PRIMER

THE UNITED STATES' NUCLEAR COMMAND, CONTROL, AND COMMUNICATIONS (NC3) OPERATIONS

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Introduction

Nuclear deterrence—the strategy of preventing attack by ensuring any aggressor faces an unacceptable retaliatory cost—rests on the credible guarantee that U.S. nuclear forces can strike under any circumstances. Traditionally, this strategy of deterrence is sustained by the nuclear triad: land-based intercontinental ballistic missiles (ICBMs), sea-based submarine-launched ballistic missiles (SLBMs), and air-based strategic bombers. The nuclear command, control, and communications (NC3) ecosystem serves as the "nervous system" that connects and animates that triad, translating raw capability into a functional deterrent.[1] By ensuring survivable command authority and connectivity, even in the face of a surprise attack, NC3 systems provide the confidence needed to dissuade an initial strike. As a result, many officials and experts have come to describe NC3 systems as the "fourth leg" of the nuclear triad: a crucial addition to nuclear deterrence that ensures the U.S. chain of command can authorize and direct the use of nuclear weapons, whether faced with an attack, a damaged network, or a disrupted chain of command.

This report serves as a primer for understanding the systems comprising the U.S. NC3 network. It also summarizes modernization plans and explores the challenges that emerge in an increasingly uncertain threat environment, complicated by multiple near-peer nuclear-armed adversaries and a list of emerging and disruptive technologies (EDTs) growing in complexity and number by the day. Since the Cold War, new kinetic and non-kinetic capabilities have emerged to disrupt the flow of information for nuclear operations, and more states are willing to use them in pursuit of their vision for the world. In the interest of global stability, U.S. NC3 systems must remain resilient, secure, and reliable in the face of these challenges.

1 This report builds on the foundation established by "Nuclear Command, Control, and Communications: U.S. Country Profile," a report written by Dr. Jeffrey Larsen for the Institute for Security and Technology (IST) in August 2019. The report can be found here: https://securityandtechnology.org/virtual-library/report/nuclear-command-control-and-communications-u-s-country-profile/.

NC3 Definition and Functions

NC3 is best understood as the people, equipment, and systems that allow the President to make nuclear decisions that are both informed and executable, no matter the circumstances. It exists primarily to provide survivable presidential authority over U.S. nuclear forces, regardless of network degradation. The U.S. Department of War (DoW) defines nuclear command and control (NC2), more broadly, as the "exercise of authority and direction by the President, as commander in chief through established command lines over nuclear weapon operations of military forces, as chief executive over all government activities that support those operations."[2] But authority and direction are only as effective as the systems that transmit them. The addition of communications to NC2—resulting in the abbreviation 'NC3'—reflects this operational reality, and the "facilities, equipment, communications, procedures, and personnel that enable presidential nuclear direction to be carried out."[3]

The Pentagon defines five critical functions of the NC3 ecosystem:[4]

1. **Situation monitoring:** the collection, maintenance, and assessment of information on friendly and adversary forces, emerging nuclear powers, and events of interest, based on sensor data, field commander assessments, classified intelligence, and open sources.
2. **Planning:** the development and modification of plans for the employment of nuclear weapons and other forces, enabling U.S. force survivability and capacity to respond quickly to any contingency.
3. **Decision-making:** the assessment, review, and consultation that occurs when the employment or movement of nuclear weapons is considered to execute orders.
4. **Force direction:** the implementation of policy regarding executing, terminating, and disabling nuclear weapons, assuring positive control and preventing unauthorized use.
5. **Force Management:** the assignment, training, deployment, and maintenance support of nuclear forces, maintaining a state of readiness to execute orders in any condition.

The five functions of NC3 listed above may look clean and straightforward, but in a crisis will blur together as leaders and operators fight the clock, reconcile conflicting inputs, and strive to avoid irreversible errors. NC3's core challenge is that the systems move information and authority via decades-old platforms and a complicated bureaucratic structure.

2 *Nuclear Matters Handbook* (Washington: Office of the Secretary of Defense, 2020), https://www.acq.osd.mil/ncbdp/nm/NMHB2020rev/index.html, Glossary.
3 *Nuclear Matters Handbook* (2020), Glossary
4 *Nuclear Matters Handbook* (2020), 14.

