	laser proximity fuze
Engine	Solid fuel rocket motor (R-77), air-breathing ramjet (R-77M1)
Wingspan	350 mm
Operational range	Strongly varying according to source: R-77:40 km (21.6 nm) - 50 km (27 nm) - 80 km (43.2 nm) R-77M1:60 km (32.4 nm) - 80 km (43.2 nm) - 160 km (86 nm)
Flight	5 m-25 km (16.5-82,000 ft)

altitude	
Speed	Mach 4.5 (R-77)
Guidance system	Inertial with mid-course update and terminal active radar homing
Launch platform	Mikoyan MiG-21-93/Lance/Bison, Mikoyan MiG-29, Mikoyan MiG-31, Mikoyan MiG-35, Sukhoi Su-27SM, Sukhoi Su-30, Sukhoi Su-34, Sukhoi Su-35, Sukhoi Su-37, Sukhoi Su-47, Yakovlev Yak-141 **Future Platforms:** HAL Tejas, Sukhoi PAK FA

The Russian **R-77 (RVV-AE) Missile** (NATO reporting name: **AA-12 Adder**) is a medium range, air-to-air, active radar-guided missile system. It is the Russian counterpart to the American AIM-120 AMRAAM missile, thus gaining a nickname: *Amraamski*.

Development



Work on the R-77 began in 1982. It represented Russia's first multi-purpose missile for both tactical and strategic aircraft for fire-and-forget use against a range of aircraft from hovering helicopters to high speed, low altitude aircraft. Gennadiy Sokolovski, general designer of the Vympel Design Bureau, said that the R-77 missile can be used against medium and long range air-to-air missiles such as the AIM-120 AMRAAM and AIM-54 Phoenix, as well as SAMs such as the Patriot. It can be used against cruise missiles and precision-guided munitions (PGMs). First seen in 1992 at the MosAeroshow '92, the R-

77RVV-AE was immediately nicknamed Amraamski by Western journalists. The Russian-language version of the acronym for the weapon is RVV-AE and it is also known as the Izdieliye-170.

The R-77 can be used by most of the Russian Air force fighter aircraft. Since many of their aircraft, primarily MiG-29, Su-27 and MiG-31, were upgraded recently. The same is true for the PLAAF of China, who use the Su-27 as well as a copy, the J-11. The newer Su-30MKK has a N001 (Su-27 radar) with a digital bypass channel incorporating a mode allowing it to use R-77s. Newer Russian aircraft from the MiG-29S (N019M radar) onward are not restricted in this regard.

There are other variants under development. One has an uprated motor to boost range at high altitudes to as much as 120–160 km; it is known as the R-77RVV-AE-PD. The 'PD' stands for Povyshenoy Dalnosti, which in Russian means Improved Range. This variant has been test-fired and uses a solid-fuel ramjet engine. Its range puts it in the long-range class and is equivalent in range to the AIM-54 Phoenix. In another version of the R-77, a terminal infra-red homing seeker is offered. This is in line with the Russian practice of attacking targets by firing pairs of missiles with different homing systems. This complicates end-game defensive actions for the target aircraft, as it needs to successfully defeat two homing systems. This method of attack may not always be available as IR seekers typically have less range and less resistance to poor weather than radar seekers, which may limit the successful use of mixed seeker attacks unless the IR missile is initially directed by radar or some other means.

The weapon has a laser fuze and an exploding rod warhead that can destroy the variable sized targets. A product-improvement of the R-77 Adder is in the works, codenamed the R-77M1, and will feature a ramjet propulsion device. This heavier missile system will have a much greater range, and will surely be the primary beyond visual range (BVR) air-to-air weapon in upcoming fifth generation Russian frontline fighters.

The radar-guided R-77 has been sold widely, with China and India placing significant orders for the weapon, as was the case for the R-73. The baseline R-77 was designed in the 1980s, with development complete by around 1994. India was the first export customer for the export variant, known as the RVV-AE, with the final batch delivered in 2002.

Vympel was the victim of a lack of adequate funding during the 1990s and the first part of this decade to support further evolution of the R-77, either for the Russian air force or the export market. The basic version of the R-77 is not thought to have entered the Russian air force inventory in significant numbers.

Additionally, Western suppliers have been pushing into some traditionally Russian markets and some major customers of the R-77 such as India and China have been pursuing their own missile programs ,with similar goals, such as the Astra and the PL-12, respectively.

Further Developments

Tactical Missile Corp., also known as TRV, unveiled its so-called RVV-SD and RVV-MD missiles for the first time at the Moscow air show in August 2009. The RVV-SD is an improved version of the R-77 (AA-12 Adder), while the RVV-MD is a variant of the R-73 (AA-11 Archer).

