The evolution trend and thinking of the modernization of command, control and communication system of American nuclear force

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Abstract. The nuclear force Command, Control and Communication System (NC3) is a variety of facilities required when the president issues nuclear operations instructions, is the central nervous system to achieve the United States "trinity" strategic nuclear strike, and is an important basis for achieving reliable and effective nuclear deterrence. The future contest between major powers is a comprehensive confrontation based on the comprehensive national strength of strategic nuclear forces. While the United States has the world's most advanced conventional combat forces and the largest nuclear Arsenal, it continues to apply new technological means to improve the operational command and control system of nuclear forces, upgrade its nuclear Arsenal, strengthen the construction and development of nuclear forces, and maintain its nuclear superiority. We should draw inspiration from this and speed up the independent research and development of a credible and reliable combat command system of nuclear forces to ensure that we will win the first opportunity in future wars.

Key words: nuclear force, command and control, communication system, United States.

1. Introductions

In the context of great power competition, while pursuing the modernization of its "triad" nuclear forces, the United States is also constantly upgrading its command, control and communications systems in pursuit of comprehensive nuclear superiority. At the same time, the command, control and communications system of nuclear weapons is an important component of the nuclear warfare system and a basic prerequisite for ensuring the effectiveness of nuclear deterrence. Its modernization process will better serve the US nuclear deterrence strategy, establish real combat deterrence in pursuit of nuclear superiority, and strengthen extended deterrence against overseas Allies. Since the Cold War, the United States has attached great importance to the development and construction of the NC3 system, and has always regarded high security, reliability and survivability as the core capabilities of the system. However, after the first nuclear attack, whether the remaining effectiveness of the NC3 system can support the United States to carry out effective nuclear counterattack remains to be studied.

2. Overview of NC3 system

2.1 NC3 system definition and functions

The U.S. Department of Defense defines the NC3 system as follows: "Facilities, equipment, communications systems, procedures, and personnel necessary to carry out presidential nuclear command." The system consists primarily of early warning systems, communications systems, fixed and mobile command posts, and the nuclear weapons systems control Center. The nuclear weapons command and control system is an important component of the U.S. nuclear deterrent, and the communications system is a necessary link to ensure that the strategic nuclear forces can be controlled under any circumstances. NC3 system is used to provide guaranteed command and control of nuclear forces, which mainly implements nuclear force management, nuclear action

planning, situation monitoring, decision execution and nuclear force command during nuclear command and control. [1-3]

2.2 Status quo and challenges of NC3 system

After decades of evolution, the NC3 system in the United States has basically built air, ground and underground combination, fixed and mobile matching command and control facilities, with global coverage of missile early warning system, as well as wired and wireless combined multi-level, three-dimensional strategic communication network. The existing NC3 system is a huge "system of systems" composed of various command facilities, early warning systems and communication systems in space, air, land and sea. It relies on a variety of land-based security and non-security telephone lines, submarine cables, air relaying (such as E-4B and E-6B), and satellite sensors to send and receive voice, video, or data. To transmit trusted data and recommendations from the sensors to the relevant centers, from the presidential adviser to the President, from the President to the National Military Command Center, and from the National Military Command Center to the nuclear weapons delivery platform. Although the NC3 system was the most advanced during the Cold War, due to the aging of the system components and growing security threats, the NC3 system has been unable to meet the needs of the United States strategic nuclear deterrence in the era of intelligence. The system mainly faces dual challenges such as aging of system components and external threats, mainly including threats from space and cyberspace, as well as limited nuclear upgrade strategy adopted by major nuclear adversaries. In particular, the emergence of anti-satellite weapons has damaged the survival and defense capabilities of US satellite systems, and offensive networks have also threatened the security and reliability of the United States in the fields of cyber defense, identification, data and information flow. [4]

2.3 Necessity of NC3 system modernization development and evolution

A In recent years, with the aging of NC3 system and the emergence of new threats, in order to adapt to the upgrading of the "trinity" strategic nuclear force, the US military officially launched the planning and construction of the next-generation NC3 system, mainly from the following five aspects:

First, the needs of the era background. It has been 30 years since the NC3 system in the United States was modernized. The US Department of Defense is in the midst of a belated overhaul of the capitalization of its nuclear forces. The development and acquisition of the new B-21 Raider long-range bomber, the new LRSO air-launched nuclear-capable cruise missile, and the new Columbia-class ballistic missile submarine have received great attention. Another important element of the U.S. nuclear force modernization program, the renewal of the nuclear warhead Arsenal, is also under way and is being handled by the Department of Energy's National Nuclear Security Administration. But without an effective and robust NC3 infrastructure, these platforms and weapons, even if modernized as planned and to the desired capability, will not provide a convincing nuclear deterrent. [1]

The second is the oppression of an adversary's military might. The military strength of adversaries forces the United States to pay attention to the reliability of the NC3 system. From the perspective of the Russia-Ukraine conflict, Russia said that if Russia is defeated, it will use nuclear weapons, the US military has been playing up the nuclear threat it faces, and Russia's nuclear modernization program has been completed more than 80%, the Russian side has deeply studied the concept of new nuclear weapons nuclear capabilities, and these weapons are not subject to any conditions. In response, the US Department of Defense is eagerly modernizing all nuclear strike platforms, including ballistic missile submarines, intercontinental ballistic missiles, long-range bombers, and dual-use battlefield strike aircraft. To support effective command and control of the next generation of nuclear weapons systems, the NC system will also be modernized once again.

Third, the threat they face. First of all, space is a threat to space-based assets. The US Department of Defense has gradually realized that space is increasingly competitive, congested and

competitive. The number of satellites launched into various orbits by countries with space combat capabilities continues to increase, and the constantly congested space puts US national security space assets at risk. The second is the security threat of cyberspace. Although NC3 system is a closed network, the security risk of cyberspace is inevitable with the continuous procurement of new equipment based on IP subsystem by the US government and the continuous access to the nuclear command and control network. The third is the transmission threat after a nuclear weapon attack. The NC3 system was originally designed to ensure that it can play a role in all stages of a nuclear attack. When nuclear threats take on different characteristics, the effects of nuclear weapons could compromise the NC3 systems of the United States and its Allies, preventing early warning and sensor transmission of commands to nuclear forces on the battlefield. Threats based on these three aspects compel the United States to continue to focus on the effectiveness of the NC3 system. [3]

The fourth is the use of external environment. The application of external environment forces the United States to pay attention to the practicability of NC system. At the beginning of the design of the NC3 system, it takes into account when and where the NC3 subsystem needs to rely on civil infrastructure to obtain some essential goods, such as power, water, transportation nodes, civil communication facilities and channels, civilian satellite and space link ground stations, civil computer server stations and cloud computing infrastructure, and other similar non-military support. The entire NC3 system must also be designed to work in the event that the supporting civil infrastructure is compromised or unavailable.

The fifth is the integration of economic benefits. The modernization of the NC3 system in the United States is the "fifth pillar" of the entire nuclear modernization. The construction of a new generation of ballistic missile submarines, intercontinental ballistic missiles, nuclear-capable long-range bombers and the life-extension program of nuclear weapons themselves, with its huge scale and high price, has received great attention. But without a nuclear command and control system to provide appropriate communications to nuclear forces in a future environment, even with these platforms and weapons in place, the United States will lack a credible nuclear deterrent capability. Of the five pillars of nuclear modernization, the NC3 system is the least expensive, but perhaps the most important. Whether or not each element of the Trinity modernization is supported, the NC3 system upgrade is critical to maintaining the communications architecture of the current nuclear deterrent.

In summary, the United States must accelerate the modernization of the NC3 system, so that it can have super survivability when it is attacked by nuclear attacks and other forms of attack, and its security, timeliness, durability, accurate reliability can be effectively guaranteed.

3. Evolution trend of NC3 system modernization

The 2018 edition of the Nuclear Posture Review Report pointed out that the NC3 system has been difficult to adapt to the current complex battlefield situation, and clarified that the US Department of Defense has developed the "next-generation NC3 system", and the Strategic Command is responsible for coordinating the construction of the next-generation NC3 system. The US Strategic Command said, The next generation NC3 system will be modernized and improved in a gradual and continuous iterative manner. [5]

