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by

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Summaries and Reports

Summary of Advanced Infrared Guided Air-to-Air Missile Technology

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Abstract: This article is divided into two sections. The first section gives a brief introduction to the characteristics of future aerial targets, and the second describes eight aspects of the advanced technology that future infrared guided air-to-air missiles may use.

Key words: Imaging guidance, multiple-mode guidance, signal processing, off-boresight launching

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Because the tactical technological performance of aerial targets such as fighter planes and cruise missiles has been enhanced greatly along with the swift development of high technology, there have been major changes in the conditions of aerial warfare. These demand that necessary measures be taken so that air-to-air missiles, some of the main weapons of aerial warfare, may deal with the challenges of these aerial targets.

1. Characteristics of Future Aerial Targets

First, future aerial targets will have greater maneuverability. According to reports, foreign fighters have a maximum maneuverability of up to 11 g's, and they can turn at a rate exceeding 16 degrees per second. This requires that missiles, especially short-range combat missiles, have greater overload capacity, can turn at a rate greater than 60 degrees per second, have a homing head with a tracking angle of between 40 and 120 degrees, and have a tracking field higher than ±60 degrees.

Second, future aerial targets will make widespread use of stealth technology. Using secondary gas exhaust systems reduces the temperature of outlet airflow by a large margin; using infrared damping and engine nozzle stealth methods decreases the size of jet exhaust; and using heat-dissipating coatings on airplanes' skins sharply lowers their radiation of infrared energy. Thus, the detection sensitivity of missiles will have to be increased greatly.

Third, future aerial targets will make large-scale use of man-made interference in order to camouflage and conceal themselves and make it impossible for most photoelectric guided weapons to accurately track them. These jamming methods include firing infrared decoy missiles, employing infrared jammers, discharging smoke screens or aerosol particles, and other methods to jam and scatter or absorb visible light and infrared energy. Thus, necessary methods must be taken to let missiles distinguish their targets more accurately.

For infrared guided missiles to be able to defeat the enemy in future aerial combat, it will be necessary to take technical measures corresponding to each of the above areas.

2. Advanced Technologies Usable in Future Infrared Guided Air-to-Air Missiles

2.1 Infrared Imaging Guidance Technology

Infrared imaging guidance is a direction of development for future infrared guided missiles. This advanced guidance system is very different from the hot point (modulation) guidance system. It has the following advantages: the targets it detects appear as pictures rather than individual hot points, thus greatly enhancing the homing head's ability to distinguish between jamming and real targets; imaging guidance detectors are detector arrays, not individual components, and they greatly increase the homing head's sensitivity and detection distance; and missiles with this kind of guidance can sense a target aircraft's infrared radiation from any entry angle, rather than just track its exhaust nozzle exit or its jet stream,

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and this raises the missile's reliability, resolving power, and all-direction attack capability when acquiring targets. At present, the United States has used medium wave detector arrays to manufacture a medium-range infrared imaging homing head for the AIM-9X missile. Because imaging detector arrays distinguish targets by forming thermal distribution images based on the minute temperature differences between the targets being detected and their backgrounds, targets can also be tracked at night according to heat contrast. This can raise homing heads' all-weather operating capabilities. If imaging detector arrays are combined with microprocessors with execution, recognition, and decision-making capabilities, they will be able not only to detect useful information about targets, but also to make automatic reactions based on target information. Thus, the system will have a certain thinking capability, and be able to accurately detect targets under complex background and strong jamming conditions. In a word, using detector arrays for imaging guidance will give homing heads a higher degree of sensitivity, a longer detection range, and a greater instantaneous field of view and tracking field of view, and can greatly enhance target recognition and antijamming capabilities. If missile-borne computer and intelligent nerve networks were also fitted, it would be possible to give the guidance system software some programming flexibility and the ability to choose vital parts to attack.

There are two kinds of imaging guidance technology. The first is secondary imaging, also known as multielement detector linear array scanning and imaging. Its linear array elements use a rotating disk scanner to form images by grid scanning. It receives images that are general outlines of the targets, and it uses a small number of elements. For example, the United States' Maverick AGM-65D/F air-to-surface missile uses a 16-element mercury cadmium telluride linear detector. The other kind is staring imaging, also known as multielement planar array non-scanning (electronic scanning) imaging. It uses tens of thousands, or even upwards of a million, detectors to form a planar array which is placed on an optical system focal plane, and the output of each element is processed simultaneously to form a panoramic image (or a more detailed image). Afterwards, an appropriate algorithm is used to separate the target from its background. The imaging devices of these two guidance technologies can be fitted to a universal support that can swing 90° and thus produce a 180° target tracking angle. This can improve off-boresight acquisition and target tracking capabilities.