The RVV-SD, along with the RVV-MD, seem to be part of Russia's bid for India's medium multirole combat aircraft competition. Both designations were included by MiG on a presentation covering MiG-35 Fulcrum armament during Aero India Air Show in February.

The basic R-77 is known as the Article 170, and the RVV-SD includes the upgrades associated with the Article 170-1 designation. The 170-1 development has been underway for some time, and testing is believed to have been carried out. The RVV-SD is in effect the export variant of the 170-1.

According to information released by the company, the missile is 15 kg (33 lb) heavier than the basic R-77/RVV-AE, weighing 190 kg (420 lb) rather than 175 kg (390 lb). Maximum range claimed is increased to 110 km (68 mi) from 80 km (50 mi). The missile is also slightly longer at 3.71 metres (12.2 ft), rather than the 3.6 metres (12 ft) of the basic variant.

The radar seeker has also probably been upgraded. Russian missile manufacturer Agat previously confirmed it was working on seeker upgrades for the R-77, implying that at least two projects were underway, one for export and one for the Russian air force.

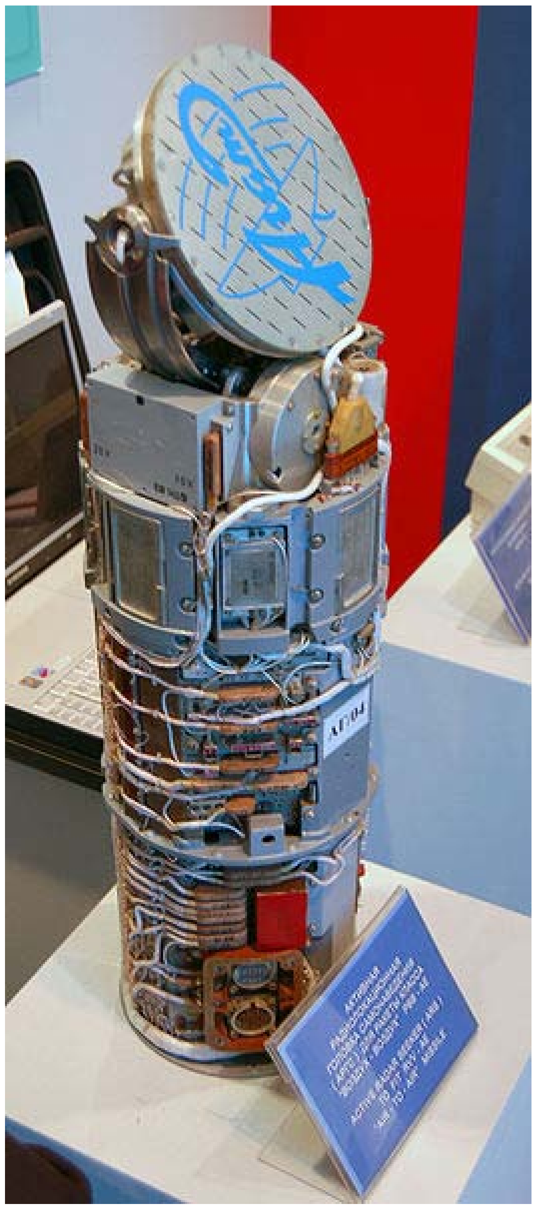
Vympel—which originally designed the R-77, and is now part of TRV—is also working on a more extensive upgrade of the missile than the 170-1. This project is designated the Article 180, and is in effect a mid-life upgrade for the weapon. This is intended to provide a further improvement in range, with the design including a dual-pulse motor configuration. Moving from the R-77's signature lattice fin configuration to a conventional fin is also part of this program.

The initial RVV-MD offering is likely no more than a stopgap to try to maintain its position, and to provide a credible radar-guided weapon to offer as part of fighter export packages and upgrade programs.

Russian industry sources indicate that both the RVV-SD and RVV-MD will have folding fins to allow for internal carriage. This at least suggests the Russian air force may be keeping its options open should it acquire the domestic variants of these upgrades to include them in the weapons inventory of its fifth-generation fighter, known as PAK-FA. India too, is a partner in the PAK-FA project, and the internal carriage modification may also have been performed with this in mind.

Description

The aerodynamics are novel, combining vestigial cruciform wings with tail control surfaces of a lattice configuration (similar devices are used on the R-400 Oka). Each surface consists of a metal frame containing a blade-like grid assembly which combines a greater control area, and thus lifting force, with reduced weight and size. The development for this control concept took three years of theoretical work and testing. Referred to by the Russians as gas dynamic declination devices, these surfaces require less powerful actuators than conventional fins, and have a lower RCS. The flow separation which occurs at high angles of attack enhances its turning ability, giving the missile a maximum turn rate of up to 150º per second.



