# Fighter aircraft targeting systems

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Analysis of fighter aircraft targeting systems: principles, technologies and role in fighter flight.

Fighter piloting relies on complex systems. Among these, aiming systems play a major role. They facilitate target detection, identification and engagement. Over the years, engineers have perfected these techniques for greater precision. Today, there are several variants: head-up displays, infrared sensors and multi-function radars.

These tools are used to locate and track targets. Their effectiveness depends on their ergonomics and ability to transmit useful information to the pilot. In a context where every second counts, even the smallest detail is important. The aim is to facilitate decision-making and optimize combat aircraft performance.

Recent data show steady progress in this field, with substantial budgets. Several countries are investing millions of euros to modernize their fleets

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and enhance their targeting capabilities. In the United States, projects worth over ten billion dollars are underway to develop new radars and sensors. In Europe, programs include improvements to integrated targeting helmets.

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These include optics, electronics, computing and artificial intelligence. For fighter jet flight, the reliability of each module is crucial. With strong international competition, researchers are constantly studying new concepts. As a result, developments in this sector influence the strategy and employment doctrine of the armed forces. At the end of the day, aim remains a decisive factor. This point will be explored in greater depth in the following technical section.

# 1. General background

*1.1 Definitions and importance of aiming*

Sighting** on fighter aircraft is a combination of optical, electronic and computer systems. These systems enable the pilot to identify and track targets, and calculate the parameters needed to engage projectiles (missiles, bombs or ammunition). These devices rely on a combination of sensors and displays to provide real-time information.

Targeting systems are designed to operate in complex environments. They must manage variables such as target speed, weather conditions or electronic countermeasures deployed by the enemy. Their importance lies in their ability to improve firing accuracy, reducing the risk of collateral damage while increasing mission effectiveness.

*1.2 Role in the operation of a fighter aircraft*.

In a fighter jet, aiming systems play a central role, integrating data collected by various sensors (radar, infrared or optronic systems). This information is transmitted to the pilot via devices such as the head-up display (HUD) or the integrated aiming helmet. For example, in the **JHMCS** system, a pilot can lock on to a target simply by looking at it, reducing reaction time in combat.

These devices can also handle multiple targets simultaneously. Calculated firing solutions take into account the trajectory, speed and distance of each target. This ensures efficient coordination with weapons systems, optimizing engagement.

*1.3 A brief historical overview of developments*

The first mechanical sights used during the First World War relied on fixed reticles to estimate the position of targets. These rudimentary tools required a great deal of pilot experience to be effective. During the Second World War, gyroscopic sights introduced automatic calculations based on target speed and distance.

In the 1950s, sights evolved with the introduction of electronics, giving rise to the first on-board radars. These systems could detect and track targets beyond visual range. Today, modern systems, such as the **AN/APG-81** fitted to the F-35 Lightning II, incorporate multi-mode detection capabilities and passive infrared sensors, offering unrivalled accuracy for both short- and long-range engagements. These developments have transformed the sight into an indispensable strategic tool for military aviation.

## 2. Architecture and basic principles

*2.1 Optical and electronic components*

Fighter aircraft sighting systems rely on a precise combination of **optical** and **electronic** elements to provide clear vision and tactical information to the pilot. Optical components include high-resolution lenses, polarizing filters and reticles, which enable precise visualization of the target. These elements are often integrated into devices such as the **head-up display (HUD)**.

The HUD projects critical data directly onto a transparent surface in the pilot's field of vision. This data includes speed, altitude, target position and aiming reticles. Electronic sensors, such as infrared cameras and electro-optical detectors, capture information on targets based on their thermal or visual signature. This data is then combined with radar data for more precise analysis. For example, front-scanning infrared sensors, such as the **IRST21**, can detect non-emitting targets at long range.

*2.2 Detection and calculation processes*

Target detection relies on specialized sensors, such as active electronically scanned array (AESA) radars or passive infrared (IR) systems. AESA radars, like the **AN/APG-81**, emit electromagnetic waves to locate objects and calculate their relative speed using the Doppler effect. Infrared systems capture thermal emissions, which are particularly useful for detecting stealthy or non-emitting targets.

Once the data has been collected, it is processed by on-board computers using advanced algorithms. These algorithms calculate **optimized firing solutions**, taking into account variables such as aircraft speed, target distance, gravity and air resistance. For example, when engaging an air-to-air missile, the system automatically adjusts trajectories to maximize the chances of hitting the target.

