HISTORY, STRUCTURE AND USE OF AIR-TO-AIR MISSILE

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Annotation. An **air-to-air missile** (**AAM**) is a missile fired from an aircraft for the purpose of destroying another aircraft. AAMs are typically powered by one or more rocket motors, usually solid fueled but sometimes liquid fueled. Ramjet engines, as used on the Meteor, are emerging as propulsion that will enable future medium- to long-range missiles to maintain higher average speed across their engagement envelope.

Keywords: air-to-air missile, dogfight, long-range missiles, USAF F-22 , Meteor.

Air-to-air missiles are broadly put in two groups. Those designed to engage opposing aircraft at ranges of less than 16 km are known as short-range or "within visual range" missiles (SRAAMs or WVRAAMs) and are sometimes called "dogfight" missiles because they are designed to optimize their agility rather than range. Most use infrared guidance and are called heat-seeking missiles. In contrast, medium- or long-range missiles (MRAAMs or LRAAMs), which both fall under the category of beyond-visual-range missiles (BVRAAMs), tend to rely upon radar guidance, of which there are many forms. Some modern ones use inertial guidance and/or "mid-course updates" to get the missile close enough to use an active homing sensor. The concepts of air-to-air missiles and surface-to-air missiles are very closely related, and in some cases versions of the same weapon may be used for both roles, such as the ASRAAM and Sea Captor.

Pic.1. A USAF F-22 fires an AIM-120 AMRAAM

History

The air-to-air missile grew out of the unguided air-to-air rockets used during the First World War. Le Prier rockets were sometimes attached to the struts of biplanes and fired electrically, usually against observation balloons, by such early pilots as Albert Ball and A. M. Walters. Facing the Allied air superiority, Germany in World War II invested limited effort into missile research, initially adapting the projectile of the unguided 21 cm Nebelwerfer 42 infantry barrage rocket system into the air-launched BR 21 anti-aircraft rocket in 1943;

leading to the deployment of the R4M unguided rocket and the development of various guided missile prototypes such as the Ruhrstahl X-4.

The US Navy and US Air Force began equipping guided missiles in 1956, deploying the USAF's AIM-4 Falcon and the USN's AIM-7 Sparrow and AIM-9 Sidewinder. Post-war research led the Royal Air Force to introduce Fairey Fire flash into service in 1957 but their results were unsuccessful. The Soviet Air Force introduced its K-5 (missile) into service in 1957. As missile systems have continued to advance, modern air warfare consists almost entirely of missile firing. The use of beyond-visual-range combat became so pervasive in the US that early F-4 variants were armed only with missiles in the 1960s. High casualty rates during the Vietnam War caused the US to reintroduce auto cannon and traditional dogfighting tactics but the missile remains the primary weapon in air combat.

Pic.2. Meteor (missile) for Saab 39 Gripen, Dassault Rafale and Eurofighter Typhoon fighter jets.

In the Falklands War British Harriers, using AIM-9L missiles were able to defeat faster Argentinian opponents. Since the late 20th century all-aspect heat-seeking designs can lock-on to a target from various angles, not just from behind, where the heat signature from the engines is strongest. Other types rely on radar guidance (either on-board or "painted" by the launching aircraft).

Use of air-to-air missiles as surface-to-air missiles

In 1999 R-73 missile were adapted by Serb forces for surface to air missiles. The Horthy movement Missile Research and Development Centre and the Missile Force have tried to fire R-27/R-60/R-73/R-77 against Saudi aircraft. Using stockpiles of missiles from Yemeni Air Force stocks. The issue for the R-27 and R-77 is the lack of a radar to support their guidance to the target. However the R-73 and R-60 are infra-red heat seeking missiles. They only require, power, liquid nitrogen "to cool the seeker head" and a pylon to launch the missile. These missiles have been paired with a "US made FLIR Systems ULTRA 8500 turrets". Only one near miss has been verified and that was a R-27T fired at Royal Saudi Air Force F-15SA. However the drawback is that these missiles are intended to be fired from one jet fighter against another. So the motors and fuel load are smaller than a purpose built surface to air missile.