Seeker Head of Vympel R-77 at 2009 MAKS Airshow

The missile uses a multi-function doppler-monopulse active radar seeker developed by OAO Agat . The radar features two modes of operation, over short distances, the missile will launch in an active "fire and forget" mode. Over longer distances the missile is controlled by an inertial auto pilot with occasional encoded data link updates from the launch aircraft's radar on changes in spatial position or G of the target. As the missile comes within 20 km (12.42 mi) of its target, the missile switches to its active radar mode. The host radar system maintains computed target information in case the target breaks the missile's lock-on.

RVV-AE (right)

If the seeker is jammed, it switches automatically to a passive mode and homes on the source of jamming. Fired against high-altitude non-maneuvering targets approaching head-on, the R-77RVV-AE has a range of 100 km (62 mi), with the seeker locking on at around 15 km (9.3 mi), and a maximum speed of Mach 4 (3,045 mph (4,900 km/h)). At short range, it can engage targets maneuvering at up to 12g. The basic version of this missile is said to have a maximum range of 90 km (55 mi). The missile can also be used from internal carriages where the control fins and surfaces will fold flat until it is catapulted clear of the aircraft for motor ignition. Future plans call for increasing the missile range well beyond 150 kilometres (93 mi).

Operators

- Indonesia
- India
- Russia
- Slovakia
- Ukraine
- Peru
- People's Republic of China

Comparison with AIM-120 AMRAAM

Range

The R-77's main advantage over the AIM-120 AMRAAM is in range and maneuverability. The longer range is because the R-77 is a larger 200 mm (7.9 in) vs 178 mm (7.0 in), heavier 175 kg (390 lb) vs 150 kg (330 lb) missile than the AMRAAM and contains more propellant. Like most AAM weapons, the claimed range is for a non-maneuvering target, at a high altitude, and probably on a head-on aspect with a respectable closing rate. Lower altitudes, rear aspect, or maneuvering targets will all reduce this range, but the same applies to the AMRAAM.

Maneuverability

The missile's maneuverability relies on the lattice work fins at the rear. The R-77's overall aerodynamic configuration is more efficient at high speed and high angles of attack than the conventional deltas used on the AIM-120 and most other missiles. This reduces the loss of energy when the R-77 is chasing a maneuvering target. However, near Mach 1, oblique shock waves can substantially increase drag of the lattice fins and reverse their advantage . If the missile was fired at a range long enough for it to decelerate to low Mach speeds, it would deplete its energy very quickly while maneuvering. The increased drag would also hamper the carrying aircraft at certain speeds unless the fins were folded or the missiles were stored internally. Nonetheless, the weapon is reported to be able to handle a target maneuvering at up to 12*g*, a substantially higher rate than any manned fighter.

Chapter- 6

Air-Launched Rockets

AIR-2 Genie

AIR-2 Genie	
	
AIR-2A Genie nuclear air-to-air rocket on a MF-9 Transport Trailer at Hill Aerospace Museum	
Type	Short-range air-to-air missile
Place of origin	United States
Service history	
In service	1958 - 1985
Production history	
Manufacturer	Douglas Aircraft Company
Produced	1957 -1962
Specifications	
Weight	822 pounds (372.9 kg)
Length	9 feet 8 inches (2.95 m)
Diameter	17.5 in (444.5 mm)
Engine	Solid-fuel rocket

Wingspan	3 ft .4 in (0.9 m)
Operational range	6 miles (9.7 km)
Speed	Mach 3.3

The Douglas **AIR-2 Genie** (previous designation **MB-1**) was an unguided air-to-air rocket with a 1.5kt W25 nuclear warhead. It was deployed by the United States Air Force (USAF) (from 1957) and Canada (Royal Canadian Air Force 1965-68, Air Command 1968-84) during the Cold War. Production ended in 1962 after over 3000 were produced, with some related training and test derivatives occurring later.

Development

A Convair F-106 of the California Air National Guard fires an inert version of the Genie

Plumbbob John Nuclear Test, the only live test of a Genie rocket on 19 July 1957. Fired from US Air Force F-89J over Yucca Flats, Nevada Test Site at an altitude of ~15,000 ft (4.5 km).

The interception of Soviet bombers was a major military preoccupation of the late 1940s and 1950s. The revelation in 1947 that the Soviet Union had produced a reverse-engineered copy of the Boeing B-29 Superfortress, the Tupolev Tu-4 (NATO reporting name 'Bull'), which could reach the continental United States in a one-way attack, followed by the Soviets developing their own atomic bomb in 1949, produced considerable anxiety.

