

China's Counterspace Capabilities:

China's Design Center For Anti-Missile and Anti-Satellite Weapons

Summary

Chinese military modernization has included the pursuit of anti-missile and anti-satellite technologies. One entity, known as the CASIC Second Systems Design Department (or just "Second Department") has been suspected of participating in this development. Research through Chinese online materials indicates that this organization is likely the control systems design center for direct-ascent missiles for use against exoatmospheric targets.

CASIC Second Systems
Design Department logo



Source: youth.cn

The Second Department has several names including a corporate cover title, Beijing Institute Of Electronic Systems Engineering. It consists of 16 numbered offices including one dedicated to "space missile defense." It is located in a new building on a large CASIC compound in west Beijing.

Although the Second Department has historically been responsible for anti-aircraft missile development, a segment of its research personnel has been working on technologies for intercepting targets beyond the earth's atmosphere. A review of the published research of this cadre identified a focus on **the development of guidance control algorithms for near-space physical intercept**. Research language shows:

- The focus on **missile-on-missile intercept** is suggested by the terms "space interception problems," and "tracking non-ballistic near-space targets."
- References to **maneuvering targets** and **non-ballistic near-space targets** suggest that this is a particular guidance problem they have recently been trying to solve.
- The Second Department has focused on **guidance software algorithms** rather than control system hardware, as indicated by the use of terms such as "interactive multiple model algorithm," "Kalman filter algorithms," and "filtering algorithms for tracking non-ballistic near-space targets."

Background

Among the many military technologies being pursued by the Chinese, one of clear concern for the United States is their development of counterspace systems. The U.S. armed forces have enjoyed a position of military superiority for decades in part because of digital technologies and communications based in orbit that directly support combat operations in other warfare domains. Put simply, U.S. combat capabilities are dependent on space-based assets. China knows this and seeks to erode any U.S. advantage by fielding systems that put on-orbit assets at risk.

In its **2020 Annual Report to Congress**, the Department of Defense outlined the kinds of Chinese systems, already fielded or in development, that present a threat to U.S. space systems. The description of this threat included the following language:

“The PRC continues to develop counterspace capabilities—including direct ascent, co-orbital, electronic warfare, and directed energy capabilities—that can contest or deny an adversary’s access to and operations in the space domain during a crisis or conflict.

“China has an operational ground-based Anti-Satellite (ASAT) missile intended to target low-Earth orbit satellites, and China probably intends to pursue additional ASAT weapons capable of destroying satellites up to geosynchronous Earth orbit. China is employing more sophisticated satellite operations and is probably testing dual-use technologies in space that could be applied to counterspace missions.”

China is largely silent about its ASAT development, but it is slightly more open about anti-missile development and testing. For example, in 2018 the Chinese government officially acknowledge an anti-missile test with the following terse report:

“China conducted a successful test of its ground-based midcourse defense system on Monday, the Ministry of National Defense announced Tuesday, Feb. 6. The missile interception test was defensive in nature and is not targeted at any country, the ministry added.”

There is a built-in ambiguity about the intent of developing either an ASAT weapon or an anti-missile weapon. Many of the technologies associated with tracking and intercept

of a fast-moving exoatmospheric target (one outside the atmosphere during the attempted intercept) are considered applicable to either category of weapon. While China has refrained from an overt ASAT test since 2007, the U.S. government has been suspicious of the goals of their anti-missile test series. For example, a State Department official responded to Chinese claims that a July 2014 was anti-missile with the statement, "Despite China's claims that this was not an ASAT test; let me assure you the United States has high confidence in its assessment, that the event was indeed an ASAT test."

China's military establishment, through its Strategic Support Force, operates space and counterspace forces, but other Chinese entities are involved in development of these systems. To explore the range of Chinese organizations playing roles in anti-satellite and anti-missile systems, China Keyhole has started exploring what was available in Chinese online materials about the design and development of counterspace systems.

Preliminary research kept pointing to an entity known as the "Second Department." Under Mao Zedong, China began exploring anti-satellite and anti-missile systems in the 1960's. Chinese media accounts state that an Anti-Missile Planning Team was formed in 1965 by the "Second Academy Second Department," and they subsequently developed an Anti-Missile Weapons System Institute. The Second Department was reportedly responsible for "all anti-missile technology and anti-ballistic-missile weapons systems research and development" through the mid-1970's. China sources have claimed that at that time they had the ability for high and low attack on ballistic missiles as well as intercept of low-earth-orbit satellites.

The Second Academy and its Second Department are now subordinate to CASIC, the Chinese mega-corporation responsible for space and missile development. The Second Department's mission appears to have remained unchanged. A 2017 CASIC report on the Second Department stated that one of its offices was honored as a "Model National Enterprise," and that "for 59 years this office has been responsible for design and implementation of China's space defense missile control systems."

Based on the above, Chinese online materials were examined to build a profile of the Second Department and provide that profile in this report. For organizational context, a quick summary of the Second Department's subordination appears below.

China Aerospace Science and Industry Corporation (中国航天科工集团有限公司, known as CASIC) is a large state-owned enterprise under the direct administration of China's central government. CASIC is China's biggest missile weapon system development and manufacturing industry. It traces its history back to its formation as the Fifth Academy of the Ministry of Defense in 1956. It has had many different names through the years, including the Ministry of Aerospace Industry, China Aerospace Corporation, China Aerospace Machinery and Electronics Corporation, and then CASIC. It claims to own more than 600 companies and institutes, and it may employ more than 140,000 people.

CASIC conducts research and development and manufacturing of air defense missile systems, cruising missile systems, and solid propellant rockets. Its space technology products have also supported manned space flight and lunar exploration. Company materials highlight its involvement in the Shenzhou manned space program, Chang'e lunar exploration, the Beidou navigation satellite constellation, Tianwen Mars exploration, and the construction of China's space station.

CASIC Second Academy (中国航天科工集团公司第二研究院) is one of several CASIC subordinate elements that are numbered research academies. Its more formal name is the CASIC Academy of Defense Technology (中国航天科工防御技术研究院). It is also known by a corporate name, the Changfeng Electromechanical Technology Research and Design Institute (长峰机电技术研究设计院). CASIC states that its Second Academy “covers every kind of systems specialty in space equipment research and development, and holds a leading position in China in complete weapons systems, missiles, guidance and control, command control, systems simulation, and other specialties.”

Second Department

The Second Department is commonly known as the CASIC Second Academy Second Department (二院二部). The Second Department was originally known as the Surface-To-Air Missile Systems Design Department (地空导弹总体设计部) when it was created in 1958. Multiple sources have shown that its official name is actually the CASIC Second Systems Design Department (第二总体设计部). For example, a Chinese video about the Second Department showed a view of the Second Department building with the name “Second Systems Design Department” by the main entrance.