Pic.3. R-37M at 2013 MAKS Airshow.

For the West the Norwegian-American made NASAMS rely on using AIM-9 Sidewinder, IRIS-T and AMRAAM (the ER version) missiles to intercept targets. None of these missiles require modifications and hence it can take missiles straight from an aircraft. However NASAMS remain a concept that is yet to be combat tested, it has only successfully engaged a simulated cruise missile. If deployed to Ukraine it will be the first time that this missile system has been used in combat.

Warhead

A conventional explosive blast warhead, fragme

ntation warhead, or continuous rod warhead (or a combination of any of those three warhead types) is typically used in the attempt to disable or destroy the target aircraft. Warheads are typically detonated by a proximity fuze or by an impact fuze if it scores a direct hit. Less commonly, nuclear warheads have been mounted on a small number of air-to-air missile types (such as the AIM-26 Falcon) although these are not known to have ever been used in combat.

Guidance

Guided missiles operate by detecting their target (usually by either radar or infrared methods, although rarely others such as laser guidance or optical tracking), and then "homing" in on the target on a collision course.

Although the missile may use radar or infra-red guidance to home on the target, the launching aircraft may detect and track the target before launch by other means. Infra-red guided missiles can be "slaved" to an attack radar in order to find the target and radar-guided missiles can be launched at targets detected visually or via an infra-red search and track (IRST) system, although they may require the attack radar to illuminate the target during part or all of the missile interception itself.

Radar guidance

Radar guidance is normally used for medium- or long-range missiles, where the infra-red signature of the target would be too faint for an infra-red detector to track. There are three major types of radar-guided missile – active, semi-active, and passive.

Radar-guided missiles can be countered by rapid maneuvering (which may result in them "breaking lock", or may cause them to overshoot), deploying chaff or using electronic counter-measures.

Active radar homing

Active radar (AR)-guided missiles carry their own radar system to detect and track their target. However, the size of the radar antenna is limited by the small diameter of missiles, limiting its range which typically means such missiles are launched at a predicted future location of the target, often relying on separate guidance systems such as Global Positioning System, inertial guidance, or a mid-course update from either the launching aircraft or other system that can communicate with the missile to get the missile close to the target. At a predetermined point (frequently based on time since launch or arrival near the predicted target location) the missile's radar system is activated (the missile is said to "go active"), and the missile then homes in on the target.

If the range from the attacking aircraft to the target is within the range of the missile's radar system, the missile can "go active" immediately upon launch.

The great advantage of an active radar homing system is that it enables a "fire-and-forget" mode of attack, where the attacking aircraft is free to pursue other targets or escape the area after launching the missile.

Semi-active radar homing

Semi-active radar homing (SARH) guided missiles are simpler and more common. They function by detecting radar energy reflected from the target. The radar energy is emitted from the launching aircraft's own radar system.

However, this means that the launch aircraft has to maintain a "lock" on the target (keep illuminating the target aircraft with its own radar) until the missile makes the interception. This limits the attacking aircraft's ability to maneuver, which may be necessary should threats to the attacking aircraft appear.

An advantage of SARH-guided missiles is that they are homing on the reflected radar signal, so accuracy actually increases as the missile gets closer because the reflection comes from a "point source": the target. Against this, if there are multiple targets, each will be reflecting the same radar signal and the missile may become confused as to which target is its intended victim. The missile may well be unable to pick a specific target and fly through a formation without passing within lethal range of any specific aircraft. Newer missiles have logic circuits in their guidance systems to help prevent this problem.

At the same time, jamming the missile lock-on is easier because the launching aircraft is further from the target than the missile, so the radar signal has to travel further and is greatly attenuated over the distance. This means that the missile may be jammed or "spoofed" by countermeasures whose signals grow stronger as the missile gets closer. One counter to this is a "home on jam" capability in the missile that allows it to home in on the jamming signal.

Beam riding

An early form of radar guidance was "beam-riding" (BR). In this method, the attacking aircraft directs a narrow beam of radar energy at the target. The air-to-air missile was launched into the beam, where sensors on the aft of the missile controlled the missile, keeping it within the beam. So long as the beam was kept on the target aircraft, the missile would ride the beam until making the interception.