*2.3 Interaction with other systems on the fighter*.

Sighting systems do not operate in isolation. They are tightly integrated with the aircraft's other subsystems, including avionics, flight controls, weapons systems and cockpit interfaces. This **system integration** is essential for maximum operational efficiency.

For example, when the radar detects a target, the data is immediately transmitted to the central computer, which displays it on the HUD or on the pilot's helmet visor via the **Joint Helmet Mounted Cueing System (JHMCS)**. This enables the pilot to quickly assess the situation and lock on to the target in a very short time. In addition, coordination with weapons management systems ensures that the right ammunition is selected, and that the firing trajectory is optimized for each type of engagement.

This interaction between systems also enables better management of combat resources, such as the distribution of targets between several aircraft in the same squadron, optimizing overall mission performance.

# 3. Categories of targeting systems

*3.1 Head-Up Display (HUD)*

The **HUD (Head-Up Display)** is an essential technology for fighter pilots. It projects critical information, such as aiming reticles, altitude, speed and target position, directly onto a transparent surface in front of the pilot's eyes. This arrangement enables the pilot to maintain his focus on the external environment while accessing vital data, avoiding the need to look down at cockpit instruments.

Modern HUDs, like those fitted to the **F-35 Lightning II**, use advanced technologies such as color display and holographic projection. These systems are capable of superimposing tactical information directly onto the observed scene, enhancing situational awareness. For example, a dynamic reticle can automatically adjust to the relative position of a target as the aircraft moves.

*3.2 Integrated headsets*

Integrated headsets, such as the **Joint Helmet Mounted Cueing System (JHMCS)** or the **DAS (Distributed Aperture System)**, offer a more intuitive and immersive interface than the HUD. These devices display information directly on the helmet visor, allowing the pilot to look in any direction and receive contextual data.

With these helmets, pilots can lock on to a target simply by looking at it. For example, on the **F-35**, the DAS system enables 360° vision, combining infrared images and radar data to track multiple targets, even outside the direct field of view. This type of system significantly reduces reaction time, enabling faster, more precise engagements.

*3.3 Infrared and radar sensors*

Infrared sensors, such as the **IRST21 (Infra-Red Search and Track)**, are designed to detect the heat signatures of targets, particularly aircraft or missile engines. These passive sensors are particularly effective against stealth targets, as they do not reveal their position by emitting active signals, unlike radar.

Radars, on the other hand, use electromagnetic waves to locate and track objects. AESA (Active Electronically Scanned Array) radars, like the **AN/APG-81**, enable multi-target detection, even at long range. These systems offer high resolution and tracking capability in disturbed environments, such as electronic warfare zones.

*3.4 Automatic target trackers* (ATTs)

Automatic tracking devices, also known as **Auto-Track Systems**, use advanced algorithms to maintain a constant lock on a moving target. These systems work by combining data from sensors, such as radar and infrared cameras, to calculate the target's trajectory in real time.

For example, the **LITENING** system or the **Sniper Advanced Targeting Pod** integrates high-definition cameras and lasers to track and designate targets with great precision. These devices can handle rapidly maneuvering targets, enabling intelligent weapons such as JDAM (Joint Direct Attack Munition) bombs to be guided. Their use reduces pilot workload by automating the tracking process, while increasing the chances of successful engagements.

# 4. Technological advances and current trends

*4.1 Artificial intelligence* innovations

The integration of **artificial intelligence (AI)** into fighter aircraft targeting systems marks a major evolution. AI makes it possible to process large quantities of data in real time, with greater speed and accuracy than traditional systems. Machine learning algorithms, such as those used for target recognition, are able to identify specific threats based on their thermal, radar or visual signature, even in complex or disturbed environments.

A case in point is the Automatic Target Recognition (ATR) system, which analyzes sensor data to differentiate between allied and enemy aircraft. This formerly manual process is now automated using deep neural networks. In addition, AI optimizes weapon trajectory calculations by taking into account dynamic variables such as enemy electronic countermeasures and weather conditions.

In addition, AI is used to provide tactical recommendations to the pilot. For example, it can prioritize targets according to their threat level, or suggest alternative flight paths to avoid dangerous areas. This reduces the pilot's cognitive load and improves combat responsiveness.