U.S. NC3 Historical Background

The first conception of nuclear "command and control" appeared in 1955, when the United States and Canada developed a Distant Early Warning Line (DEW) of fifty-seven radar stations around the Arctic Circle to detect Soviet bomber threats.[5] The project was completed in 1957, at which point the two countries established the North American Air Defense Command (NORAD) to provide early warning of an attack on North America. Around the same time, the Semi-Automatic Ground Environment (SAGE) provided some of the earliest communications between early warning systems and nuclear operators, connecting direction centers and combat centers controlling anti-aircraft missiles and fighter-interceptors through one of the first computer networks.[6]

By 1957, the Soviet Union developed the first ICBM, capable of hitting the continental United States in less than thirty minutes, which the DEW radars were not equipped to detect. The Air Force then developed the Ballistic Missile Early Warning System (BMEWS), which was completed in 1961.[7] The Air Force's launch of Defense Support Program (DSP) satellites in the 1970s marked NC3's entry into the space domain. Combined with the BMEWS radars, the DSP satellites created a comprehensive missile warning architecture. NC3 equipment and facilities last received a significant upgrade in the 1980s, when the Reagan administration became concerned about the flexibility and survivability of NC3 systems in the event of large-scale nuclear war. Upgrades included more mobile command posts, the deployment of GPS satellites, and bolstered protections against electromagnetic pulse (EMP) effects.[8]

As the American nuclear arsenal grew and different delivery systems began taking shape, the United States needed a more centralized form of communication connecting the President with the emerging elements of what would eventually become the nuclear triad. While the Defense Reorganization Act of 1958 rationalized the military command structure and strengthened civilian authority, the NC3 system continued to develop incrementally across separate programs and platforms. And for contingencies where leadership was unable to transmit nuclear operations orders, the Emergency Rocket Communications System (ERCS), developed in 1961, was an ICBM-launched device that would broadcast launch codes to the

5 Eric Schlosser, *Command and Control: Nuclear Weapons, the Damascus Accident, and the Illusion of Safety* (New York: Penguin Press, 2013), 151.

6 Schlosser, 151.

7 Deptula et. al., 14.

8 Schlosser, *Command and Control*, 442; "Effects of Electromagnetic Pulses on Communication Infrastructure: An IST Primer," *The Institute for Security and Technology,* January 16, 2024, https://securityandtechnology.org/virtual-library/primer/effects-of-electromagnetic-pulses-on-communication-infrastructure/.

operating centers.[9] The result is a system often described as a "patchwork" of systems, built up over decades rather than designed as a coherent structure.[10]

In the decades that followed, NC3 expanded through incremental, mission-driven additions, which were often developed and sustained within separate service and functional communities. As a result, integration frequently lagged behind operational demands. Late-Cold War concerns about survivability and continuity reinforced the need for redundancy and dispersed facilities to make a surprise attack harder, driving investments that improved resilience but also increased architectural complexity. After the Cold War, the change in national focus from nuclear war to counterterrorism, aging infrastructure, and uneven ownership across nuclear systems and operations together contributed to deferred modernization. By the 2010s, successive reviews including the 2010 Nuclear Posture Review helped re-center attention on NC3 oversight and modernization planning.

The Tatalina Air Force Station in Alaska, which was part of the Cold War-era Distant Early Warning (DEW) System.

SOURCE: UNITED STATES ARMY AIR FORCES VIA CHLOE, JOHN HALE, (1984), TOP COVER FOR AMERICA

9 Oliver Parken and Joseph Trevithick, "This ICBM-Launched Satellite Could Transmit Nuclear Codes When Nothing Else Was Left To," *TWZ*, August 29, 2023, https://www.twz.com/this-icbm-launched-satellite-could-transmit-nuclear-codes-when-nothing-else-was-left-to.

10 Kristin Goodwin, "Nuclear Command, Control, and Communication (NC3): Strengthening a Neglected, but Critical Component of the U.S. Deterrent," *Nuclear Notes* 3, no. 1, CSIS (August 2013), https://csis-website-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/130904_Weiner_NuclearNotes3-1_WEB.pdf.