This entity also has a corporate name: the Beijing Institute Of Electronic Systems Engineering (北京电子工程总体研究所), hereafter called “Beijing Institute.” This name was tied to the Second Department and Second Systems Design Department names in multiple official postings. In several instances, sources listed the contact email for the Beijing Institute as “erbuzhaopin@163.com.” The text string “erbuzhaopin” is a transliteration of the Chinese term “Second Department Recruiting.”

Chinese official media have called the Second Systems Design Department “responsible for advanced defensive missile weapons systems’ complete research and development, design, integration, and testing, and serves as the Second Academy’s lead unit for missile weapons systems.” Although “Second Systems Design Department” is the fuller name, for simplicity’s sake this entity will be referred to below as the Second Department.

Second Department Structure

The Second Department is divided into a series of numbered offices. Fragmentary references were found to a 1st Office, 2nd Office, 4th Office, 6th Office, and 16th Office.

One detailed 2014 job listing for the Second Department enumerated offices from 1-11 and 15-16, and gave the names of open positions and the expertise the Second Department was seeking for each position (see chart below).

Organization data and positions in Second Department 2014 recruiting announcement

| Element | Position | Required Expertise |
|------------------|---|--|
| First Office | Flight Vehicle Design | Flight vehicle related |
| First Office | Anti-Missile Missile Design | Flight vehicle related |
| Second Office | Combat Applications and Effectiveness Research | Electronics, communications, control |
| Second Office | Weapons Systems Complete Design | Aerospace related |
| Second Office | Weapons Systems Integration Design, Certification | Electronics, communications, control |
| Second Office | Advanced Defense Technology Research | Aerospace related |
| Third Office | Rocket Engines | Engines |
| Third Office | Aerodynamics | Aerodynamics |
| Third Office | Missile General Design | Comms, electronics, computers |
| Fourth Office | Intelligent Distributed Command Control | Electronics, communications, control |
| Fourth Office | Shipborne Weapons Technology | Electronics, communications, control |
| Fifth Office | Missile Guidance and Control | Missile guidance and control |
| Sixth Office | Electronic Combat | Info and communications engineering |
| Sixth Office | Optical Image Processing | Optical image processing |
| Seventh Office | Comprehensive Testing | Testing technology and automation |
| Eighth Office | Aerodynamic Flexibility Design | Aerodynamic flexibility design |
| Eighth Office | Space Structures and Organizations | Engineering physics, mechanical design |
| Eighth Office | Airborne Missile Structure Design | Engineering physics, mechanical design |
| Eighth Office | Missile Overall Equipment Structure Design | Engineering physics, mechanical design |
| Ninth Office | Space Environment Applications and Testing | Space engineering technology |
| Ninth Office | Back-End Safeguards, Supply Chain Development | Comprehensive safeguards |
| Ninth Office | Design and Testing For New Domain Environment | Environment engineering |
| Tenth Office | Guidance and Control Systems Simulation | Guidance and control simulation |
| Tenth Office | Systems Simulation | Computer related expertise |
| Tenth Office | Target and Environment Simulation | Electromagnetic theory and calculation |
| Eleventh Office | Computer Simulation | Computer simulation |
| Eleventh Office | Cloud Manufacturing Design | Computer and related expertise |
| Eleventh Office | Information Security | Info security and related expertise |
| Fifteenth Office | Missileborne FPGA Software Design | Computer apps & info processing |
| Fifteenth Office | Software Testing | Computer software, software testing |
| Fifteenth Office | Database Software Design | Computer software, databases |
| Fifteenth Office | Missileborne Info Processing Systems Design | Computer apps & info processing |
| Fifteenth Office | Software Structure | Computer related |
| Sixteenth Office | Anti-Near-Space Systems Overall Design | Flight vehicle design and exploration |

While the details in the table above hint at the missions of each office, the functional names of the various offices have not been found, except that one online source stated that the Second Department's 16th Office was also known as the "Advanced Design Office." One of the Second Department offices is known as the "Zhang Yiqun Research Office." Zhang Yiqun (张奕群) is the name of an engineer that started work in the Second Department in 1999 and is held up by CASIC as an exemplar of skill and dedication. A biographic sketch published by CASIC in 2011 stated "Deputy Chief Engineer Zhang" has served as the chief designer for many important projects. He has won several awards for his contributions, and in 2003 was named as one of the top 100 academics in national defense industries.

Zhang Yiqun in 2011



Source: casic.com.cn

Zhang was born in 1968. In 1983 he entered Harbin Shipbuilding Engineering College, and after graduation in 1987 he joined the faculty there as an instructor in the Automation and Control Department. He holds a doctorate in engineering. He later did post-doctoral work at Tianjin University's Precision Instruments Department and then at Tsinghua University. From there, he joined CASIC and became involved in the design and development of military products. As of October 2020 he had been promoted to a Second Department staff position and appointed as representative to the People's Congress. A 2021 posting identified Zhang Yiqun as nominee for the title of Academic in the China Academy of Engineering.

Second Department Leadership

As of late 2020, the Director of the Second Department was Zhang Weigang (张维刚). The Deputy Director was identified at the same time as Wang Mengyi (王蒙一), who was previously the Director of the Zhang Yiqun Research Office. Another Deputy Director, Yu Daolin (于道林), was identified in June 2019, but it is unclear whether there are two Deputy Directors or if Meng Mengyi replaced Yu Daolin. The Deputy Chief Designer was identified as Shi Guoqiang (施国强), and Han Zhiping (韩志平) is the Party Secretary. A 2020 posting also identified Zhang Weigang and Wang Mengyi as deputy directors of the editorial board for the publication "Modern Defense Technology." Zhang Yiqun was also listed as a board member.

Director
Zhang Weigang



Source: sxsqyjxh.org

Deputy Director
Wang Mengyi



Source: xjyu.edu.cn

Deputy Director
Yu Daolin

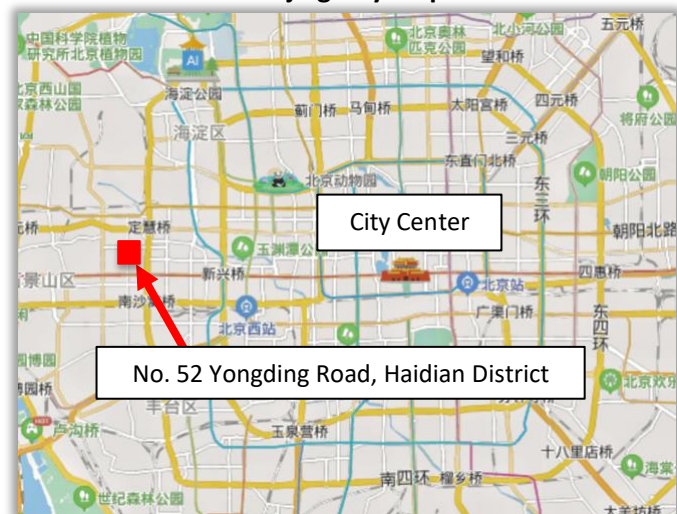


Source: nciae.edu.cn

Finding the Second Department

Several sources gave the Second Department's address as No. 52 Yongding Road, Haidian District, Beijing (北京市海淀区永定路 52 号). This address refers to a vast compound (rather than one building) located just outside the Fourth Ring Road on Beijing's west side. Chinese online map systems identify this compound with a label that translates as "China Aerospace Science and Industry," or CASIC. Confirmation that this compound belongs to the CASIC Second Academy can be found in nearby references to the Second Academy and to Changfeng, the corporate name for that academy.