The World War II-vintage fighter armament of machine guns and cannon were inadequate to stop attacks by massed formations of high-speed bombers. Firing large volleys of unguided rockets into bomber formations was not much better, and true air-to-air missiles were in their infancy. In 1954 Douglas Aircraft began a program to investigate the possibility of a nuclear-armed air-to-air weapon. To ensure simplicity and reliability, the weapon would be unguided, the large blast radius making precise accuracy unnecessary.

The resultant weapon carried a 1.5-kiloton W25 nuclear warhead and was powered by a Thiokol SR49-TC-1 solid-fuel rocket engine of 162 kN (36,500 lbf) thrust. It had a range of slightly under 10 km (6.2 mi). Targeting, arming, and firing of the weapon were coordinated by the launch aircraft's fire-control system. Detonation was by time-delay fuze, although the fuzing mechanism would not arm the warhead until engine burn-out, to give the launch aircraft sufficient time to turn and escape. Lethal radius of the blast was estimated to be about 300 meters (1,000 ft).

The first test firings of inert rounds took place in 1956, and the weapon entered service with the designation **MB-1** in 1957. The popular name was *Genie*, but it was often nicknamed "Ding-Dong". About 3,150 rounds were produced before production ended in 1963. In 1962 the weapon was redesignated **AIR-2A Genie**. Many rounds were upgraded with improved, longer-duration rocket motors, the upgraded weapons sometimes known (apparently only semi-officially) as **AIR-2B**. An inert training round, originally **MB-1-T** and later **ATR-2A**, was also produced in small numbers.

A F-89 Scorpion fires a live Genie

A live Genie was detonated only once, in Operation Plumbbob on 19 July 1957. It was fired by AF Captain Eric William Hutchison (pilot) and AF Captain Alfred C. Barbee (radar operator) flying a F-89J over Yucca Flats at an altitude of 4,500 m (15,000 ft). A group of five USAF officers volunteered to stand hatless in their light summer uniforms underneath the blast to prove that the weapon was safe for use over populated areas. They were photographed by George Yoshitake who stood there with them. Gamma and neutron doses received by observers on the ground were negligible. Doses received by aircrew were highest for the fliers assigned to penetrate the airburst cloud ten minutes after explosion.

The Montana Air National Guard F-89J that launched the live Genie.

The Genie was cleared to be carried on the F-89 Scorpion, F-101B Voodoo, F-106 Delta Dart, and F-104 Starfighter in U.S. service. However, the Starfighter never carried it in operational service. Convair offered an upgrade of the F-102 Delta Dagger that would have been Genie-capable, but it was not adopted. Operational use of the Genie was discontinued in 1988 with the retirement of the F-106 interceptor.

The only non-U.S. user was Canada, whose CF-101 Voodoos carried Genies until 1984 via a dual-key arrangement where the missiles were kept under American custody, and released to Canada under circumstances requiring their use. The RAF briefly considered the missile for use on the English Electric Lightning.

Safety features included final arming by detecting the acceleration and deceleration of a fast aircraft at high altitude. The weapon was built too early to use a permissive action link security device.

The F-89J that was used to launch the only live test is on static display at the Montana Air National Guard in Great Falls, MT.

RS-82 (rocket family)

RS-82 and **RS-132** (Reaktivny Snaryad; Russian: Реактивный Снаряд; rocket-powered projectile) were unguided rockets used by Soviet military aircraft in World War II.

Development

Design work on RS-82 and RS-132 rockets began in the early 1930s, by a team led by Georgy Langemak, and including Vladimir Artemiev, Boris Petropavlovsky, Yuriy Pobedonostsev, and others. The 82 mm (3.2 in) and 132 mm (5.2 in) diameters were chosen because the standard smokeless gunpowder charge used at the time was 24 mm (0.94 in) in diameter and seven of these charges fit into an 82 mm cylinder. First test-firing was done in November 1929. In 1937, aerodynamically-efficient **RO-82** rail launchers were designed for mounting these weapons on the aircraft. During the Great Purge in 1937, Langemak was imprisoned, tortured, tried on what are commonly viewed as trumped-up charges and then executed.

RS-82

Operational history

First-ever use of aircraft-launched unguided rockets in combat took place August 20, 1939, during the Battle of Khalkhin Gol. Five Polikarpov I-16 fighters launched RS-82 rockets against a flight of Japanese fighters, shooting down 2. Six Tupolev SB bombers also used RS-132 for ground attack during the Winter War. RS-82 and RS-132 officially entered service in 1940.