NC3 Requirements

The Department of War sets forth strict requirements for U.S. NC3 systems, ensuring the network remains "assured, reliable, and resilient."[11] The system must provide support for the President, advisors, military officials, and U.S. allies in a degraded environment. This means it must withstand disruptive effects, including EMPs emitted from a nuclear detonation, counterspace attacks, cyber attacks, and AI-enabled deception.[12] This requirement is increasingly strained as the DoW upgrades NC3 communications to rely on internet-like networks and digital services that may or may not be battle-tested for all degraded environment use cases. However, survivability and cybersecurity continue to be a leading priority for U.S. Strategic Command (STRATCOM) as it acquires next-generation capabilities.[13] STRATCOM is the unified combatant command responsible for the nation's strategic deterrence mission and for providing the President and Secretary of Defense with strategic options in crisis and conflict. In the NC3 context, it is the central operational command working in conjunction with NORAD that conducts operations to deter strategic attack and, if directed, employs forces to protect the United States and its allies.

U.S. NC3 systems operate under a strict "always/never" requirement.[14] NC3 must always ensure that when the President orders a nuclear launch, the military operators are able to carry out this order in any conditions. At the same time, NC3 systems must never allow a nuclear weapon to be launched or detonated without Presidential authority or as a result of an accident. This is a difficult balance of two outcomes in opposition to each other, but it is an essential element in making U.S. nuclear deterrence credible.[15]

11 *Nuclear Matters Handbook* (2020), 18.

12 Peter Hayes, Binoy Kampmark, Philip Reiner, et al., "NC3 Systems and Strategic Stability: A Global Overview," *Institute for Security and Technology*, May 2019, https://securityandtechnology.org/wp-content/uploads/2024/10/nc3_synthesis_report_may_6_2019_IST.pdf.

13 Gen. Anthony Cotton, "Statement of General Anthony J. Cotton: Commander, United States Strategic Command," *House Armed Services Committee,* April 9, 2025, https://www.congress.gov/event/119th-congress/house-event/11811criterion,5.

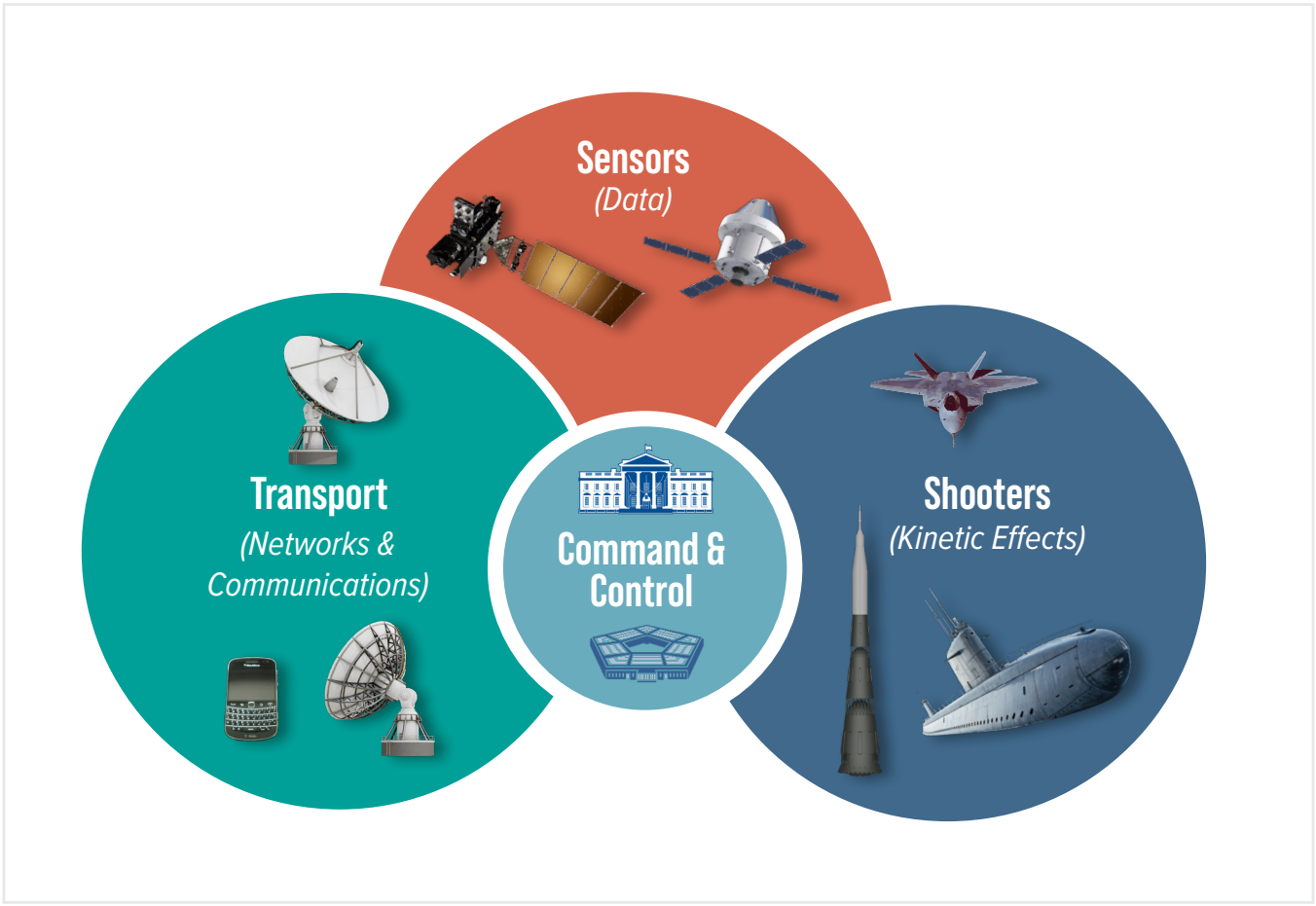
14 *Nuclear Matters Handbook* (2020), 89.