3.1 Expanding the "dual" architecture enhances the elasticity and operational flexibility of the NC3 system

Driven by emerging technologies such as artificial intelligence and quantum science, the architecture of NC3 system will have a revolutionary change. On the one hand, the "distributed" architecture is adopted to improve the survivability and elasticity of the system; On the other hand, it adopts "open" architecture to improve system adaptability and flexibility. The next generation NC3 system will focus on enhancing resilience and flexible combat capabilities while further

improving reliability, security and survivability. On the resiliency front, the evolving Resilient Ground Systems Evolution (FORGE) enables data fusion across multiple types of probes by adopting an "open" architecture. It ensures that NC3's performance is not destroyed in the event of an attack, and that it can recover quickly after falling below a certain threshold. In terms of flexibility, the new generation of space-based early warning satellite system will break the existing system architecture of large satellite constellations, and gradually transition to the combination of "large satellite constellation + small satellite constellation", with multi-platform, multi-orbit and decentralized deployment to achieve rapid space reconstruction. It will meet the needs of "tailor-made" nuclear deterrence, and effectively respond to various potential threat targets and combat scenarios in the future. [6]

Special attention needs to be paid to strengthening the defense against threats in cyberspace, as the introduction of advanced technologies such as artificial intelligence and the digital transformation during the NC3 modernization improvement process have triggered technological uncertainties and risks such as cyber security. To this end, enhancing the network defense capability will become one of the main tasks in the first phase of the next-generation NC3 system. In the future, the focus will be on the development of new network architecture, the realization of dynamic software reconfiguration and other capabilities, and the improvement of network resilience.

3.2 Using digital means to accelerate the iterative improvement of new capabilities of NC3 system

In recent years, the US NC3 system has made extensive use of digital means to carry out research and development work and promote the digital transformation of the NC3 system. At present, the US Strategic Command has established a digital modeling and engineering environment, using "Development, Safety and Operation DveSeeOp",[4] cloud computing and digital analysis technologies to accelerate the development and delivery of new capabilities, and provide a collaborative platform with standard development and test engineering specifications for the modernization and improvement of NC3 system. At the same time, US Strategic Command will also. In addition, to meet new operational environment changes and capability requirements, the US military is integrating automation and emerging technologies such as artificial intelligence and quantum science to promote the digital transformation of the next-generation NC3 architecture. In 2021, Gen. Charles Richard, commander of the U.S. Strategic Command, said that the NC3 system will use artificial intelligence, digital engineering, simulation and simulation as key technology enabators. The command has set up a "Command Data and Artificial Intelligence Center" to focus on the application of advanced AI/machine learning.

3.3 Construction of space-based early warning system to achieve early warning capability of various advanced missile targets

The new generation of space-based early warning satellite system in the United States will form a multi-level, seamless integration of missile detection, tracking and identification capabilities. By adopting the development approach of multi-orbit and distributed deployment, it will not only greatly enhance the survivability of the system, but also realize the complementary capabilities of early-warning satellites in different orbits. [8]More importantly, it can cope with the future emergence of hypersonic missiles, mobile missiles and other possible advanced missile threats. The new generation NC3 system must reduce threats to NC3-related space-based infrared systems, advanced extremely high frequency satellites and defense satellite communication systems through countermeasures or replacement systems, upgrade space-based infrared system constellation, ground-based missile early warning radar, nuclear explosion system sensors, and improve the fusion of data provided by these systems. Can further enhance integrated tactical early warning and attack assessment capabilities.

3.4 Improving the communication capability of strategic communications satellites and their data terminals to achieve resilience

Due to the advantages of 5G communication, such as large bandwidth, low delay, high reliability and high connection density, 5G communication technology can be applied in the future to enhance the NC3 system's communication capability to be efficient, flexible, sustainable and with global coverage. Through the development of system defense capabilities that combine active and passive, the strategic communications satellite platform will further enhance its survivability, enhance the destruction resistance of space systems, and continue to operate during and after attacks. By upgrading the mobile command post (such as the National Airborne Operations Center and E-6B), ground command post and data link, as well as the transmitters and terminals of the entire NC3 system, improving command post and communication link, so that it has stronger anti-jamming capability, anti-radiation reinforcement and cyber defense capability, and expanding its coverage to the Arctic region, Ensuring reliable communication between detection systems, weapon platforms, and decision makers. [7]

3.5 The integrated development of multiple systems will promote the integrated capability of nuclear and permanent operations management