Beijing City map



Source: 2345.com

Compound (in blue) at No. 52 Yongding Road

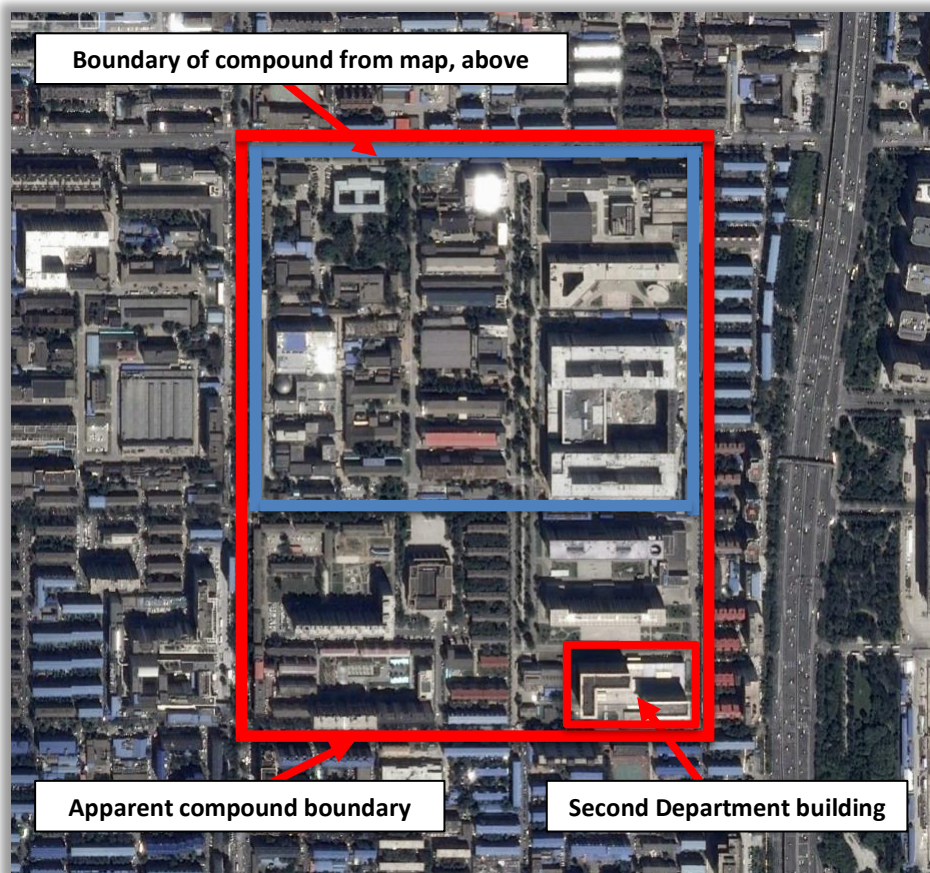


Source: 2345.com

Satellite imagery (see image below) of this same location shows the buildings in the compound highlighted above in blue. However, the grouping of buildings and the wall configuration in this area indicate that the Second Academy operates a bigger facility that includes the buildings in the area south of the boundaries shown on the Chinese map. Evidence that the area within the red boundary in the image below is all one facility includes the fact that the eastern third of both components were largely demolished since 2006 and a suite of new buildings was constructed that runs the full length of the larger compound from north to south.

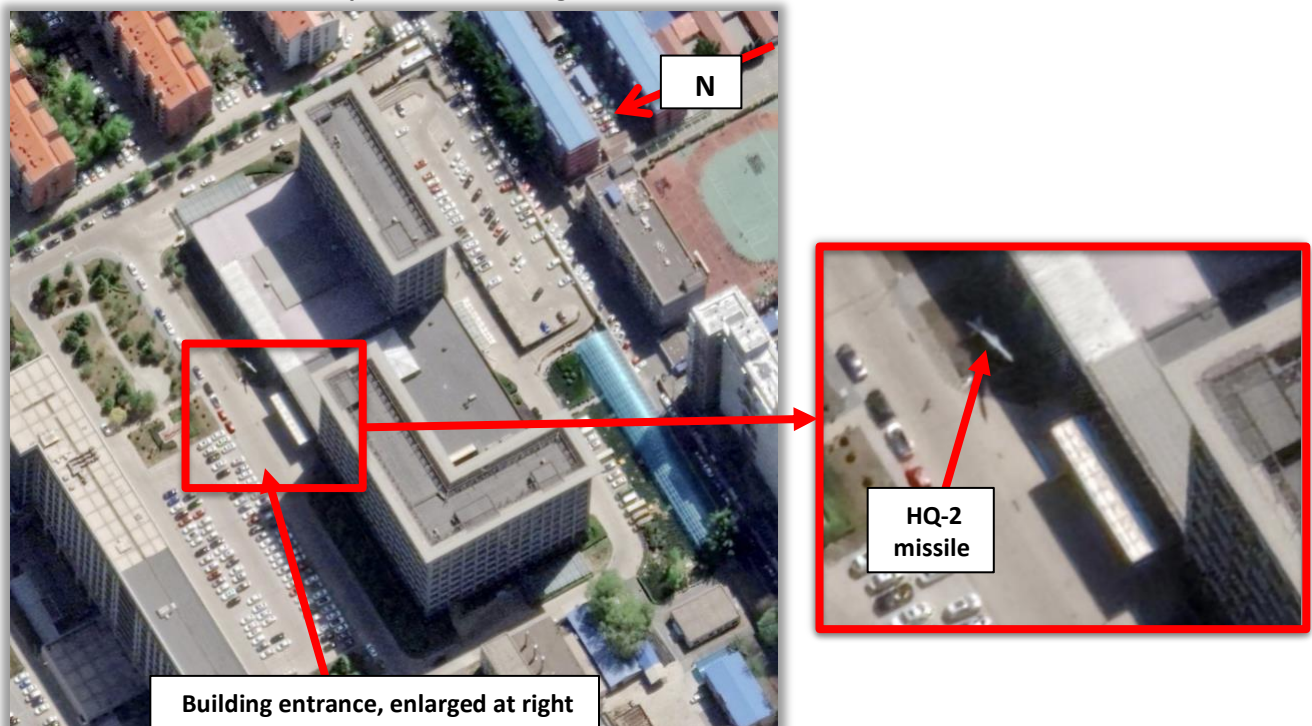
A search of satellite imagery of this larger compound showed a structure at the southern end of the new construction complex, as indicated in the image on the following page. This building, seen in detail in the second set of images on the following page, appears to be the Second Department facility. Historical imagery showed that this building was under construction in 2009 and 2010 and was apparently complete and working by 2012. Its identity as the Second Department is based in part on the appearance of a surface-to-air missile on a launcher, perhaps a memorial of sorts from the days when this entity's predecessor was known as the Surface-To-Air Missile Systems Design Department.

