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The Evolution of Night Vision Equipment: An Analysis Based on Modern and Contemporary Military Operations

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Abstract. In recent years, night vision devices, as part of individual-soldier equipment, have increasingly attracted the attention of various enforcement units and enthusiasts. Under these circumstances, domestic night vision manufacturers in China have gradually rose to prominence, breaking the foreign monopoly on the producing and exporting night vision equipment and supplies for the People's Liberation Army of China and the People's Police. These night vision devices have also gradually appeared in the promotional videos of the People's Liberation Army of China and the People's Police of China. Against this backdrop, this study will mainly focus on the practical applications of night vision equipment, and use modern combat cases, such as the the Cold War-era Falklands War and the early 21st-century Global War on Terror, to discuss its necessity as individual soldier equipment and its current limitations, thereby briefly discussing the possible future development trends of night vision equipment. In conclusion, it is inevitable that night vision devices, as individual soldier equipment, will be widely equipped by the military forces of various countries in the future. Technologically, their development will also focus on enhancing stability and improving combat effectiveness.

Keywords: Night Vision Equipment, War, Individual-soldier Equipment

1. Introduction

Nighttime has never been the main battlefield of war from ancient times to the present, but it has always been an important component that cannot be ignored in military strategy. Traditionally, night battles have been mostly confined to small-scale surprise attacks and other tactical operations, while large-scale night operations have been relatively rare. However, with the development of night vision technology, night warfare is no longer confined to small-scale battles but has gradually become an important part of modern warfare. Large-scale night operations have gradually become more common with the development and popularization of night vision equipment. Therefore, the development of night vision equipment has become increasingly important in modern weaponry and equipment systems. For some elite forces, night vision equipment has become a vital component of their operations. However, current research primarily focuses on its application in training and the analysis of night vision devices' principles, there are few studies that specifically connect it with actual combat to discuss the role of night vision devices in combat.

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This paper will take the night operations carried out by various countries during the Cold War and the U.S. military's War on Terror as examples to discuss the role of the development of night vision equipment in improving the success rate of missions, to demonstrate the necessity of night vision devices as individual soldier equipment, and to explore the development direction of night vision devices and the trend of individual-soldier night vision equipment. To study the role of night vision devices and other night vision equipment in modern warfare, as well as their future development trends. It fills the gap in the research on the role of night vision devices in enhancing combat efficiency and reducing casualties.

2. Theoretical foundation

2.1. History and development of night vision since the late 19th century

The history of night vision devices can be traced back to the late 19th century. In 1872, a professor from the Norwegian University discovered the role of a multi-angle light-sensing system in forming clear images, based on the eyes of dung beetles, and called on the military to design night vision equipment based on this theory [1]. After World War I, German researchers and scientists discovered that although visible light was weaker at night, the temperature generated by the heat of objects and the fluorescence reflected by objects were more obvious at that time. Based on this principle and the invention of other infrared transmitting materials such as lead sulfide. Germany was the first to develop an active infrared night vision device. After that, the United States followed and put its early infrared night vision devices into practical use first [2]. Subsequently, during the Cold War, the United States developed a large number of night vision devices and was the first to deploy low-light night vision devices on the battlefield—a technological advantage that later laid the foundation for its success in conflicts like the Iraq War. As the 21st century has entered its second decade, emerging digital technologies has also been utilized to manufacture night vision equipment.

2.2. Research on the current status of low-light night vision device technology

In the Western world, due to the early development of night vision technology and equipment, many scholars began to explore the principles and practical applications of night vision devices at an early stage. In Neil L. Whitehead, and Finnström, Sverker's book Virtual War and Magical Death: The Role of Night Vision Devices in the Iraq War, explores technologies and imaginaries for terror and killing [3]. Compared with the anxieties about nighttime during the Vietnam War, the U.S. military relied on night vision devices to make the nights seem more reassuring during the Iraq War. Other night vision devices, such as thermal imagers, are also highly praised for their ability to precisely strike military targets [3]. Meanwhile, this book also discusses the experiences and benefits that night vision devices bring to users. By wearing night vision devices, users can effectively mitigate the constraints of darkness, and soldiers can also patrol at night, making night patrols safer compared to the Vietnam War period [3]. In another article, Night Operations, it is noted that darkness facilitates the effect of surprise attacks, and night vision devices enable attackers to aim effectively [4]. This gives troops and Combatants equipped with night vision devices a distinct advantage [4]. However, the mental pressure is great at night, and night vision devices cannot fully alleviate. In weather conditions such as snow accumulation and heavy rain, even when wearing a night vision device, one still needs to rely more on hearing to perceive the surrounding environment. It also led to the night operations requiring physical and mental balance [4].

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3. The principle of night vision devices and countermeasures

3.1. Basic principle of the night vision devices

Between the 1960s and 1990s, night vision equipment also developed rapidly. Night vision devices gradually became popular among elite troops and eventually became standard equipment for ordinary soldiers. During this period, the iteration and improvement of night vision devices undoubtedly accelerated the advancement of night vision technology. Low-light night vision devices have also replaced the early infrared night vision devices and have become the mainstream of night vision equipment to date.