15 Lt Gen David A. Deptula et. al., "Modernizing US Nuclear Command, Control, and Communications," *Mitchell Institute for Aerospace Studies and the MITRE Corporation,* February 2019, 11, https://www.mitchellaerospacepower.org/modernizing-u-s-nuclear-command-control-and-communications/.

NC3 Architecture and Organization

The NC3 architecture is described as a "system of systems," consisting of four primary subsystems: early warning systems, facilities, communication links, and command posts, as illustrated in Figure 1. These subsystems encapsulate over 250 individual components, including early warning satellites, radars, and sensors; facilities to collect and interpret early warning information; fixed and mobile command posts; and a communications infrastructure including land lines, satellite links, radios, and receiving terminals in ground stations and aboard strike vehicles.[16]

Figure 1: Nuclear Command, Control, and Communications Architecture



SOURCE: DOD NUCLEAR MATTERS HANDBOOK 2020

16 Anya Fink, "Defense Primer: Nuclear Command, Control, and Communications (NC3)," *Congressional Research Service,* August 15, 2025, https://www.congress.gov/crs-product/IF11697; Jeffery Larsen, "Nuclear Command, Control, and Communications: US Country Profile," *Institute for Security and Technology,* August 22, 2019, 2, https://securityandtechnology.org/virtual-library/report/nuclear-command-control-and-communications-u-s-country-profile/

Command and Control

The Pentagon operates multiple fixed, ground-mobile, or air-based command posts to ensure uninterrupted communication between presidential authority and U.S. nuclear forces. The National Military Command Center (NMCC), located within the Pentagon, serves as the primary hub supporting the President, Secretary of War, and Chairman of the Joint Chiefs of Staff (CJCS) in continuous monitoring of nuclear forces.[17] The Global Operations Center (GOC), located at STRATCOM Headquarters in Omaha, Nebraska, supports the STRATCOM Commander to facilitate maximum visibility on global situations and provide Emergency Action Messages (EAM) to missile silos, bombers, and submarines.[18] DoW additionally operates multiple survivable command centers, including the E-4B National Airborne Operations Center (NAOC) with at least one of four planes always in the air at all times, and the E-6B Looking Glass Take Charge and Move Out (TACAMO)/Airborne Command Post, enabling the President to communicate with nuclear forces and operators to launch a nuclear strike.[19]

Sensors

The core of the missile defense system is the early warning system, a vast network of assets and capabilities responsible for detecting nuclear and conventional missile launches.[20] The network includes space- and ground-based sensors that identify projectile threats to the U.S. homeland and its allies, giving the air defenses the most time possible to react. These sensors operate across two key phases of a missile's flight path. In the boost phase, satellites detect a launch within minutes of liftoff. The Space-Based Infrared System (SBIRS) constellation consists of geosynchronous Earth orbit (GEO) satellites that detect infrared signals generated during the initial boost phase.[21] In the mid-course phase, ground-based early warning radars track the missile along its trajectory, reinforcing the space-based sensor data. These radars include the Solid State Phased Array Radar System (SSPARS), with sites in California, Alaska, Massachusetts, the United Kingdom, and Greenland; the PAVE Phased Array Warning System (PAVE PAWS); and one Sea-Based X-band radar (SBX-1).[22]