Today, materials which can be used to make focal plane arrays include platinum silicide, mercury cadmium telluride, and indium antimonide. Of these, platinum silicide is the most mature: 512×512 element arrays have been produced, and 1024×1024 element arrays will soon be produced. 256×256 element mercury cadmium telluride arrays and 128×128 element indium antimonide CID arrays have been manufactured. High-temperature superconducting materials and strain layer superlattice materials are also being developed.

Air-to-air missiles which employ or will soon employ imaging guidance include France's MICA-SRAAM, England's AIM-32 (ASRAAM), the United States' AIM-9R and AIM-9X, and Israel's Python IV. According to reports, the United States' Hughes corporation is carrying out a project called "Top Hat" whose goal is to produce a infrared imaging planar array device for a target-seeking head which can be incorporated into the AIM-9X Sidewinder missile and the ASRAAM. This array-type detector uses a 3-to-5μm wave band 128×128 element mercury cadmium telluride device. According to reports, it is possible to install many detectors on a single scanning mechanism, and thus greatly increase sensitivity.

2.2 Target Recognition Technology

In modern air warfare, it is difficult for infrared guided missiles to accurately recognize targets in the complex environment of natural and man-made interference. In addition to having high-performance detectors, it is necessary to have advanced target recognition technology. Technology in this field being developed in foreign countries includes:

A. Spectral discrimination. The principle behind this is the use of differences in spectral distribution of targets, their backgrounds, and some man-made radiation sources, and distinguishing targets from natural and man-made interference by limiting the system's spectral bandwidth.

B. Monochromatic multiple wave band discrimination. This is based on the principle that infrared camouflage can only have an effect on one certain infrared wave band. By using several infrared bands simultaneously to form images, it is possible to achieve recognition of true from false targets.

C. Use of polychromatic sensors. This includes, for example, infrared/ultraviolet dichromatic homing heads and rose scanning technology. The Stinger missile uses a homing head of this kind. It uses CdS ultraviolet elements, operates on the 0.3μm wave band, and is used to detect the ultraviolet light in the sunlight reflected from the aluminum nose cone coverings of airplanes during daytime. Because their spectral radiation brightness is one to four magnitudes as great as the cloudless sky, the homing head can easily distinguish targets from the sky background. Another element is InSb, which operates between the 3 and 5 μm bands and is used to detect targets' infrared radiation.

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Two detectors are bonded together using intercalated bed superimposition, and the signals they receive are sent separately to two microprocessors. By comparing these two signals, it is possible to analyze which is the source of jamming and which is the real target.

D. Development of space wave filtering technology. [This is] application of special modulation technology and corresponding electronic circuits to differentiate targets from their backgrounds, based on the difference between the sizes of point-source targets and their large-area backgrounds. A series of algorithms have been developed to extract targets from their backgrounds:

a. Area equilibrium algorithm. This method consists of setting up a tracking window in the viewing field, splitting the viewing field into four quadrants, labeling the areas of useful signals in each quadrant that exceed threshold values, and finally deriving the target coordinates based on sum-and-difference algorithms.

b. Centroid coordinate algorithm. This method also consists of setting up a tracking window in the field of view, seeing image signals that exceed threshold values as useful target signals, then calculating target coordinates according to ordinary centroid calculation methods.

c. Graphics matching correlation algorithm. With this algorithm, reference images of targets are stored in the homing head's image memory. The imaging homing head searches among the large images it finds for the target image that is most similar to the reference images, derives the target's position, then uses similarity coefficients to measure its similarity. Minimum variance, minimum absolute average error, and maximum correlation coefficient can be used to determine similarity coefficients.

After the missile acquires the target, it first uses symbolic imagery matching to distinguish the target image from the whole true image, then decides which algorithm to use, depending on the amount of area taken up by the target image in the detector's viewing field. When the area of the target image is small, centroid algorithms are generally used, and when it is large, self-correlating algorithms are used.

2.3 Readout and Processing of Images and Signals

When imaging homing [heads] or other advanced homing heads are used, the amount of target information received from the field increases greatly, and this requires the use of advanced imaging and signal processing technology to synthesize and analyze target images or information and extract targets' characteristic quantities. There are two aspects to this: developing readout technology and developing computer hardware to increase the calculation speed of missile-borne computers.