The traditional low-light night vision device is composed of an objective lens, a tube, an image amplification tube, an eyepiece, a circuit system and a connection system. Among them, the image amplification tube is the main component that determines the performance of the night vision device. Internationally, the generation classification of night vision devices is primarily distinguished by the difference in image amplification tubes. Meanwhile, the external eyepiece, objective lens and tube can be used in conjunction with image amplification tubes of different generations [5]. The working principle of the low-light night vision device relies on the image amplification tube: weak light is converted into electrons through the photocathode, and these electrons then multiplied and accelerated by a high-voltage electric field and a micro-channel plate. (MCP). After the energy is enhanced, it bombards the fluorescent screen behind the image amplification tube, converting it into a visible light signal that can be seen by the naked eye.

Since military adopted low-light night vision devices as mainstream equipment, research and development efforts for multi-tube night vision devices have gradually been advanced. Eventually, they can be roughly divided into monocular night vision devices, binocular night vision devices, ground panoramic night vision devices, and the latest thermal fusion night vision devices.

With the advancement of electronic technology, digital night vision has undergone a gradual evolution. Compared with low-light night vision devices, digital night vision devices is relatively simple. It primarily utilizes low-light charge-coupled devices or complementary metal-oxide-semiconductor (CMOS) image sensors. These sensors captures the dimmer light, convert it into a digital signal and transmitted it to an LCD screen.

However, digital night vision devices have not been widely equipped as mainstream equipment at present. On the Contrary, they remain available as civilian alternatives on the market. The primary reason for this is that with the large-scale popularization of low-light night vision in military applications: while digital night vision devices offer strong light resistance and fewer usage restrictions, it still requires supplementary lighting operation. This lighting equipment can expose the user's position, a factor that has prevented the widespread adoption of digital night vision devices.

3.2. Counter methods of the night vision devices and gate control devices

Therefore, countermeasures against low-light-level night vision devices are gradually being developed. During the development of low-light-level night vision devices, laser interference methods have been gradually regarded as efficient means to counteract night vision devices. Directly shining a laser beam at the optical entrance of a low-light night vision device has become the main countermeasure. Low-power lasers can induce temporary blindness in the device, disrupting the enemy's night vision capabilities, while high-power lasers or intense light can directly damage the night vision equipment, rendering the enemy unable to see at night [6].

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To counter laser irradiation, manufacturers have incorporated gate control technology into night vision devices. By automatically adjusting the amount of incoming light through a gate control device, it prevents intense light or laser from suddenly shining on the optical entrance of the night vision device, thereby protecting the night vision equipment from damage. Meanwhile, the new generation of digital night vision devices can also reduce the impact of laser countermeasures. Due to the different principles of digital night vision devices, they are rarely directly affected by the energy brought by lasers. Optical sensors are less likely to be damaged by strong light, and the generated light signals will also be continuously displayed on the screen. Therefore, compared with low-light night vision devices, Digital night vision devices have strong anti-interference and countermeasures capabilities. However, as a new generation of night vision equipment, although digital night vision devices are not yet fully developed, they are still deeply appreciated by hunting enthusiasts due to their low cost, ease of maintenance, and resistance to damage.

4. Practical application of night vision devices

4.1. The early practical application of night vision devices

Following the end of World War II, night vision devices, as well as various types of weaponry and equipment also entered a period of rapid development. The beginning of the Cold War and the outbreak of the Korean War marked the beginning of a period of bipolar opposition. Local hot battles and special operations also promoted the rapid research, development, and application of various special equipment. On the Korean battlefield, the Chinese People's Volunteers once seized the latest M3 night vision sniper carbine and the T120 infrared night vision sight installed on it from U.S. snipers. After being captured, China also produced its earliest infrared Night Vision Devices in 1958, following research by domestic teams and research institutes. During the Vietnam War, various branches of the U.S. military began to be equipped with night vision sights. As one of the early night-vision sights used by U.S. military, the AN/PVS-2 was employed by helicopter pilots, marines, and special forces, attached to helmets or rifles to defend against guerrilla attacks or carry out specialized tasks.

With the development and equipment of night vision devices, their role has been proven by the armies of various countries in one war after another. For instance, during the Falklands War in 1982, 3,000 British troops, equipped with night vision devices, launched an attack on the Afghan army under the cover of artillery. However, due to the lack of night vision equipment, the Afghan army was unable to resist the British attack, and the British army took the opportunity to occupy the main high points on the defense line. This put the Argentine army under the control of British firepower, and they eventually surrendered to the British on June 14th [1]. During the subsequent U.S. military invasions of Grenada and the Panama War, night vision devices also greatly boosted the confidence of the U.S. military in night battles, making these two wars the testing ground for the U.S. military to overcome the "moon fear" [7]. These battles have all demonstrated the role of night vision devices as auxiliary military equipment in helping the army achieve victory. This also proves that even with the help of early infrared night vision devices, the army can still strike at a lower dimension against the enemy without the assistance of night vision equipment. The subsequent Gulf War further demonstrated this point. With the assistance of advanced infrared night vision, the U.S. tanks were able to detect the enemy before those of the Iraqi army and fire, creating a significant exchange ratio. These wars all showcased the help of night vision devices as cutting-edge technology in warfare, as well as their role in reducing casualties and enhancing combat efficiency.