*4.2 Integrating Augmented Reality* (AR)

Augmented reality (AR)** transforms the pilot's experience by superimposing critical information directly onto the visual environment. This technology is used in systems such as the **HMDS (Helmet-Mounted Display System)**, where tactical data, firing trajectories and threat alerts are displayed in real time on the visor.

Thanks to AR, pilots benefit from enhanced **situational awareness**, even in conditions of reduced visibility. For example, on-board sensors can generate a synthetic vision of terrain or targets, superimposed on the actual scene observed by the pilot. This is particularly useful for night missions or in areas where complex geography limits vision.

AR also enables intuitive interaction. With simple head movements or voice commands, pilots can select targets or activate systems without diverting their attention from the battlefield. This interface improves the fluidity of operations and reduces the risk of error in stressful situations.

*4.3 Impact on fighter aircraft flight*

These technological advances have a significant impact on fighter aircraft performance. The integration of AI and AR enables **simultaneous multi-target engagement**, increasing the chances of success in complex scenarios. For example, an aircraft equipped with intelligent AESA radar, coupled with automated targeting systems, can identify and engage multiple threats while coordinating with other units.

What's more, these technologies offer greater adaptability to modern **threats**, such as autonomous drones or hypersonic missiles. For example, the **Loyal Wingman** system, developed to collaborate with intelligent drones, uses AI to coordinate actions between several platforms.

In operational terms, these technologies reduce pilots' dependence on manual systems, enabling them to concentrate on strategic decision-making. At the same time, they offer gains in safety, precision and efficiency, enhancing air forces' ability to carry out complex missions in hostile environments.

# 5. Operational and strategic aspects

*5.1 Influence on tactics and missions*

Advanced targeting systems have revolutionized military tactics, enabling more precise and coordinated engagements. Thanks to modern technologies such as AESA (Active Electronically Scanned Array) radars and long-range infrared sensors, pilots can **identify and track multiple**

**targets simultaneously**, even at distances of several tens of kilometers. For example, the F-35's AN/APG-81 radar can track up to 20 targets and engage several of them in a matter of seconds.

These systems also enable **long-range precision strikes**, minimizing collateral damage. Laser-guided bombs, such as the GBU-12 Paveway II, use targeting systems to adjust their trajectory according to the target's movements. In addition, air interdiction and air superiority missions benefit from these capabilities, offering decisive tactical superiority in complex scenarios.

Networked coordination, integrating data from targeting systems with that from other units (aircraft, UAVs, satellites), enables a collaborative approach to missions. This interconnectivity enhances **real-time decision-making**, making tactics more adaptable to dynamic threats.

*5.2 Maintenance and training issues*

The growing complexity of sighting systems poses major maintenance and training challenges. Modern sensors, such as cooled infrared cameras and AESA radars, require regular inspection and careful maintenance to maintain their performance. For example, infrared sensors need to be calibrated periodically to ensure their accuracy in a variety of thermal environments.

Pilot training is also a key aspect. Sophisticated interfaces, such as the **Joint Helmet Mounted Cueing System (JHMCS)**, require in-depth familiarization. Pilots need to master the interpretation of real-time data displays and target locking procedures. This training often includes advanced simulators, which recreate realistic combat scenarios to improve reflexes and decision-making.

Maintenance personnel, meanwhile, need specialized technical training to diagnose and repair malfunctions. Air forces are therefore investing in intensive training programs and the creation of dedicated maintenance centers, such as those operated by Lockheed Martin for the F-35.

*5.3 International cooperation and technology transfer*

The development and acquisition of targeting systems often involves international cooperation, due to the high costs and technological requirements involved. Programs such as the **Future Combat Air System (FCAS)** or the **F-35 Lightning II Joint Strike Fighter Program** bring together several countries to share resources and knowledge.

These partnerships facilitate technology transfer, enabling partner countries to benefit from the latest innovations. For example, the F-35's advanced infrared sensors were co-developed by American and European companies, sharing costs and expertise.

However, such collaborations require harmonization of standards and protocols. This includes intellectual property agreements and export restrictions to ensure that sensitive technologies do not fall into the wrong hands.

Sighting systems are more than just technological advances; they directly influence tactics, defense policies and international cooperation, making these strategic devices essential in today's military landscape.

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