For either linear detectors or focal plane detectors to simultaneously access and process the target information they receive, they must first have advanced readout technology. Today, relatively mature devices used as readouts include the CCD (charge coupled device) and the CID (charge injected device). Recently, Japan, Great Britain, and other countries have invented a novel readout structure called the charge scanning device (CSD). Characteristics of this structure include increased duty factors, large capacity for charge processing, high transfer efficiency, low-voltage scanning operation, and random vertical access capability.

At present, CCDs have been made into 256×256 element medium- and long-wave monolithic devices together with HgCdTe planar arrays. CIDs are x-y matrix readout arrays, integrated with silicon A/D (analog/digital) large-scale integrated circuit chips. Digital CMOS integrated circuits produce ordered pulses to drive each row, and analog CMOS integrated circuits read out the photoelectric signals of each column. Their elements can be made as small as 20×20 microns, and they can be made into devices inlaid with 512×512 picture elements. According to a report from the 1993 SPIE conference, 256×256 element InSb CID array devices have been produced.

Generally speaking, there are two ways to enhance the performance of missile-borne computers: one is to develop high-density, high-speed, large-scale integrated circuits and employ high-speed devices to increase the device's switching speed; the other is to use parallel processing technology in the system's structure to raise the system's overall processing capability. According to a foreign expert's estimate, preprocessing requires a computer speed of five hundred million calculations per second, signal processing requires a speed of fifty million calculations per second, and data processing requires a speed of five million calculations per second.

The Martin Marietta company has developed an information processing device — the geometric algorithm parallel processor (GAPP) — for the infrared imaging sensor of a new automatic target recognition system. Its working principle is for each pixel to correspond to one processing element. It is said that a 128 processing-element chip has been achieved. Thirty-two chips make up a board, and a black box holds 12 boards. Demonstrations have been made with terrain display panels which show that it can simultaneously analyze the several thousand picture elements that make up an infrared image and completely process and recognize a target in less than a second. This time can be shortened to two-tenths of a second.

AT&T Bell Labs is developing a parallel multiprocessor which is a kind of network structure

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processor. Its throughput is up to a billion floating point calculations (10^{12} floating point calculations per second), and it can be used in advanced packaging technology microcomputers. By employing advanced packaging technology chips, the processor's computation density has reached 3531.47kM floating point calculations per cm^3.

The British Aerospace company has produced a descriptive language machine (DLM), which is the world's fastest computer and could be a basis for artificial intelligence. This computer runs a "limited concatenated prefacing experimental program" with a speed of 620k logical inferences per second. It is expected that this will first be used in imagery analysis and imagery recognition. This shows that it is feasible to use high-speed programmable digital signal processors in advanced homing heads.

Using focal plane technology, detection elements are combined with necessary signal readout and processing circuits to form a whole that can both receive light radiation and convert photoelectric signals into usable data. [Focal planes] can be divided into monolithic, planar mixed, and Z-plane structure types. The monolithic type has photosensitive elements and signal processing elements manufactured on the same piece of material. The planar mixed type has detector and signal processing chips which are manufactured separately, then joined to each other. The Z-plane structure has signal processing circuits which are combined using stacking methods to form a module which is placed vertically beneath the detector array; upside-down interconnection technology is used to connect the detector to the side of the signal processing module to form a "three-dimensional" focal plane. The latter is so-called Z-plane technology.

Z-plane technology makes full use of Z-directional space, which expands the space used on the focal plane for signal processing by several tens to over a hundred times. In this way, preamplification, band pass filtering, multiplex transmission, gain bias compensation, delay and integration, A/D conversion, and other circuits can be integrated on the focal plane and installed in the Dewar flask, thus reducing volume, conserving materials, and lowering cost.

2.4 Composite and Multiple Mode Guidance Technology

Generally, composite and multiple mode guidance indicates combined usage of two or more guidance methods on a single missile. They can operate together, alternately, or one can be selected automatically to operate depending on the specific situation at the time. This guidance technology is divided into dual mode composite and multiple mode composite types, with dual mode composite as the main type. Examples include ultraviolet/infrared, visible light/infrared, laser/infrared, microwave/infrared, and millimeter wave/infrared dual mode guidance methods, as well as multiple mode composite methods such as inertial guidance + data transmission equipment for mid-course target correction + infrared guidance. Today, several foreign short range and above-short-range antiaircraft missiles, anti-missile missiles, anti-satellite missiles, and anti-radiation missiles employ dual mode composite guidance, including the United States' POST-Stinger, France's Mistral, Japan's "*Kaike*,"[1] Russia's SA-13, and the United States' SDI kinetic energy missile and HARM anti-radiation missile. These technologies can quickly be transplanted to infrared guidance of short-range dogfighting air-to-air missiles. There are plans at present to employ infrared imaging and inertial reference devices on ASRAAM and make similar improvements to Sparrow missiles. Before infrared guided missiles can use multiple mode composite guidance, as in France's MICA and the United States' AAAM and AIM-120, there still remain problems to be solved regarding use of infrared for terminal guidance beyond visual range.