17 *Nuclear Matters Handbook* (2020), 15.
18 *Nuclear Matters Handbook* (2020), 15.
19 *Nuclear Matters Handbook* (2020), 15.
20 Alice Saltini et. al., "Nuclear Command, Control, & Communications: A Primer on Strategic Warning, Decision Support, and Adaptive Targeting Subsystems," *Institute for Security and Technology,* July 7, 2025, https://securityandtechnology.org/virtual-library/report/nuclear-command-control-and-communications-nc3-a-primer-on-strategic-warning-decision-support-and-adaptive-targeting-subsystems/.
21 Lt Gen David A. Deptula et. al., "Modernizing US Nuclear Command, Control, and Communications," 9.
22 Fink, "Defense Primer."

Transport

The backbone of these facilities, sensors, and nuclear forces is a highly survivable network of communications to ensure continuous connectivity with the President in a nuclear crisis. NC3's communication network uses land-based connections (secure phone lines and undersea cables), airborne command posts (E-4B and E-6B aircraft), and satellites (Advanced Extremely High Frequency (AEHF) satellite constellation) to both transmit and receive messages and data.[23] The network relies on both government and commercial infrastructure with varying degrees of sophistication. Some systems are simple phone lines, while others are highly classified communication methods. Some of these communication systems are designed to survive disruption post-nuclear use or kinetic attacks, but experts frequently question their actual survivability in a degraded environment.[24]

Shooters

The fourth subsystem consists of the U.S. nuclear triad itself, in which operators receive launch authorization through the chain of command from the President. The triad includes the Minuteman III ICBM forces, the Trident II SLBM forces from the Ohio-class submarines, as well as air-launched cruise missiles (ALCM) and B-61 gravity bombs from the B-52 Stratofortress, the B-2 Spirit stealth bomber, and soon the B-21 Raider aircraft. The NC3 system's imperative is to ensure the President is always connected to these platforms in all phases of a conflict to maintain a credible deterrent.

23 *Nuclear Matters Handbook* (2020), 16.

24 See James Action, "The Survivability of Nuclear Command-and-Control Capabilities," *Journal of Strategic Studies* 48, no. 2 (Dec. 2024): 407–64. https://www.tandfonline.com/doi/full/10.1080/01402390.2024.2435957; Adam Lowther, "The Big and Urgent Task of Revitalizing Nuclear Command, Control, and Communications," *War on the Rocks,* October 4, 2019, https://warontherocks.com/2019/10/the-big-and-urgent-task-of-revitalizing-nuclear-command-control-and-communications/.

NC3 Modernization

Much of the U.S. NC3 architecture is antiquated, raising questions about its reliability. All aspects of the U.S. nuclear force are undergoing a multi-decade modernization program to replace legacy systems and prepare the United States for 21st-century conflict. The modernization process has faced many funding challenges and setbacks in terms of the timeline to acquire next-generation systems. Despite these challenges, the Pentagon has moved forward with multiple initiatives to meet mission requirements. Below is a condensed list of NC3 modernization activities.

COMMAND AND CONTROL:

- **E-6B Mercury → E-130J Phoenix II aircraft**: The Navy is designing the E-130J "Phoenix II" to provide airborne nuclear command and control for submarine-launched weapons, which is expected to replace the E-6B Mercury fleet in the late 2020s.[25]

- **E-4B Nightwatch → E-4C SAOC aircraft:** The Air Force plans to replace the E-4B NAOC with the E-4C Survivable Airborne Operations Center (SAOC), which will be operational in the mid to late 2030s.[26]

- **Airborne Launch Control System (ALCS) → Airborne Launch Control System- Replacement (ALCS-R)**: The Air Force is replacing its ICBM launch capability aboard the E-6B Mercury with upgraded equipment, which will also be compatible with the Sentinel ICBM.[27]

SENSORS:

- **SBIRS → Next-Gen OPIR satellites:** The Space Force is developing four Next-Generation Overhead Persistent Infrared (Next-Gen OPIR) satellites to replace the six SBIRS satellites. Primary contractor Lockheed Martin pushed the first launch date to 2026.[28]