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4.2. Practical applications of night vision devices in the 21st century

With the outbreak of the Global War on Terror, the role of night vision devices in the military has become increasingly important as the military's combat objectives have evolved. During the war in Afghanistan, the U.S. military was equipped with various night vision devices, including the helmet-mounted PVS-14 monocular, the PVS-10 Night sniper sight, and the GPNVG-18 used by elite forces.

These night vision devices have played a crucial role in low-intensity and high-precision counterterrorism and public security operations. The most famous example is the Neptune Spear operation carried out in May 2011. When the When the U.S. Naval Special Warfare Development Group (DEVGRU) raided Osama bin Laden's residence, they used the most advanced GPNVG-18 four-eye night vision device at that time. In this operation, DEVGRU relied on Black Hawk helicopters with stealth coating and GPNVG-18 Night vision devices. Entering Pakistan from low altitude, this type of night vision device provided the commando team with a field of view of nearly 120 degrees, making it easier for pilots and special forces members to spot targets. It also reduced the blind spots caused by the night vision device, enabling combat personnel to observe details more clearly. It was also with the help of this kind of equipment that DEVGRUs successfully beheaded Osama bin Laden in Pakistan [8]. Since then, more special forces in various countries have chosen to be equipped with the more advanced GPNVG-18 Night Vision Device as the standard configuration for their special forces.

4.3. Practical application of night vision devices in the modern large-scale warfare

With the end of the war on terror and the withdrawal of the U.S. military from Afghanistan, the frequency of various special operations and security operations has gradually declined, and parts of the world entered a brief lull in large-scale conflict. However, with the start of Russia's special military operation in 2022, parts of the world were plunged back into turmoil and armed conflict. During this period, the special operations of both sides have often been active as reconnaissance forces behind enemy lines. With the shift in combat methods, the equipment used by special forces has also changed. Night vision devices and thermal imaging equipment have become essential equipment for all levels, from special forces to ordinary combat forces. Even many units have resorted to using civilian night vision devices as their combat equipment. Meanwhile, drones integrated with night vision and thermal imaging capabilities have also become a necessity for frontline combat forces. Therefore, in combat footage from the Russia-Ukraine battlefield, it is common to see forces or ordinary troops wearing night vision devices engaging in firefights. It can be seen from this that the demand for night vision equipment is no longer limited to special forces and reconnaissance forces but extends to the entire military.

5. Future development trend for night vision devices

In modern and future wars, the development of technology has become inseparable from the needs of warfare. Various advanced technologies are also reflected in a wide range of equipment. Therefore, night vision devices, as individual-soldier equipment, will likely be interconnected with other devices in the future, thereby enhancing the ability to share information and perceive situations effectively. In terms of imaging principles, low-light-level night vision devices offer better imaging and stability compared to digital night vision devices.

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However, due to their imaging principles, they are not easily compatible with other devices. Currently, the main solution is to replace the imaging tube to achieve thermal imaging and other effects. However, this does not mean that low-light-level night vision devices will be phased out in the future. Low-light night vision devices will continue to be used as equipment for special forces, special police, and other combat personnel, who are primarily engaged in asymmetric operations for a long time. Due to the unique imaging principle, digital night vision devices are relatively easy to connect with other devices. Compared with the price of low-light night vision devices, they are more suitable for ordinary infantry teams and vehicle drivers. Currently, the development of digital night vision devices primarily focuses on enhancing the screen frame rate and integrating additional functions to obtain information more efficiently. In conclusion, technology will also develop towards miniaturization, intelligence, and multi-functional integration, integrating with other information and communication technologies to provide more powerful intelligent combat capability support for modern warfare.

6. Conclusion

In conclusion, this study primarily examines the role of night vision devices in enhancing the combat effectiveness of the U.S. and British armies. In today's NATO forces, night vision devices have become almost standard equipment for every infantryman. Such an individual infantry configuration has significantly enhanced the combat capabilities of each combatant, making the night no longer peaceful. With the help of night vision devices, the repeated battles for positions have become more frequent. However, this has also brought about many problems, such as a significant increase in the price of individual-soldier equipment. Additionally, the improper use and maintenance of low-light night vision devices can lead to a sharp increase in combat costs. Therefore, in the future, low-cost night vision devices and ordinary digital night vision devices may gradually become the primary night vision equipment for ordinary soldiers and be combined with other devices to form information terminals, enhancing soldiers' battlefield perception and improving enemy detection efficiency. For low-light night vision devices, the primary goal is to reduce costs and develop automatic gate control technology to prevent interference from strong light and lasers. As for digital night vision devices, the main development goal is to reduce the need for additional supplementary IR lights and decrease the probability of being detected. At the same time, night vision devices and corresponding training should not be confined to the elite force alone but should be deeply integrated into the grassroots level and become an integral part of the training and life of ordinary soldiers.

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