Use of composite and multiple mode guidance in infrared guided missiles can enhance their antijamming capabilities, target recognition capabilities, ability to engage multiple targets, and all-weather combat capabilities. They are important technological methods to make missiles capable of dealing with modern electronic countermeasures, stealth technology, and the complex, ever-changing combat environment.

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[1] Actual Japanese name was not available. Name given is in Chinese pinyin romanization.

2.5 Off-boresight Launching Technology

Today, off-boresight launching is an important technology for close-range infrared dogfighting missiles, because in modern air combat, off-boresight launching, especially rearward launching (firing missiles toward the rear of the launching aircraft) is an important method of attack in aerial combat. In future aerial warfare, whoever can first detect and acquire a target and fire the first missile may be able to attain victory. With off-boresight launching technology, it is unnecessary to vie for firing positions, and this dramatically increases the number of opportunities to fire missiles. So-called off-boresight launching means that the missile's homing head can acquire and track a target that deviates from the carrier plane's boresight, and the airplane controlling the missile does not need to aim at the target before firing. Missiles must meet the following requirements before off-boresight missile launching can be achieved:

A. First, missiles must have large tracking fields. This problem has been solved by making the position indicator into an "eyeball" frame installation. This is a patented United States invention. It is a biaxial rotating frame, and the

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driving components and measurement components of the inner and outer frames are installed in the missile. In this way, the maximum space for motion in the frame is provided for the detector.

B. Missiles must be able to provide sufficiently great maneuvering overload, their control systems must have a large output moment of force, and their reactions must be quick. In other words, after missiles are launched, they must be able to make sharp turns, in order to eliminate guidance error brought about by the off-boresight angle.

C. Missiles must have an off-boresight control system that is suited to off-boresight launching and must be linked to the pilot's helmet sight or the carrier plane's radar and fire control system.

Most present-day infrared dogfighting missiles can carry out off-boresight launching, but their off-boresight angle is not very large. According to reports, the detectors of all future missiles fitted with infrared imaging detectors will have frames that can swing 90 degrees and off-boresight angles of as much as 90 degrees, thus producing tracking angles of up to 180 degrees.

2.6 Increasing Missile Range

Missile range is related to the following factors: total impulse of missile engines, operation time of engines, aerodynamic drag of missiles, and effective distance of missile homing heads.

A. Missile range is directly related to the size of total engine impulse. The only way to increase total engine impulse is to enlarge the charge capacity, but this will unavoidably make missiles larger and heavier and thus affect their maneuverability. Other methods must be considered to enhance the engine charge performance and engine structure design.

B. Try to enhance specific impulse of engine charge.

C. Reduce the aerodynamic drag of missiles by, for example, reducing the area and thickness of wings and control surfaces, or eliminating wings and control surfaces and using thrust vectoring control to raise their maneuverability. In the future, the AIM-32 and AIM-9X will adopt this form.

D. Enhance the effective distance of homing heads. Although the effective distance of homing heads is not directly related to the range of missiles, it is an important factor limiting range, because if missile homing heads cannot acquire and track a target [beyond a certain distance], it is useless to make the range of the missiles any longer. By adopting advanced infrared focal planar array detectors, this problem can be solved. At present, a middle-range focal planar array infrared imaging detector has been developed for the AIM-9X.

Single-stage dual-propulsion solid rocket engines will still primarily be used for infrared combat missiles in the future. It will be possible to adopt air-breathing power plants, such as ramjets or combined ramjet/rocket power plants, to increase the range of long-range air-to-air missiles that use infrared for terminal guidance.

2.7 Development of New Materials

The materials used for the parts of infrared guided missiles are of key importance in giving missiles more advanced performance. Sweden has developed a forward-looking infrared dome whose infrared window is made of zinc sulfide material. This material can allow far infrared wave bands to penetrate, is stronger than germanium, can be used as a nose cone for infrared guided missiles, and can be used as an antireflective membrane.

England's TIALD dome is a television, infrared, and laser dome, but it uses a shared window made of a new kind of multispectral material. Moreover, these three sensors share a single optical path. This provides food for thought about applications of nose cone and optical system materials in multiple mode composite guidance.