Like most unguided rockets, RS suffered from poor accuracy. Early testing demonstrated that, when fired from 500 m (1,640 ft), a mere 1.1% of 186 fired RS-82 hit a single tank and only 3.7% hit a column of tanks. RS-132 accuracy was even worse with no hits scored in 134 firings during one test. Combat accuracy was even worse since the rockets were typically fired from even greater distances. To further complicate the matters, RS-82 required a direct hit to disable light German armor with near-misses causing no damage. RS-132 could defeat medium German armor with a direct hit but caused almost no damage to light or medium armor with a near-miss. Best results were usually attained when firing in salvos against large ground targets.

Almost every Soviet military aircraft of World War II was known to carry RS-82 and RS-132, often using field-made launchers. Some Ilyushin Il-2 were field-modified to carry up to 24 rockets although the added drag and the weight made this arrangement impractical.

RS-derived **M-8** and **M-13** rockets were used by the famous Katyusha rocket artillery

SNEB

A Matra Type 155 SNEB rocket launcher pod with two red-tipped 68mm dummy rocket projectiles.

The **SNEB** rocket (French: *Societe Nouvelle des Etablissements Edgar Brandt*) is an unguided air-to-ground 68 mm rocket projectile (RP) manufactured by the French company *TDA Armements*, designed for launch by combat aircraft and helicopters. Two other rockets were developed in the 37mm and 100 caliber. The 37mm caliber was one of the earliest fold fin free flight rockets developed after WW2 and was developed mainly for air to air engagements and is no longer in service. The 100mm caliber is in service with the French Air Force and couple other air forces. The 68mm caliber is by far the most popular in use today in both the time span of service and numbers produce, even out pacing the Russian 57mm air to ground rocket, and is commonly referred in both military and civilian publications as the "SNEB rocket pods". Besides France, several other nations produce the SNEB 68mm rocket under license. In France today, the SNEB has been reorganized to the firm of Thomas-Brandt.

The caliber of 68 mm was preferred by the French over other international designs of 57 mm, 70 mm, or 80 mm. The **SNEB** rocket projectile is propelled by a single rocket motor, and, depending on the warhead loadout on the launchers, it can be used against armoured fighting vehicles, bunkers, or soft targets.

Recent development

The *Systeme de Roquette A Corrections de Trajectoire (SYROCOT)* is a program where a laser-guided seeker is incorporated into the design. It is compatible with the existing SNEB system. It is comparable to the US *Advanced Precision Kill Weapon System* project.

Warheads

Matra Type 116M rocket launcher mounted on a Fiat G.91, on display at the Luftwaffenmuseum der Bundeswehr, Berlin

Two Matra Type 155 rocket launchers with 36× SNEB 68 mm RPs

The **SNEB** rocket projectiles could be armed with the following warheads:

- High explosive (HE)
- High explosive anti-tank warhead (HEAT)
- Multi-purpose fragmentation
- Flechette anti-personnel/material
- Smoke
- Illuminating
- Training rocket

Rocket launchers/pods

The French armament company of Matra produced the following types of rocket launcher for use with the SNEB 68 mm RPs:

- Matra **Type 116M** rocket launcher — This was lightly constructed and is used as an expendable rocket launcher pod with a frangible nose cone, loaded with *19*× SNEB 68mm RPs which were fired in a single rippled 0.5 second salvo with a time interval of 33 milliseconds between each rocket firing, the pod is automatically jettison after all the rockets are expended.

- Matra **Type 155** rocket launcher — Widely produced, this was a reusable device manufactured completely from metal with a fluted nose cone through which the RPs were fired. Loaded with *18*× SNEB 68mm RPs, it can be pre-programmed on the ground to fire in shots or in one single ripple salvo as the *Type 116M*.

- Matra **JL-100** drop tank/rocket pack — This unique arrangement combines a 66 US gallons (250 l) drop tank with a rocket launcher containing *19*× SNEB 68 mm RPs in front to form an aerodynamically-shaped pod which can be mounted on over-wing or under-wing hardpoints. One notable aircraft equipped with this was the English Electric Lightning F.53 of Royal Saudi Air Force.