- **SBIRS → Next-Gen Polar satellites:** The Space Force is also launching two Next-Gen OPIR Polar satellites, designed by Northrop Grumman to watch the northern region, with a 2028 launch date.[29]

25 "E-130J Phoenix II," *Northrop Grumman,* https://www.northropgrumman.com/what-we-do/aircraft/e-130j-phoenix-ii.
26 Fink, "Defense Primer."
27 "Lockheed Martin Awarded $81 Million Contract to Modernize U.S. Air Force Airborne Launch Control System," *Lockheed Martin Newsroom,* January 31, 2018, https://news.lockheedmartin.com/2018-01-31-Lockheed-Martin-Awarded-81-Million-Contract-to-Modernize-U-S-Air-Force-Airborne-Launch-Control-System.
28 Theresa Hitchens, "First Next-Gen OPIR missile warning launch pushed to 2026," *Breaking Defense,* June 11, 2025, https://breakingdefense.com/2025/06/first-next-gen-opir-missile-warning-launch-pushed-to-2026/.
29 "Next Gen OPIR Polar (NGP)," *Northrop Grumman,* https://www.northropgrumman.com/what-we-do/space/spacecraft/next-gen-polar.

TRANSPORT:

» **AEHF → SATCOM (ESS) satellite system**: The Space Force is responsible for fielding the Evolved Strategic SATCOM (ESS) satellite system for improved communications linkage to replace AEHF.[30]

SHOOTERS:[31]

» **LAND-BASED:**

  » **Minuteman III ICBM → Sentinel ICBM:** The Air Force plans to begin replacing Minuteman III ICBMs with the SENTINEL ICBMs in 2029.[32]

» **SEA-BASED:**

  » **Ohio-class submarine → Columbia-class submarine**: The Navy is building twelve Columbia-class submarines to replace fourteen Ohio-class submarines by 2030.[33] In addition, the Navy is extending the life of the Trident II SLBM (also referred to as the D5) through 2040 via the D5 Life Extension Program.[34]

» **AIR-BASED:**

  » **B-2 Spirit → B21 Raider strategic bomber:** The Air Force is developing the B-21 Raider to replace the B-2 Spirit strategic bomber force by 2027.[35] The Air Force will also extend the life of the B-52 Stratofortress through 2050.[36]

  » **Air-Launched Cruise Missile (ALCM) → Long-Range Standoff weapon (LRSO):** The Air Force is designing a Long-Range Standoff (LRSO) cruise missile to replace the ALCM force by 2030.[37]

30 Fink, "Defense Primer."

31 "2022 Nuclear Posture Review," *U.S. Department of Defense,* October 27, 2022, https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.pdf, 21.

32 Anya Fink, "Defense Primer: LGM-35A Sentinel Intercontinental Ballistic Missile", *Congressional Research Service*, March 4, 2026, https://www.congress.gov/crs-product/IF11681.

33 O'Rourke, Ronald, "Navy Columbia (SSBN-826) Class Ballistic Missile Submarine Program: Background and Issues for Congress," *Congressional Research Service*, December 4, 2025, https://www.congress.gov/crs-product/R41129.

34 April Crew-Kelly, "Successful Trident II D5 Life Extension (D5LE) Launches Demonstrate Continued Readiness of Nation's Sea-Based Deterrent," *U.S. Navy Press Office*, September 23, 2025, https://www.navy.mil/Press-Office/News-Stories/display-news/Article/4312684/successful-trident-ii-d5-life-extension-d5le-launches-demonstrate-continued-rea/.

35 "DAF increases B-21 Raider production capacity to deliver combat capability faster," *U.S. Air Force,* February 23, 2026, https://www.af.mil/News/Article-Display/Article/4412198/daf-increases-b-21-raider-production-capacity-to-deliver-combat-capability-fast/.

36 "Boeing wins $2B award to modernize the B-52," *Boeing,* January 6, 2026, https://www.boeing.com/features/2026/1/boeing-wins--2b-award-to-modernize-the-b-52.

37 "Long Range Stand Off Weapon (LRSO): FY 2024 President's Budget," *Defense Acquistion Visibility Environment (DAVE), Department of Defense,* December 2022, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2022_SARS/LRSO_SAR_DEC_2022.pdf.