Second Academy compound with Second Department building



Source: map.google.com

Second Department building



Source: map.google.com

The appearance of the missile in satellite imagery, the short roof section over the apparent entrance to the building nearby, and the configuration of the building's roof and windows match a building shown in a video found online about the Second Department (see below, left). The missile is a Hongqi-2 (HQ-2), an early anti-aircraft missile. The short roof over the entrance and the roof overhang of the taller portion are visible in this image. In addition, the name placard mounted next to the entrance is visible and legible, reading "Second Systems Design Department." This combination of evidence indicates that this is the Second Department. The approximate geographic coordinates for this building are 39 54 35N 115 15 55E.

Image of entrance from Second Department video



Source: thepaper.cn

Building name placard



"Second Systems
Design Department"

Second Department Research

Other than the passing references noted above about the "space defense missile" development responsibilities of the Second Department, neither CASIC nor the Second Department advertise the space-related systems that they have worked on. Nevertheless, there is useful information available from the research reports that the Second Department has published in academic journals over the years, information that points to the kind of work being done. This research, as described in this public media, is also not weapon-specific but rather a discussion of the technologies that the Second Department has developed for application to weapons systems.

The abstracts of Chinese research papers are available from several online academic repositories, and so a search was conducted for Second Department work. Much of what was found could be tied to defensive systems such as anti-aircraft missiles, still a

responsibility for the Second Department. However, a body of Second Department work was found that hints at their focus on anti-missile or anti-satellite technologies. An initial set of these papers was identified that contain in their abstracts explicit references to anti-missile/ASAT-related technologies such as “near-space attack,” “exoatmospheric intercept,” “targets in near space,” and “non-ballistic near-space targets.” Shown below is a chronological list of this set of papers by Second Department researchers, with publication year, article title, Second Department authors, and a text segment from the abstract that made it research of interest for this profile. The full-text English abstract for each paper appears in the Appendix at the end of this report.

2003

Foreign Anti-satellite Weapons Development Review

Authors: Wen Xianjiao, Li Ying, Liu Haijun

Abstract text: “Two kinds of typical **anti-satellite weapons** are introduced, and the development characteristics and trend of anti-satellite weapons are discussed.”

2008

Research On Variable-Structure Control System With Sliding Mode Navigation Law Applied On KKV

Authors: Yan Baoqin, Jin Yuhua, Li Junlong

Abstract text: “For the discontinuity and indeterminacy of **KKV [kinetic kill vehicle] control systems** in the atmosphere, a new navigation law ... was designed to enhance the anti-disturbed ability and maneuverability of a KKV control system.”

2011

Design Of High-Precision Terminal Guidance Law Based On The Zero Effort Miss

Authors: Tan Liwei, Duan Xingliang, Guo Dayong

Abstract text: “The laser rangefinder is proposed to involve as an instrument for **exoatmospheric interceptor** to get distance.”

2012

Challenge And Consideration Of Early Warning Detection & Guidance Technique Of Near-Space Weapons

Authors: Bao Yunxia, Zhang Weigang, Li Junlong

Abstract text: “**Near-space attacking weapons** will be the significant threats for space security in the future.”

Research On Configuration Of Attitude Control Thrusters

Authors: Shi Kaiyu, Cheng Yingrong, Zhang Yiqun

Abstract text: "The attitude control of the **exoatmospheric vehicles** is usually carried out by the attitude control thrusters (ACT), and the configuration of ACT has great influence on the control effect."

Research On A Navigation Approach Of Conical Scan Using Starlight Refraction Measurements

Authors: Song Feng, Zhang Yiqun

Abstract text: "According to the features of **cross-orbit vehicles** and the demands of light miniaturization, a navigation approach of conical scan is proposed."

2014**Tracking For Near Space Target Based On IMM Algorithm**

Authors: Qin Lei, Li Junlong,

Abstract text: "For **high-supersonic maneuvering targets in near space**, it is often tracked with multiform maneuvering target models, since precision of single target maneuvering model cannot satisfy the requirement of tracking."

2015**Tracking For Near Space Non-Ballistic Target Based On Several Filter Algorithms**

Authors: Qin Lei, Li Junlong

Abstract text: "Recently, different countries have made rapid developments in the field of **near-space hypersonic vehicles**. Among which successful hypersonic vehicle flight tests of X-51 A and HTV-2 are representative."

Estimate Methods Research On Thrust Eccentricity And Centroid Drift Of Exoatmospheric Aircraft

Authors: Zhang Peng, Tan Xiangxia

Abstract text: "To cause them to roll, **exoatmospheric vehicles are controlled by direct lateral yaw**."

2016**IMM Locating and Tracking In Near Space Algorithm Based on Target Space**

Authors: Li Junlong, Qin Lei

Abstract text: "The **target in near space** is deeply analyzed. According to the characteristics of state equation, the merit and demerit of Kalman filter (KF) and particle filter (PF) in object tracking are analyzed."

Problem And Challenge On The High-Precision Guidance And Control Defending In Near Space

Authors: Li Junlong, Li Yang, Liu Chenghong, Xie Xiaoying, Qin Lei

Abstract text: "The current situation of technologies of **foreign vehicles and defending in near space** are introduced, and vehicle motion characteristics and striking patterns in near space are mainly analyzed."

2017

Maneuver Models Tracking Filter of Non-Ballistic Near-Space Targets

Authors: Li Junlong, Qin Lei, Xie Xiaoying

Abstract text: "Obviously, it will be a key technology to design accurate filtering algorithms for tracking such **non-ballistic near-space targets** in the future air defense systems."

Research on Important Control Scientific Problems of Near-Space Hypersonic Vehicles

Author: Qin Lei

Abstract text: "To achieve large-scale maneuver of **hypersonic aircraft in near space**, four scientific problems are introduced with respect to guidance and control technology."