In recent years, the U.S. military has conducted research on the relevance of NC3 system and Joint global Command and Control (JADC2), and verified some technologies of NC3 system in the Air Force's "Advanced Battle Management System" (ABMS) exercise, exploring a variety of communication means and technology support common combat scenarios. [4]To establish a baseline or proof-of-concept for integrating NC3 into JADC2 and the future framework of ABMS. Gen. Charles Richard, commander of U.S. Strategic Command, told the Senate Armed Services Committee that there is a strong link between Joint Global Command and Control and Nuclear Command Control and Communications (NC3) for integration and other reasons, and that JADC2 represents a radical overhaul of how the U.S. Department of Defense (DOD) approaches the way military actors communicate and process information with each other, Breaking down the barriers that have kept each service dependent on its own network. NC3 is the foundation of America's nuclear weapons and is needed to ensure weapons of destruction are readily available. NC3 is like two sides of a coin with JADC2, whose conventional side can provide the redundancy and resilience of the nuclear side. Judging from the development trend, the future JADC2 system is likely to drive the next generation NC3 system in the network, data, software, security and other architecture changes. [6-8]

4. Enlightenments and reflections from NC3 system modernization evolution

Since the emergence of nuclear weapons, the strategic nuclear force of the United States has been in a leading position in the world in terms of force scale, operational use, command and control, etc. It is not difficult to see its unique construction and development characteristics throughout its development history. Through the analysis and research of the NC3 system, the command system and the construction and development of the strategic application of the US military. The following enlightenments can be drawn from the study:

4.1 Strengthen top-level design and continue to deepen the nuclear combat command system

In accordance with the reverse thinking of operational demand-command information-command means construction, focusing on the needs of its own core military capabilities, starting from the planning and demonstration of equipment construction, strategic planning and top-level design are carried out from top to bottom, and the hardware and software of the system are standardized through unified planning, unified standards and unified management, so as to gradually solve the compatibility problem between various systems. Prevent scientific research units from developing systems independently, and the system is incompatible and interoperable. Gradually, all kinds of geographically dispersed command organs, business departments and related civilian systems at all levels can be closely connected together, so as to improve the timeliness and effectiveness of combat command, and finally realize the network interconnection, information exchange and user interoperability among information systems of various elements.

4.2 Expand the function space of communication systems and enhance the development and utilization of battlefield space

The cutting-edge technology will be transformed into a military communication system at a high intelligent speed, and the battlefield space is the commanding height of the future high-tech war, who can control and use the communication system well, who can become the master and winner of the battlefield. In particular, in the area of minimal communications, there is a need to improve the very low frequency/low frequency and very high frequency military satellite communications system and to improve the computer security terminals of the nuclear command centre for the transmission of emergency operational instructions (EAM) to troops to ensure uninterrupted command and control systems. Therefore, while developing our own nuclear command and control systems, we should make comprehensive use of satellite communications, optical cable communications, mobile communications, data links, computer communications and other communication means, give full consideration to the role of communication systems in battlefield space, and strengthen and improve information exchange with various space-based systems in strategic and tactical command and control.

4.3 Use emerging technologies to upgrade existing systems and equipment

At present, the construction mode of spiraling and rolling development of the US military reflects unprecedented flexibility. NC3 system adopts standardized information transmission format and large-capacity transmission channel to achieve comprehensive transmission of multiple services. On the basis of learning, we should not only apply various high-tech technologies to the improvement and upgrading of existing weapons and equipment systems, but also implement comprehensive transmission of multiple services. It is also necessary to carry out sufficient feasibility demonstration before the transformation, ensure that the performance of the equipment is greatly improved after the upgrade and improvement, and prevent the phenomenon that the upgrade and improvement project is blindly approved and cannot be effectively implemented, resulting in the project stopping. Especially after the upgrading, we should pay attention to the adoption of information encryption technology and security protection measures to improve the security of information transmission and the reliability of communication systems.

5. Conclusions and Recommendations

The modernization of NC3 system is a project without a deadline. At present, the United States has not fully determined the architecture of the next generation NC3 system, but under the new military requirements, the future NC3 system may be more complex and become a "network of networks". The new generation of NC3 system will gradually realize the transformation from analog system to digital system, from a relatively isolated system to an open, distributed, networked, multi-domain collaborative system. In the situation of great power competition, the NC3 system of the United States will further improve the reliability, security and survivability, and highlight the elasticity and operational flexibility of the system to meet the long-term strategic and military needs in the future.

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