SNORA and SURA-D rockets

SNORA	
Type	Unguided air-to-surface and surface-to-surface rocket
Place of origin	Switzerland
Service history	
In service	1980's
Used by	Swiss Air Force
Production history	
Manufacturer	Oerlikon-Bührle
Variants	High-explosive fragmentation and hollow-charge
Specifications	
Length	Varies by model
Caliber	81-mm warhead
Maximum range	10 kilometers
SURA-D	
Type	Unguided air-to-surface

	rocket
Place of origin	Switzerland
Service history	
In service	1980's - present
Used by	Swiss Air Force
Production history	
Manufacturer	Oerlikon-Bührle
Variants	High-explosive fragmentation, hollow-charge, incendiary, marker, and training
Specifications	
Length	Varies by model
Caliber	80-mm warhead
Maximum range	2.5 kilometers

The Oerlikon-Bührle **SNORA** and **SURA-D** are 81-mm and 80-mm rockets developed in Switzerland in the late 1970's and fielded in the 1980's. The SNORA could be used in both air-to-surface and surface-to-surface (rocket artillery) roles, while the SURA-D is an air-to-surface rocket. The SNORA was developed as a cooperative endeavor with the Italian firm SNIA-Viscosa (later SNIA-BPD).

History

The original version of the SURA rocket, the SURA 80R, was developed by Hispano-Suiza in the 1960's. In 1971 Oerlikon-Buhrle took over the military division of Hispano-Suiza and redesignated the SURA 80R, the SURA-FL, and further developed the SURA-FL which is the current SURA-D. The SNORA rockets can be fired from either a supersonic or subsonic aircraft. The SURA-D though, is limited to subsonic aircraft.

Oerlikon also developed the RWK 014, a surface-to-surface launcher for the type SNORA rockets. The RWK 014 has dual launchers of 15 tubes each and has been mounted on the MOWAG Tornado APC as well as the M113 armored personnel carrier. The RWK 014 can fire 10 rounds per second and has a reload time of six minutes.

The SNORA rocket was still in service as late as 1998 and the SURA-D is still in operational use. SNORA rockets are launched from a variety of pods housing from either six or twelve rockets, while SURA-D rockets are mounted as a vertical array with only the top-most rocket attached to an aircraft hardpoint. In this system, rockets are fired individually from the bottom of the tier to the top. The unique sliding fixed fin arrangement of the SURA-D acts as the forward hanger for the rocket below it. As the rocket is fired, the four fixed fins mounted on a ring slide down the body till they are stopped at the expansion area of the rocket motor nozzle and are locked in place. The SURA-D increased its accuracy by the addition of flutes inside the nozzle rear to give a low rotation rate in addition to the stabilization effected by four fixed fins which take effect shortly after launch.

Overview

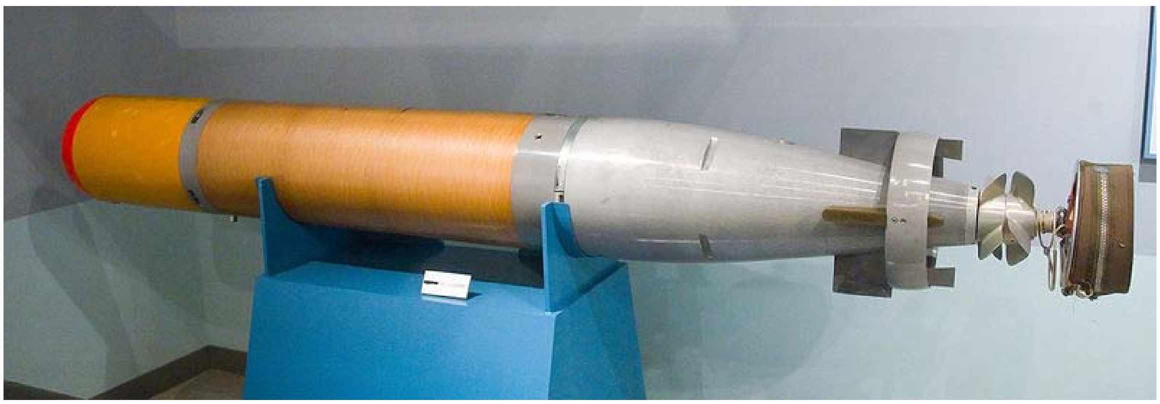
The 80-mm hollow-charge warhead on the SURA-D has been demonstrated by Oerlikon to penetrate 33 cm (13 in) of armor. The SNORA rocket can mount one of two hollow-charge warheads, either the RAK 026 which can penetrate 35 cm (14 in) of armor, or the RAK 054, capable of penetrating 45 cm (18 in) of armor.

Both rockets were exported by Switzerland and adopted by other nations, among them Spain, Qatar, and Botswana. Italy later used the motor of the SNORA rocket as the basis for the development of the 81-mm Medusa rocket.

Chapter- 7

Air-Launched Torpedoes

Mark 44 torpedo



A Japanese built Mk44 torpedo at the Kanoya museum, Japan.