Tracking Filter For Non-Ballistic Near-Space Targets Based On MVSIMM Algorithm

Authors: Qin Lei, Li Junlong

Abstract text: "As representative of **hypersonic vehicles in near space**, X-51A and HTV-2 with characteristics of high speed and irregular acceleration often adopt the way of non-ballistic maneuver flight."

2020

A Real-Time Estimation Algorithm For Slope Error Of Radome Of Radar Seeker

Authors: Li Junlong, Yuan Yuqi

Abstract text: "Firstly, a complete mathematical description of **target missile relative motion** problem, which consider the slope error of seeker radome is established, including nonlinear state equation and measurement equation."

Optimal Two-Impulse Space Interception With Multiple Constraints

Authors: Zhang Yiqun, Xu Junyan

Abstract text: "The multiple constraints are imposed on the **terminal position of a space interceptor**, impulse and impact instants, and the component-wise magnitudes of velocity impulses."

2021

Capture Zones And Differential Game Guidance Law For High-Speed Maneuvering Target Interception

Authors: Mao Boyuan, Li Junlong, Zhang Rui, Zhang Pengfei

Abstract text: "Aiming at the **high-speed maneuvering target interception scenario**, the conditions for the existence of the capture zone in the terminal guidance phase and the differential game guidance law were studied."

Differential Game Guidance Law For Intercepting The Active Defense Target

Authors: Zhang Hao, Zhang Yiqun, Zhang Pengfei

Abstract text: "Firstly, the relative **motion models of attacking missile target and defending missile** are established, and linearization around the current collision triangles is performed."

Research Summary

What can be inferred about Second Department research from the language in the abstracts in this research paper set? It seems clear that this set of 18 Second Department research papers and their authors are focused on **the development of guidance control algorithms for near-space physical intercept**. This is indicated by thematic trends in the abstracts of these papers, which appear in full text in the Appendix at the end of this report. The key language trends include:

- The focus on **missile-on-missile intercept in near space** is suggested by the terms "high-speed maneuvering target interception," "target missile relative motion," "space interception problems of ballistic missiles," and "tracking such non-ballistic near-space targets."
- References to **high-speed maneuvering targets** and **non-ballistic near-space targets**, especially over the last five years, suggest that this is a particular guidance problem they have recently been trying to solve.
- The focus on **guidance software algorithms** rather than control system hardware is indicated by the use of terms such as "guidance law," "linear quadratic differential game problem," "interactive multiple model algorithm," "unscented Kalman filter algorithm," "particle filters," and "filtering algorithms for tracking non-ballistic near-space targets."

The fact that guidance control algorithms are discussed in terms of missile-on-missile intercepts does not negate the application (or intent) of this research to anti-satellite operations. As mentioned above, the technologies for these respective missions, while not identical, are related enough that Chinese test flights of what they call anti-missile systems are suspected by the U.S. government to be intended for development of ASAT capabilities.

The authors that are most closely associated with this research set are Zhang Yiqun (张奕群), Li Junlong (李君龙), and Qin Lei (秦雷). As mentioned above, Zhang Yiqun has been in the Second Department since 1999 and is apparently considered a major

contributor to Second Department accomplishments in missile guidance control systems. In this research set, he has authored reports in 2012, 2020, and 2021. Li Junlong is the most consistent author of this research, being author or co-author of 9 of the 18 papers included in this set. Qin Lei first appeared as an author in the research set in 2014 and wrote or co-wrote 7 of the papers, usually co-authoring with Li Junlong. All three authors have published papers in the last three years, so it appears that they will be continuing research in this discipline.

Each of these three researchers has published many other papers that deal with aspects of missile guidance and intercept problems without specific reference to anti-missile or ASAT missions. In addition to his work about exoatmospheric intercept, Li Junlong published more than 30 other papers, many discussing guidance algorithms and high-speed targets. Zhang Yiqun published 15 papers over the past ten years that mostly dealt with missile guidance and target intercept algorithm development. Many of these focused on details of tracking algorithm alternatives such as global nearest neighbor (GNN), probabilistic data association (PDA), joint probabilistic data association (JPDA), and multiple-hypothesis tracking (MHT), without necessarily mentioning exoatmospheric intercept.

Conclusions

The CASIC Second Systems Design Department, based in Beijing on the Second Academy compound, appears to play a distinctive role in the development of Chinese direct-ascent anti-missile and anti-satellite weapons. The department as a whole may be working primarily on technologies for surface-to-air missiles such as the HQ-9 and HQ-19. Yet there is an office or set of offices in this department, including the so-called “Zhang Yiqun Research Office,” that has worked and is now working on guidance systems for attack on near-earth exoatmospheric targets. This means that the Second Department is part of a set of Chinese organizations that are involved in the design, manufacture, testing, and operation of counterspace weapons.

Post-Script: Second Department on the U.S. Entity List

The U. S. Department of Commerce's Bureau of Industry and Security (BIS) publishes the names of certain foreign persons, businesses, and government entities that are subject to restrictions for the export or transfer of specified items. These names make up what is known as the Entity List. An August 2018 amendment to the BIS Entity List added the Second Academy and its Second Department:

"The Entity List (Supplement No. 4 to part 744) identifies entities reasonably believed to be involved, or to pose a significant risk of being or becoming involved, in activities contrary to the national security or foreign policy interests of the United States. This rule adds the following entities to the Entity List:

"China Aerospace Science and Industry Corporation Second Academy, a.k.a., the following aliases, and subordinate institutions:

- China Changfeng Mechanics and Electronics Technology Academy;
- China Chang Feng Mechano-Electronic Engineering Academy;
- CASIC Second Academy;
- China Chang Feng Mechano-Electronic Engineering Company;
- CASIC Academy of Defense Technology;
- Second Research Academy of CASIC;
- Changfeng Electromechanical Technology Design Institute; and
- China Chang Feng Mechanics and Electronics Technology Academy.

"Subordinate Institution: **Second Design Department,** a.k.a., the following two aliases:

- Beijing Institute of Electronics Systems Engineering;** and
- Second Planning Department.

"The following addresses apply to the entity:

- 50 Yongding Road, 51 Yongding Road, and **52 Yongding Road,** Haidian District, Beijing, China."