NC3 Norms and Guardrails

During the Cold War, nations developed a series of norms and rules for nuclear weapon usage, including the importance of guaranteeing the ability to retaliate even after sustaining a surprise attack. This premise is referred to as the "delicate balance of terror,"[38] and is in a continuous state of flux as global conditions change. Arms control treaties or Presidential Nuclear Initiatives lay the framework for a more stable global environment by attempting to limit the development and deployment of additional weapons. For example, the Intermediate Nuclear Forces treaty between the United States and the Soviet Union sought to avoid devastating Europe by limiting intermediate and shorter range ground-launched ballistic and cruise missiles.[39] The Treaty on the Non-Proliferation of Nuclear Weapons (more commonly known as the NPT),[40] established in 1970, is another example of an arms control treaty. The NPT manages which countries can legally possess nuclear weapons. Another example of an arms control treaty is the New Strategic Arms Reduction Treaty (New START), which limits the number of weapons to prevent nuclear proliferation.[41]

However, there has been a lack of norms and guardrails surrounding "autonomous" command and control, defined as a system that will execute operations without human input.[42] Only recently has the emergence of artificial intelligence and its application for NC3 systems prompted conversations about norms in this context. Some progress has been made at a bilateral level to preserve a specified degree of human authority over nuclear operations. The idea of having a "human-in-the-loop" has gained increasing popularity with the advent of autonomous weapon platforms. The premise of "human in the loop" is that humans are the authoritative and morally responsible decision-maker on the application of lethal force. In November 2024, U.S. President Joe Biden and Chinese President Xi Jinping agreed on the need to "maintain human control over the decision to use nuclear weapons."[43]

38 Albert Wohlstetter, "The Delicate Balance of Terror," *RAND*, 1958, https://www.rand.org/pubs/papers/P1472.html.

39 Daryl G. Kimball, "The Intermediate-Range Nuclear Forces Treaty at a Glance," *Arms Control Association*, August 2019, https://www.armscontrol.org/factsheets/intermediate-range-nuclear-forces-inf-treaty-glance.

40 "Treaty on the Non-Proliferation of Nuclear Weapons," *The United Nations Office for Disarmament Affairs*, https://disarmament.unoda.org/en/our-work/weapons-mass-destruction/nuclear-weapons/treaty-non-proliferation-nuclear-weapons.

41 "New START Treaty," *The United States Department of State, Bureau of Arms Control & Nonproliferation*, https://www.state.gov/new-start-treaty.

42 Michael Horowitz and Paul Scharre, "An Introduction to Autonomy in Weapon Systems," *Center for a New American Security*, February 13, 2015, https://www.cnas.org/publications/reports/an-introduction-to-autonomy-in-weapon-systems.

43 "Readout of President Joe Biden's Meeting with President Xi Jinping of the People's Republic of China," *U.S. Embassy in China,* November 17, 2024, https://china.usembassy-china.org.cn/readout-of-president-joe-bidens-meeting-with-president-xi-jinping-of-the-peoples-republic-of-china-3/.

At this time, there is no legal framework to bind nuclear-armed states to the premise of "human in the loop," but a promising starting point is the Franco-German 11 Principles on Lethal Autonomous Weapons Systems (LAWS), which has been a foundational document in exploring the topic.[44] In a United Nations report on Lethal Autonomous Weapons Systems in 2024, China's response states, "To safeguard the common values and interests of humanity, all countries have the responsibility and the security and development need to effectively manage the security, legal, ethical and humanitarian risks posed by artificial intelligence."[45] In the same report, the Russian Federation's response begins by providing a proposed definition for LAWS and legal limitations. The United States, meanwhile, focuses its response in the report on defining why "human in the loop" obscures the true meaning of autonomous platforms, as many platforms already in common use have minimal human interaction. While each nuclear-armed state takes its own stance, the similar concerns listed in their responses for the United Nations' report suggest promising common ground to start from, even in the midst of growing international unease and competition.

Challenges to U.S. NC3 systems

While the United States conducts a massive multi-decade effort to bring its nuclear arsenal into the 21st-century, its modernization must be adaptable to address the threats presented in the mid-2020s and beyond, rather than the threat assumptions that framed the early stages of the program when it launched more than a decade ago. The NC3 enterprise has slowly consolidated and streamlined its efforts to improve the modernization plan's efficiency and effectiveness. Still, future NC3 systems face at least two major challenges in the emerging security environment: governance oversight and modernization, as well as new and emerging disruptive threats.