The **Mark 44 torpedo** is an obsolete air-launched and ship-launched **lightweight torpedo** manufactured in the U.S., and under licence in Canada, France, Italy, Japan and the United Kingdom with 10,500 being produced for U.S. service. It was superseded by the Mark 46 torpedo. The Royal Australian Navy, however, continued to use it alongside its successor for a number of years, because the Mark 44 was thought to have superior performance in certain shallow-water conditions.

Deployed by many navies and air forces including the USN, Royal Navy, Royal Australian Navy and the Royal Air Force from various launch vehicles. These include long-range maritime patrol aircraft, eg. P-3 Orion, RAF Nimrod, LAMPS and other embarked naval helicopters, ASROC missiles, Ikara missiles.

Development

During the 1950s the US Navy ordered development of a new generation of lightweight anti-submarine torpedoes. Two programs were started, the EX-2A at the Naval Ordnance Test Station Pasadena (NOTS-Pasadena) and the EX-2B at General Electric Ordnance Department, Pitsfield. The EX-2A was to have its counter rotating propeller driven directly by an electric motor, while the EX-2B was to use a gas turbine connected to a gearbox.

After an accident with the proposed fuel for the EX-2B (Propyl Nitrate) the US Navy ordered the halting of its use. This resulted in the EX-2B development team shifting to an electric motor using the design for a jet engine starter motor as the basis to give the high torque and RPM the counter-rotating gearbox needed. The shroud design around the control surfaces of the EX-2B was also redesigned, as it was discovered that the having shroud around the control surfaces themselves reduced their effectiveness, as a result the length of the shroud was reduced.

After several evaluations the EX-2B was selected and designated the Mark 44 Mod 0. After some fine tuning of the design, an enhanced version the Mark 44 Mod 1 entered United States service in 1956. However shortly after the Torpedo entered service it became apparent that newer Soviet submarines were both faster and deeper diving, and could potentially both outrun and out-dive the Mk.44 which was designed to attack targets with a maximum speed of only 17 knots. To address this an operational requirement was issued in 1960 resulting in the acceptance into service of the Mk.46 torpedo in 1963, when it began to replace the Mk.44 in U.S. service.

A number of upgrade packages have been offered for the torpedo, a 1986 Honeywell kit replaced the magentostrictive transducers with ceramic transducers in a planar array, and the replacement of the analogue guidance electronics with a digital system. The overall effect of these changes was to triple the searched volume of the torpedo by increasing detection range by 75% and reducing the minimum shallow water search depth by 47%. The so-upgraded Torpedo is in South Korea as the KT44.

A South African upgrade package offered an extensive upgrade, replacing the warhead with a 45 kilogram shaped charge device capable of penetrating 40 millimeters of steel behind a 1.5 meter water filled double hull. The package also included a comprehensive digital electronics upgrade tripling the target acquisition range to 1,000 meters in ideal conditions, and containing a number of counter-counter measures along with a variety of attack modes.

The torpedo is, however, coming to the end of its usable life as the batteries have expired in many of the torpedoes. The New Zealand navy retired its Mark 44s in 1993 because it decided against renewing the batteries.

Description

The Mark 44 is a modular design, consisting of four main sections. The blunt nose contains the active sonar seeker with the 75 pound (34 kg) high explosive warhead immediately behind it. The second section contains the guidance and gyroscopes. The third contains the 24 kilowatt seawater battery which uses silver chloride and magnesium electrodes with seawater acting as the electrolyte. Finally is the propulsion section which houses the electric motor, four rectangular control fins and two contra-rotating propellers.

The vacuum tube based guidance system is more sophisticated than earlier torpedoes, using pre-launch settings enabling an initial search depth of 50,150,250,450,650 or 900 feet as well as a search floor at 150,250,450,650 or 900 feet as well as a maximum dive/climb angle of 4.5,6 or 7 degrees. On impacting the water the torpedo either runs out for 1,000 yards or performs a dive at a 30 degree angle to the search depth. After completing this it may perform a flat turn and begins a helical search pattern proceeding up or down until it hits either the minimum depth of 50 yards or the search floor. When it hits either top or bottom it performs a flat turn and begins to execute the search in reverse. It continues executing this search until it either finds a target or exhausts its six minute endurance.

The guidance system could drive the active sonar at either a slow rate or a fast rate, which it used when the target drew near to obtain a precise proximity and rate of closure.

The air dropped version of the torpedo is fitted with a parachute retarding system to slow entry into the water, and the nose is protected from the impact by a fairing which is immediately discarded upon entering the water. The propellers are covered by a ring fairing.