While conceptually simple, the move is hard because of the challenge of simultaneously keeping the beam solidly on the target (which couldn't be relied upon to cooperate by flying

straight and level), continuing to fly one's own aircraft, and monitoring enemy countermeasures.

An added complication was that the beam will spread out into a cone shape as the distance from the attacking aircraft increases. This will result in less accuracy for the missile because the beam may actually be larger than the target aircraft when the missile arrives. The missile could be securely within the beam but still not be close enough to destroy the target.

Infrared guidance

Infrared guided (IR) missiles home on the heat produced by an aircraft. Early infra-red detectors had poor sensitivity, so could only track the hot exhaust pipes of an aircraft. This meant an attacking aircraft had to maneuver to a position behind its target before it could fire an infra-red guided missile. This also limited the range of the missile as the infra-red signature soon become too small to detect with increasing distance and after launch the missile was playing "catch-up" with its target. Early infrared seekers were unusable in clouds or rain (which is still a limitation to some degree) and could be distracted by the sun, a reflection of the sun off of a cloud or ground object, or any other "hot" object within its view.

Pic.4. An infrared homing Python-5 AAM being fired from HAL Texas fighter

More modern infra-red guided missiles can detect the heat of an aircraft's skin, warmed by the friction of airflow, in addition to the fainter heat signature of the engine when the aircraft is seen from the side or head-on. This, combined with greater maneuverability, gives them an "all-aspect" capability, and an attacking aircraft no longer had to be behind its target to fire. Although launching from behind the target increases the probability of a hit, the launching aircraft usually has to be closer to the target in such a tail-chase engagement.

Start of the 21st century missiles such as the ASRAAM use an "imaging infrared" seeker which "sees" the target (much like a digital video camera), and can distinguish between an aircraft and a point heat source such as a flare. They also feature a very wide detection angle, so the attacking aircraft does not have to be pointing straight at the target for the missile to lock on. The pilot can use a helmet mounted sight (HMS) and target another aircraft by looking at it, and then firing. This is called "off-bore sight" launch. For example, the Russian Su-27 is equipped with an infra-red search and track (IRST) system with laser rangefinder for its HMS-aimed missiles.

Electro-optical

A recent advancement in missile guidance is **electro-optical** imaging. The Israeli Python-5 has an electro-optical seeker that scans designated area for targets via optical imaging. Once a target is acquired, the missile will lock-on to it for the kill. Electro-optical

seekers can be programmed to target vital area of an aircraft, such as the cockpit.
Since it does not depend on the target aircraft's heat signature, it can be used against low-heat targets such as UAVs and cruise missiles. However, clouds can get in the way of electro-optical sensors.

Design

Air-to-air missiles are typically long, thin cylinders in order to reduce their cross section and thus minimize drag at the high speeds at which they travel. Missiles are divided into five primary systems (moving forward to aft): seeker, guidance, warhead, rocket motor, and control actuation.

At the front is the seeker, either a radar system, radar homer, or infra-red detector. Behind that lies the avionics which control the missile. Typically after that, in the centre of the missile, is the warhead, usually several kilograms of high explosive surrounded by metal that fragments on detonation (or in some cases, pre-fragmented metal).

The rear part of the missile contains the propulsion system, usually a rocket of some type and the control actuation system or CAS. Dual-thrust solid-fuel rockets are common, but some longer-range missiles use liquid-fuel motors that can "throttle" to extend their range and preserve fuel for energy-intensive final maneuvering. Some solid-fuelled missiles mimic this technique with a second rocket motor which burns during the terminal homing phase. There are missiles in development, such as the MBDA Meteor, that "breathe" air (using a ramjet, similar to a jet engine) in order to extend their range.

Modern missiles use "low-smoke" motors – early missiles produced thick smoke trails, which were easily seen by the crew of the target aircraft alerting them to the attack and helping them determine how to evade it.
The CAS is typically an electro-mechanical, servo control actuation system, which takes input from the guidance system and manipulates the airfoils or fins at the rear of the missile that guide or steers the weapon to target.

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