Governance Oversight and Modernization

Continuous struggles to accelerate the NC3 modernization process have stemmed from unclear and divided responsibilities among the combatant commands and military branches. This issue has been partially alleviated by designating the STRATCOM Commander as responsible for the health and sustainment of the entire NC3 enterprise, a change that took effect in 2018.[46]

44 "11 Principles on Lethal Autonomous Weapons Systems (LAWS)," *The French Ministry for Europe and Foreign Affairs*, https://www.diplomatie.gouv.fr/en/french-foreign-policy/france-and-the-united-nations/multilateralism-a-principle-of-action-for-france/alliance-for-multilateralism/article/11-principles-on-lethal-autonomous-weapons-systems-laws.

45 "Lethal Autonomous Weapons Systems: Report of Secretary General," *United Nations General Assembly*, July 1, 2024, https://docs.un.org/en/A/79/88.

46 Sandra Erwin, "U.S. STRATCOM to take over responsibility for nuclear command, control and communications," *Space News,* July 23, 2018, https://spacenews.com/u-s-stratcom-to-take-over-responsibility-for-nuclear-command-control-and-communications/.

Still, each modernization component is in different stages of development and is experiencing cost and schedule overruns.[47] As the security environment continues to shift towards a more dangerous threat landscape, the mission objectives of NC3 systems will have to adapt to meet the challenge. As experts have pointed out, the United States' current modernization period is "necessary" but not sufficient to address tripolar strategic competition.[48]

New and Emerging Threats

According to the Pentagon's 2022 Nuclear Posture Review, there are a number of kinetic and electronic threats to the security and survivability of future NC3 systems. One of the modernization project's central aims is to employ numerous approaches to protect against these threats. Measures may include "enhanced protection from cyber, space-based, and electromagnetic pulse threats; enhanced integrated tactical warning and attack assessment; improved command post and communication links; advanced decision support technology; and integrated planning and operations."[49]

Adversarial interference using EDTs is one of the greatest existential threats to U.S. NC3. For example, artificial intelligence (AI) could compromise NC3 reliability by disrupting either orders or sensor data, causing confusion and slowing reaction times. AI-enabled cyberattacks could also harass subsystems in ways that could be interpreted as an attack on capabilities, potentially with false attribution.[50] In addition, new cyberattack capabilities jeopardize the survivability and security of NC3 systems. As the United States digitizes its communications infrastructure, the design elements must focus on security from the silicon up.[51]

Novel delivery systems, such as hypersonic cruise and hypersonic glide missiles, present new challenges to U.S. early warning sensors, confuse missile defense systems, and complicate force planning. Sophisticated and agile systems like the Russian Avangard hypersonic glide missile are designed specifically to defeat missile defenses and hit quickly enough that decision-making time will be greatly reduced. With reduced flight times and more difficult missile tracking, NC3 systems will be under more strain than ever.

47 Heather Williams, "Updating Nuclear Command, Control, and Communication," *Center for Strategic and International Studies,* December 10, 2024, https://www.csis.org/analysis/updating-nuclear-command-control-and-communication.

48 Creedon et. al. "America's Strategic Posture: The Final Report of the Congressional Commission on the Strategic Posture of the United States," *Institute for Defense Analyses*, https://www.ida.org/research-and-publications/publications/all/a/am/americas-strategic-posture.

49 "2022 Nuclear Posture Review," 22.

50 John Harvey, "U.S. Nuclear Command and Control for the 21st Century," *Institute for Security and Technology*, May 23, 2019, https://securityandtechnology.org/wp-content/uploads/2024/10/john_harvey_u.s._nuclear_command_and_control_for_the_21st_century_IST.pdf.

51 Ron Minnch, "Hardware that is Less Untrusted: Open Source Down to the Silicon," *Institute for Security and Technology,* June 9, 2020, https://securityandtechnology.org/virtual-library/report/hardware-that-is-less-trusted-open-source-down-to-the-silicon/.

Conclusion

The picture that emerges of the NC3 enterprise is one being modernized in pieces, while adversaries probe it as a comprehensive target set. The central challenge has shifted: it is no longer enough to solely replace aging platforms; instead, we must focus on whether governance and operational doctrine can withstand the speed and ambiguity of the third nuclear age. If the core institutional norms binding nuclear-armed states cannot keep up, then even the most successful technical modernizations will leave the United States with an NC3 system that is dangerously unpredictable under stress.

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