Appendix: Second Department Research Papers and Abstracts

The following are the names, authors, full-text abstracts, organizations as given with the papers, and repository sources for the Second Department research work that was listed in the main text of this report:

2003

Foreign Anti-satellite Weapons Development Review

(国外反卫星武器发展述评)

Authors: Wen Xianjiao (温羨娇), Li Ying (李英), Liu Haijun (刘海军)

Organization: CASIC Second Academy Second Department

Abstract: "Based on the demand of anti-satellites, the definition, classification, characteristics, composition, battle process and the development of anti-satellite weapon of America and Russia are introduced, the two kinds of typical anti-satellite weapons are introduced, and the development characteristics and trend of anti-satellite weapons are discussed."¹

2008

Research on Variable-Structure Control System With Sliding Mode Navigation Law Applied On KKV

(滑模变结构导引律在动能拦截器上的应用研究)

Authors: Yan Baoqin (闫宝琴), Jin Yuhua (金玉华), Li Junlong (李君龙)

Organization: CASIC Second Academy Second Department

Abstract: "For the discontinuity and indeterminacy of KKV [kinetic kill vehicle] control systems in the atmosphere, a new navigation law, variable-structure control system with sliding mode navigation was designed to enhance the anti-disturbed ability and maneuverability of a KKV control system. Through end navigation trajectory emulator, this new navigation law was used on KKV end navigation to intercept 3D roll maneuver target. The emulator results showed that variable-structure control system with sliding mode navigation law had the merits of fast response, easy to realize, and powerful to intercept high maneuver target etc. Also, it had strong robustness for a KKV to intercept 3D roll maneuver target."²

2011

Design Of High-Precision Terminal Guidance Law Based On The Zero Effort Miss

(基于零效脱靶量的高精度末制导律设计)

Authors: Tan Liwei (谭丽伟), Duan Xingliang (殷兴良), Guo Dayong (郭大勇)

¹ lsp.gdstl.net/articles/article_detail.aspx?id=8034256.

² 202.202.215.138/KCMS/detail/detail.aspx?filename=XDFJ200801014&dbcode=CJFD&dbname=CJFD2008.

Organization: CASIC Second Academy Second Department

Abstract: "The laser rangefinder is proposed to involve as an instrument for exoatmospheric interceptor to get distance. The velocity can be obtained through information fusion with infrared seeker and then the zero effort miss (ZEM) can be calculated and used to terminal guidance. The terminal guidance law based on ZEM realizes the orbit control by using constant force only one time, and then realizes the pulse control by using memorial time variant stepped parameter as control threshold. The guidance law takes the advantages of both fuel economization in the normal ZEM guidance and high precision in the proportional guidance. According to the realistic characteristics of the orbit control thrusters, the design of the on-off control laws can avoid the repeated turn-on of the thrusters. The simulation results show the validation of the performance of the guidance law on fuel and precision." ³

2012

Challenge And Consideration Of Early Warning Detection & Guidance Technique Of Near-Space Weapons

(临近空间武器对预警探测制导技术的挑战)

Authors: Bao Yunxia (包云霞), Zhang Weigang (张维刚), Li Junlong (李君龙)

Abstract: "Near-space attacking weapons will be the significant threats for space security in the future, which have a series of special characteristics of high speed, long flight and strong maneuverability. The development status and main characteristics or specialties of the worldwide near space weapons are summarized briefly, including the two main threats as hyper-sonic cruise missile and high speed boost-glide warhead. Then it points out several big challenges to the early warning detection and guidance techniques against the near space attacking weapons in the views of early warning, detection and guidance. Moreover, it brings forward much thought about the key techniques and approaches to overcome these problems." ⁴

Research On Configuration Of Attitude Control Thrusters

(姿控发动机布局方式研究)

Authors: Shi Kaiyu (石凯宇), Cheng Yingrong (程英蓉), Zhang Yiqun (张奕群);

Organization: Beijing Institute of Electronic Systems Engineering

Abstract: "The attitude control of the exoatmospheric vehicle is usually carried out by the attitude control thrusters (ACT). And the configuration of ACT has great influence on the control effect. A summary of the development of the research on ACT is given. Some contradictory factors while designing ACT configuration are discussed in view of engineering practice. Then, an idea of using coupling to solve the problem is put forward

³ www.semanticscholar.org/paper/Design-of-High-precision-Terminal-Guidance-Law-on-Dayong/b1b14a2c819ec4051818a9813d30d118b2205f13.

⁴ 120.209.85.3:8091/KCMS/detail/detail.aspx?filename=XDFJ201201011&dbcode=CJFQ&dbname=CJFD2012.

and three basic principles of ACT configuration are presented. Simulation results indicate that the ACT effect is improved by using coupling.”⁵

Research On A Navigation Approach Of Conical Scan Using Starlight Refraction Measurements

(星光大气折射圆锥扫描观测导航方法研究)

Authors: Song Feng (宋峰), Zhang Yiqun (张奕群)

Organization: Beijing Institute of Electronic Systems Engineering

Abstract: “According to the features of cross-orbit vehicles and the demands of light miniaturization, a navigation approach of conical scan is proposed, which uses refraction measurements of starlight passing through the upper atmosphere. Then, the model of the system is built and linearized. The algorithm is based on EKF and is proved by simulation at last. The approach provides a new idea to the design of a small light autonomous navigation system.”⁶

2014

Tracking For Near Space Target Based On IMM Algorithm

(基于交互式多模型算法跟踪临近空间目标)

Authors: Qin Lei (秦雷), Li Junlong (李君龙), Zhou Di (周荻)

Organizations: 1. Beijing Institute of Electronic Systems Engineering; 2. Harbin Institute of Technology

Abstract: “Due to the current maneuvering target model is developing towards more and more modular and parallel computing, which puts forward higher requirements for calculation efficiency of algorithm. For high-supersonic maneuvering targets in near space, it is often tracked with multiform maneuvering target models, since precision of single target maneuvering model cannot satisfy the requirement of tracking. So it is necessary to use the interactive multiple model algorithm for cross coupling based on a variety of models. The characteristic of this algorithm is adapted to that of high speed and high maneuver for near space target. At the same time, considering the filtering result of extended Kalman filter (EKF) algorithm for strong nonlinear targets is bad, unscented Kalman filter (UKF) algorithm can be solved very well for this problem. So through simulation contrast experiment of two kinds of algorithms, it proves that interacting multiple model-unscented Kalman filter (IMM-UKF) algorithm guarantees the target tracking accuracy is within the allowable range, validity of the algorithm is verified with Matlab simulation results.”⁷

⁵ r.cnki.net/kcms/detail/detail.aspx?filename=XDFJ201202011&dbcode=QTZT_CJFD&dbname=CJFD2012&v=MjEyNzFMVGcyWDJoc3hGckNVUjd1ZlI1UnRGaTNrV3lzTFBTbk5aTEc0SDIQTXJZOUVaWVlrQzM4NHpoNFhuRDA=.

⁶ r.cnki.net/kcms/detail/detail.aspx?filename=XDFJ201201022&dbcode=QTZT_CJFD&dbname=CJFD2012&v=MjE1OTBSdEZpM2tXcjNMUFNuTlplMRzRIOVBNCm85SFpvUitDMzg0emg0WG5EMExUZzJYMHzeEZYQ1VSN3VmWXU=.

⁷ gb.oversea.cnki.net/KCMS/detail/detail.aspx?filename=XTYD201407005&dbcode=CJFD&dbname=CJFD2014.