Mark 46 torpedo

A French *Lynx* helicopter carrying a mk46 torpedo

A MK-46 exercise torpedo launched from *USS Mustin*

Designed to attack high-performance submarines, the **Mark 46 torpedo** is the backbone of the U.S. Navy's lightweight ASW torpedo inventory, and is the current NATO standard. These aerial torpedoes, such as the Mark 46 Mod 5, are expected to remain in service until the year 2015. In 1989, a major upgrade program for the Mod 5 began to improve its shallow-water performance, resulting in the Mod 5A and Mod 5A(S).

General characteristics, Mark 46 Mod 5

- Primary Function: Air and ship-launched lightweight torpedo
- Contractor: Alliant Techsystems
- Power Plant: Two-speed, reciprocating external combustion; Mono-propellant (Otto fuel II)
- Length: 8 ft 6 in (2.59 m) tube launch configuration (from ship), 14 ft 9 in (4.5 m) with ASROC rocket booster
- Weight: 508 lb (231 kg) (warshot configuration)
- Diameter: 12.75 in (324 mm)
- Range: 12,000 yd (11 km)
- Depth: > 1,200 ft (365 m)
- Speed: > 40 knots (46 mph, 74 km/h)
- Guidance System: Homing mode: Active or passive/active acoustic homing
- Launch/search mode: Snake or circle search
- Warhead: 96.8 lb (44 kg) of PBXN-103 high explosive (bulk charge)
- Date Deployed: 1967 (Mod 0); 1979 (Mod 5)

Yu-7 Torpedo

The Chinese Yu-7 torpedo is said to be based on the Mk 46 mod 2. Currently the Chinese navy use the Yu-7 primarily as an ASW torpedo, deployed on ships and ASW helicopters.

Sting Ray torpedo

The **Sting Ray torpedo** is a current British acoustic homing light-weight torpedo (LWT) manufactured by GEC-Marconi, who were later bought out by BAE Systems. It entered service in 1983.

Design and development

The early 1960s concept was to provide the Royal Navy with a British-built torpedo to replace the imported Mk 44 and Mk 46 US weapons. In the 1950s the Royal Navy was equipped with British designed and built Mk 30 air-dropped torpedoes. These were passive homing weapons which relied on detecting the noise from submarine targets. However, as submarine noise levels reduced, these weapons became ineffective. Nuclear submarines could easily out-run and out-dive the Mk 30.

A design for a British Mk 31 torpedo, which would have used active echo-location sonar, failed to receive Government approval for production and US Mk 44 torpedoes were purchased for the Royal Navy in the 1960s. These were later replaced by US Mk 46 torpedoes.

A desire not to be dependent on US torpedo purchases led to a research programme starting in 1964 to develop a British torpedo. Initially designated Naval and Air Staff Requirement (NASR) 7511, it was subsequently designated the Sting Ray torpedo.

Design studies in the mid-1960s proposed that a tank of polyethylene oxide be carried behind the warhead. This polymer would be exuded at the nose to reduce the drag coefficient. Experiments using buoyancy-propelled torpedoes in 1969 had shown reductions in the drag coefficient up to 25%. However, by 1969 this scheme had been rejected in favour of carrying a larger battery.

The homing system developed in the mid-1960s incorporated a spinning magnetic disc onto which the acoustic correlation algorithms were etched but this was replaced by integrated circuit technology when the disc sometimes failed to survive the impact of the weapon with the sea from high altitude launches.

The original warhead concept was for a simple omnidirectional blast charge. However, studies in the 1970s showed that this would be inadequate against the large double-hulled submarines then entering service. A directed energy (shaped charge) warhead was used in the production weapon.

The original in-service version (Sting Ray Mod 0) entered service in 1983. It is propelled by a pump jet driven by an electric motor. Power is supplied by a magnesium/silver-chloride sea water battery. The propulsion method combines high speed, deep diving, agility and low noise levels. The weapon is provided with target and environmental information by the launching platform. Once launched it operates autonomously, with tactical software searching for the target using active sonar and then homing in without any further assistance. The software is designed to deal with the employment of countermeasures by the target. The weapon is designed to be launched from fixed wing or rotary winged aircraft and surface ships against submarine targets. Sting Ray has a diameter of 324 mm (12¾ inches) and a length of around 2.6 metres (8.5 feet). It has a launch weight of 267 kg (589 lb), and carries a 45 kg (99 lb) Torpex warhead. It has a speed of 83 km/h (45 knots) over a range of 8,000 metres (4.3 nautical miles).

Sting Ray Mod 1 is intended to used against the same targets as Sting Ray Mod 0 but with an enhanced capability against small clad conventional submarines via a shaped-charge warhead, and an improved shallow-water performance. It shares many hull components with the original weapon.