At present, in foreign countries, a great deal of research and investigation is being carried out on materials for detectors. Relatively mature materials include PtSi (platinum silicide), InSb (indium antimonide), and medium wave HgCdTe (mercury cadmium telluride). Research has shown that HgCdTe is not an ideal material for manufacturing advanced infrared detectors: because its leakage current is too great and its junction impedance is too low between 8 and 12 µm bands, the detector and multiplexer cannot match effectively. Today, foreign countries are advancing towards being able to manufacture highly stable mercury-free multiple-layer chemical compounds. The basic principle behind this is to use indium antimonide/indium arsenide (InSb/InAs) and indium arsenic antimonide bismuth (InAsSb:Bi) alloys to produce superlattice structures to be used as semiconductor materials. The United States' Hughes corporation is producing a kind of "super crystal lattice" structure material. The molecular structure of this man-made crystal has distinctive characteristics. Its optical absorption rate is very high and it is especially sensitive to light, but its electronic background noise level is low. This can ensure extremely high imaging quality, and thus make it possible to see more clearly in the dark and take pictures of smaller features of objects.

Semiconducting materials are also being studied in other countries for use as high-quality detector materials.

Future air-to-air missile engine casings may be made of alloys of graphite and PMR-15 high-temperature polyamide resin.

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The American Have Dash II air-to-air missile is said to use this material.

2.8 Missile External Aerodynamic Design

The following are possible future developments in air-to-air missile external aerodynamic design:

A. All-new design. Unlike traditional missile bodies which have round cross sections, this design uses a triangular missile body and a flat belly portion. When suspended on the outside of the carrier aircraft, the missile lays tightly against the fuselage, and this can reduce the area of radar reflection and has a certain stealth function. Since the missile body has no fins or tail control surfaces, drag is reduced. While in flight, the missile body produces lift, and thrust vectoring control carries out "banked turn" maneuvers. When turning, the rolling of the missile body causes the lifting surface to coincide with the target maneuvering surface and simultaneously make turning maneuvers. According to reports, the Have Dash II jointly developed by the Loral corporation and the United States Air Force, as well as the AIM-9X, may adopt this aerodynamic shape.

B. Changing the aerodynamic layout of the missile body. The Raytheon corporation carried out a project called "Box Office" from 1984 to 1991 which modified the body of the AIM-9 Sidewinder missile by removing its fins and moving its control surfaces to the tail end. The resulting missile was called the tail-controlled Sidewinder (TCS). It is said that this aerodynamic layout could form the basis for the future AIM-9X missile. This kind of aerodynamic layout was also selected for the medium range S225X air-to-air missile jointly developed by England's BAe corporation and Sweden's Saab Missile corporation.

C. Integrating thrust vectoring and aerodynamic control. The MICA missile made by France's Matra corporation, Russia's R-73 (AA-11), and the AAAM (Advanced Air-to-air Missile) manufactured by the United States' General Dynamics and Westinghouse corporations have adopted this structure. They have aerodynamic control surfaces and use thrust control vectoring.

D. Adopting ring-shaped fins. These fins are flexible metal bands which are forced around the missile body. When the missile is launched, the fins open upward and outward, forming an umbrella-shaped lifting surface. Tail control surfaces, which are also forced around the missile body, can stabilize and control the missile upon springing open. Upon launching, the rear fins open first to stabilize the missile, and then the forward fins open. It is said that this design can greatly increase a missile's range and terminal maneuverability.

E. Aerodynamic external design of new fin surfaces. These include, for example, butterfly-shaped wings (AA-10), grid-shaped wings (AA-12), complex wings staggered at the front and rear edges, and others which have been applied and developed.

Reference Documents

[1] "Future Missile Systems." *Defence*, June, 1993.

[2] United States Patent No. 5,129,595.

[3] Su, Jiuzhou, "An Analysis of Development Trends of Infrared Guided Air-to-air Missiles." *Aerial Weapon Shooting Range Tests* (*Hangkong Bingqi Bachang Shiyan*), Number 4, 1993.

[4] Sun, Juan and Tian, Zhongyun, "Development of Z-Plane Focal Plane Technology." China Weapons Industry Institute Number 211, May, 1991.

[5] Wang, Xiquan, "Considerations of Infrared Imaging Air-to-air Missiles and Their Guidance Systems." *Aerial Weaponry* (*Hangkong Bingqi*), Number 6, 1993.

[6] Li, Ling, "Newest Developments in Infrared Planar Array Detectors." *Information Acquisition and Processing Technology* (*Xinxi Huoqu yu Chuli Jishu*), Number 4, 1990.