2015**Tracking For Near Space Non-Ballistic Target Based On Several Filter Algorithms**

(基于交互式多模型算法跟踪临近空间目标)

Authors: Qin Lei (秦雷) [1], Zhou Di (周荻) [2], Li Junlong (李君龙) [1]

Organizations: 1. Beijing Institute of Electronic Systems Engineering; 2. Harbin Institute of Technology

Abstract: "Recently, different countries have made rapid developments in the field of near-space hypersonic vehicles. Among which successful hypersonic vehicle flight tests of X-51 A and HTV-2 are representative. They often adopt the way of non-ballistic maneuver flight with characteristics of high speed and lift-to-drag ratio, flying in atmosphere for a long time. Their motion trajectory is sometimes characterized by "hopping," which induces difficulties of non-ballistic target acceleration estimation, trajectory tracking and prediction. This paper introduces four typical non-ballistic maneuver models of near space targets, and then introduces target ballistic equation and design of tracking filter. At last, four tracking filters are used to estimate target acceleration. Simulation results show that a particle filter algorithm is the best one to guarantee the target tracking accuracy within allowable ranges." ⁸

Estimate Methods Research On Thrust Eccentricity And Centroid Drift Of Exoatmospheric Aircraft

(飞行器推力偏心及质心漂移总体估算方法研究)

Authors: Zhang Peng (张朋), Tan Xiangxia (谭湘霞)

Organization: Beijing Institute of Electronic Systems Engineering

Abstract: "For the will cause them to roll, exoatmospheric vehicles that are controlled by direct lateral yaw and on. If the disturbance torque is model of the aircraft based on the centroid drift model is deduced pitch and generate attitude interference torque du too large, it can lead to loss of stability attitude force, divert thruster ring thruster switching. Firstly, a simulation direct lateral force is established. Secondly, a thrust eccentricity and through extended Kalman filter (EKF) and unscented Kalman filter (UKF) based on kinetic equation. Finally, a simulation example is given to verify the correctness of the model and two filter models' characteristics was compared." ⁹

2016**IMM Locating And Tracking In Near Space Algorithm Based on Target Space**

(临近空间目标交互式多模型跟踪定位算法研究)

Authors: Cao Yajie (曹亚杰) [1], Li Junlong (李君龙) [2], Qin Lei (秦雷) [2]

Organizations: 1. PLA 95899 Unit; 2. Beijing Institute of Electronic Systems Engineering

⁸ kns.cnki.net/KCMS/detail/detail.aspx?dbcode=IPFD&filename=KZLL201507003290.

⁹ 222.198.130.40:81/Qikan/Article/Detail?id=665729845&from=Qikan_Search_Index.

Abstract: "The target in near space is deeply analyzed. According to the characteristics of state equation, the merit and demerit of Kalman filter (KF) and particle filter (PF) in object tracking are analyzed, and combined KF and PF with interacting multiple model (IMM), the IMM-KF and IMM-PF are presented. An analysis through the constant velocity (CV), constant acceleration (CA) and constant turning (CT) dynamics model is carried out. The computer-aided experiment shows that the IMM-KF and IMM-PF can satisfy tracking the target in near space, so it is of practical engineering value." ¹⁰

Problem And Challenge On The High-Precision Guidance And Control Defending In Near Space

(临近空间防御高精度制导控制面临的技术挑战)

Authors: Li Junlong (李君龙), Li Yang (李阳), Liu Chenghong (刘成红), Xie Xiaoying (谢晓瑛), Qin Lei (秦雷)

Abstract: "The current situation of technologies of foreign vehicles and defending in near space are introduced. And then vehicle motion characteristics and striking patterns in near space are mainly analyzed. On this basis, the main key technology problems for defense facing in near space are put forward, which provides solutions for the key technology of systems of guidance and control in near-space defense to achieve fast breakthrough." ¹¹

2017

Maneuver Models Tracking Filter Of Non-Ballistic Near-Space Targets

(临近空间目标非弹道式机动模式跟踪滤波技术)

Authors: Li Junlong (李君龙), Qin Lei (秦雷), Xie Xiaoying (谢晓瑛)

Organization: Beijing Institute of Electronic Systems Engineering

Abstract: "Recently, America has successfully tested several flight vehicles flying in near space with high speed and maneuverability which brings a great security threat to other countries. The maneuvering target with high speed is hard to be tracked by ground defense systems. Traditional filtering algorithms obviously cannot give accurate state estimation for such targets. Obviously, it will be a key technology to design accurate filtering algorithms for tracking such non-ballistic near-space targets in the future air defense systems. Four typical non-ballistic maneuver modes of near-space targets are proposed, and then the modes are discussed from three aspects including tracking filter ways of different maneuver modes, tracking filter ways of unknown maneuver modes, tracking filter ways of a combination of variety of maneuver modes. In the end the non-ballistic tracking filter question and solutions are expounded." ¹²

¹⁰ 113.31.19.9/Qikan/Article/Detail?id=667964925&from=Qikan_Search_Index.

¹¹ 113.31.19.22/Qikan/Article/Detail?id=669323723.

¹² d.wanfangdata.com.cn/periodical/xdyjs201701018.

Research On Important Control Scientific Problems Of Near-Space Hypersonic Vehicles (临近空间领域面临的重大控制科学问题研究)

Author: Qin Lei (秦雷)

Organization: Beijing Institute of Electronic Systems Engineering

Abstract: "In order to satisfy the need of military technology development in the future, to achieve large-scale maneuver of hypersonic aircraft in near space; firstly, four scientific problems are introduced with respect to guidance and control technology of hypersonic aircraft, including principle and analysis methods of lateral jet interference effects in the condition of side window jet cooling multi-field coupling, tracking and trajectory prediction for non-ballistic maneuvering target, principle and analysis methods of multi-constraint midcourse guidance control for non-ballistic maneuvering target with large space and Mach number, and principle and analysis methods of terminal guidance control with high precision for hypersonic maneuvering target. The scientific problems above are described respectively, as well as the relationships among them. The research status and development trends are summarized, to give reference to the future development of near-space hypersonic vehicles' control technology."¹³

Tracking Filter For Non-Ballistic Near-Space Targets Based On MVSIMM Algorithm (临近空间非弹道式目标跟踪修正变结构滤波)

Authors: Qin Lei (秦雷) [1], Zhou Di (周荻) [2], Li Junlong (李君龙) [1]

Organizations: 1. Beijing Institute of Electronic Systems Engineering; 2. Harbin Institute of Technology

Abstract: "As the representative of hypersonic vehicles in near space, X-51A and HTV-2 with characteristics of high speed and irregular acceleration often adopt the way of non-ballistic maneuver flight, which cannot make an accurate estimation of the motion state. For tracking near-space targets with four typical non-ballistic maneuver types, a modified variable structure interacting multiple model (MVSIMM) algorithm is designed. This algorithm takes the current statistical (CS) model as the central model and the coordinated turn (CT) model on the left side and right side, which solves the problem of model switching delays can be faster than compared with the traditional VSIMM algorithm on the aspect of model switching, can be achieved tracking target in the near space with higher real-time and higher accuracy. The effect of MVSIMM algorithm is better than the fixed structure interacting multiple model (FSIMM) filter algorithm towards four non-ballistic maneuver models with Matlab simulation results above."¹⁴

2020

A Real-Time Estimation Algorithm For Slope Error Of Radome Of Radar Seeker (一种雷达导引头天线罩斜率误差实时估计方法)

Authors: Zhou Di (周荻) [1], Li Junlong (李君龙) [2], Yuan Yuqi (袁宇祺) [2]

¹³ cqvip7.dqkj.com/article/detail.aspx?id=671527652.

¹⁴ cqvip7.dqkj.com/article/detail.aspx?id=672405628.

Organizations: 1. Harbin Institute of Technology; 2. Beijing Institute of Electronic Systems Engineering

Abstract: "Firstly, a complete mathematical description of target missile relative motion problem, which consider the slope error of seeker radome is established, including nonlinear state equation and measurement equation. Secondly, the simplified mathematical model of target missile relative motion considering radome error slope in the elevation channel is given, and the mathematical model of joint estimation of line-of-sight rate and radome error slope in the elevation channel is derived. The observability of the joint observation system of line-of-sight rate and radome error slope corresponding to the above mathematical model is proved. Finally, an extended Kalman filter is designed to estimate the line-of-sight rate and radome error slope in the elevation loop and azimuth loop, respectively. The filters are applied in the simulation experiments and compared with the Kalman filter of line-of-sight rate estimation without considering the error slope of radome. The simulation results show that the extended Kalman filter with joint estimation of line-of-sight rate and radome error slope is effective, since it can significantly improve the guidance accuracy of a guidance system with radome error slope." ¹⁵

Optimal Two-Impulse Space Interception With Multiple Constraints

(多约束条件下的最优两脉冲空间拦截)

Authors: Xie Li (谢力) [1], Zhang Yiqun (张奕群) [2], Xu Junyan (徐俊艳) [2]

Organizations: 1. North China Electrical Power University; 2. Beijing Institute of Electronic Systems Engineering

Abstract: "We consider optimal two-impulse space interception problems with multiple constraints. The multiple constraints are imposed on the terminal position of a space interceptor, impulse and impact instants, and the component-wise magnitudes of velocity impulses. These optimization problems are formulated as multi-point boundary value problems and solved by the calculus of variations. Slackness variable methods are used to convert all inequality constraints into equality constraints so that the Lagrange multiplier method can be used. A new dynamic slackness variable method is presented. As a result, an indirect optimization method is developed. Subsequently, our method is used to solve the two-impulse space interception problems of free-flight ballistic missiles. A number of conclusions for local optimal solutions have been drawn based on highly accurate numerical solutions. Specifically, by numerical examples, we show that when time and velocity impulse constraints are imposed, optimal two-impulse solutions may occur; if two-impulse instants are free, then a two-impulse space interception problem with velocity impulse constraints may degenerate to a one-impulse case." ¹⁶

¹⁵ r.cnki.net/kcms/detail/detail.aspx?filename=XDFJ202005001&dbcode=QTZT_CJFD&dbname=CJFDLAST2020&v=MTcxNTZVYnpOUFNuTlpMRzRITkhNcW85RlpZUitDMzg0emg0WG5EMExUzZjYmMhzeEZyQ1VSN3VmWXVSckZpcmg=.

¹⁶ r.cnki.net/kcms/detail/detail.aspx?filename=JZUS202007010&dbcode=QTZT_CJFD&dbname=CJFDLAST2020&v=MTkxNjJlEMExUzZjYmMhzeEZyQ1VSN3VmWXVSdEZpcmhXci9LTHpmZWZiRzRITkhNcUk5RVpJUitDMzg0emg0WG4=.

2021**Capture Zones And Differential Game Guidance Law For High-Speed Maneuvering Target Interception**

(拦截高速机动目标的捕获区及微分对策导引律)

Authors: Mao Boyuan (毛柏源), Li Junlong (李君龙), Zhang Rui (张锐), Zhang Pengfei (张鹏飞)

Organization: Beijing Institute of Electronic Systems Engineering

Abstract: "Aiming at the high-speed maneuvering target interception scenario, the conditions for the existence of the capture zone in the terminal guidance phase and the differential game guidance law were studied. The relative motion model of missile and target was established and the control dynamics model was introduced, and the relative motion model was reduced by terminal projection method. Based on the differential game theory, an analytic capture zone was derived, which can be used in the interception of maneuvering targets by a missile with dual control. The existence of the capture zone can ensure the accurate capture of any maneuvering target. The performance index function was re-selected, and the guidance problem of the target and the dual control missile with the collision angle constraint at the end was transformed into the zero-sum differential game problem, and the optimal interception strategy was solved. The simulation analyzed the existence of the capture zone of the dual control missile intercepting the target in several cases. Simulation results of the guidance law show that the differential game guidance law has better performance when intercepting high-speed maneuvering targets." ¹⁷

Differential Game Guidance Law For Intercepting The Active Defense Target

(拦截主动防御目标的微分对策制导律)

Authors: Zhang Hao (张浩), Zhang Yiqun (张奕群), Zhang Pengfei (张鹏飞)

Organization: Beijing Institute of Electronic Systems Engineering

Abstract: "For the scenario where the target can actively defend against the attacking missile, a differential game guidance law for intercepting the active defense target is proposed. Firstly, the relative motion models of attacking missile target and defending missile are established, and linearization around the current collision triangles is performed. Secondly, assuming that the defending missile is using a known linear guidance law, the confrontation problem between the attacking missile and the target is described as a linear quadratic differential game problem with inequality constraint. Finally, based on the differential game theory, the guidance law of the attacking missile is designed. Using the guidance law, two objectives can be achieved simultaneously, which are evasion from the defending missile with specified miss distance; and perfect

¹⁷ cqvip7.dqkj.com/article/detail.aspx?id=7104735149.

interception of the target. Simulation results show the high performance of the guidance law.”¹⁸

¹⁸ r.cnki.net/kcms/detail/detail.aspx?filename=XTYD202105023&dbcode=QTZT_CJFD&dbname=CJFDAUTO&v=MjY1MDBGckNVUjd1ZlI1UnRGaXJoV3lvS1BUbINhckc0SE5ETXfvOUhaNFirQzM4NHpoNFhuRDBMVGcyWDJoc3g=.