NUCLEAR COMMAND, CONTROL & COMMUNICATIONS

A PRIMER ON STRATEGIC WARNING, DECISION SUPPORT, AND ADAPTIVE TARGETING SUBSYSTEMS

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This primer provides a comprehensive overview of Nuclear Command, Control, and Communications (NC3) systems and subsystems, focusing specifically on Strategic Warning mechanisms, Decision Support frameworks, and Adaptive Targeting capabilities. This technical document serves as a foundation designed to inform the scenario-driven exercises on AI-NC3. As the scenario explores various contingencies and decision points, developing a comprehensive understanding of these subsystems is essential.

Background: Nuclear Command, Control, and Communications

Within the U.S. context, Nuclear Command, Control, and Communications (NC3) refers to the infrastructure, protocols, and systems that enable national leadership to maintain control over nuclear forces. This critical "system of systems" ensures the authorized use of nuclear weapons while preventing unauthorized or accidental launches. This architecture—composed of what some estimate to be more than 200 individual ground, space, and airborne systems spread across Air Force, Navy, Army, Combatant Commands, and U.S. Department of Defense (DOD) components—supports the President's exercise of nuclear employment authority.[1] Taken together, these interconnected nodes deliver situational awareness, early warning, authentication, and two-way secure communication that enable the President's exclusive authority to employ nuclear weapons. NC3 supplements the triad, composed of bombers, intercontinental ballistic missiles (ICBMs), and submarines, and is often referred to as the "fourth leg" of the nuclear enterprise. The current Commander of U.S. Strategic Command, General Anthony Cotton, stated it perhaps most clearly and succinctly: "it's pretty much that simple: know when to shoot, know that that order was authentic, and know when to stop. And that's what the NC3 does for us."[2]

Every nuclear weapons state's approach to NC3 varies dramatically in scale, complexity, doctrine, civil-military oversight, geography, and technological advancements. For example, the United States and Russia operate vast, decade-old systems linking hundreds of ground, space, and airborne nodes under a single decision-maker. These architectures were built during the Cold War to reflect the geopolitical environment of a bipolar world. Consequently, they no longer meet the requirements of today's environment marked by diverse threats and adversaries. These systems, therefore, require modernization to remove aging components

1 Anya Fink, "Defense Primer: Nuclear Command, Control, and Communications," Congressional Research Service, IF11697, February 21, 2025, https://www.congress.gov/crs-product/IF11697.

2 Kari Bingen and Anthony Cotton, "Modernizing the Whole Nuclear Enterprise - CSIS PONI fireside chat," speech, U.S. Strategic Command, November 19, 2024, https://www.stratcom.mil/Media/Speeches/Article/3975969/modernizing-the-whole-nuclear-enterprise-csis-poni-fireside-chat/.

while ensuring zero downtime, since failure at any point would jeopardize deterrence credibility. China, by contrast, fields a much simpler baseline NC3 free from the burden of retrofitting Cold War hardware, thus enabling the rapid deployment of contemporary technologies.[3] India and Pakistan employ more centralized, regionally-focused structures under collective oversight, with India's two-tier Nuclear Command Authority (Political Council chaired by the Prime Minister, supported by an Executive Council), and Pakistan's National Command Authority (also Prime Minister-led), with its Strategic Plans Division as the *de facto* and *de jure* authority on nuclear matters.[4] Moreover, India and Pakistan concentrate command hubs closer to political centers, meaning that there is more centralized control with reduced infrastructure–a configuration which raises concerns about single points of failure. These structural and technological differences across nuclear-armed states mean that each state faces unique modernization challenges and risk profiles.

The modernization, development, and maintenance of NC3 systems and their major components are vital to national security, helping to deter adversaries and manage escalation risks and crises. According to DOD, "U.S. NC3 is necessary to ensure the authorized employment and/or termination of nuclear weapons operations, to secure against accidental, inadvertent, or unauthorized access, and to prevent the loss of control, theft, or unauthorized use of U.S. nuclear weapons."[5]

Overall, the NC3 systems form an integral part of nuclear deterrence strategy to ensure nuclear weapons are operated safely and securely and only under authorized conditions. NC3 systems incorporate safeguards to detect and thwart any malicious attempts to use or tamper with nuclear weapons, and reinforces deterrence. "The current NC3 architecture consists of components that support day-to-day nuclear and conventional operations prior to a nuclear event as well as those that provide survivable, secure, and enduring communications through all threat environments. Though some NC3 systems are specific to the nuclear mission, most support both nuclear and conventional missions."[6]

The NC3 system is not solely a "nuclear" only system. The dual nature of NC3 systems—with both conventional and nuclear architectures—creates significant technical and operational challenges for integration into a unified NC3 system-of-systems when developed by separate organizations with different priorities.

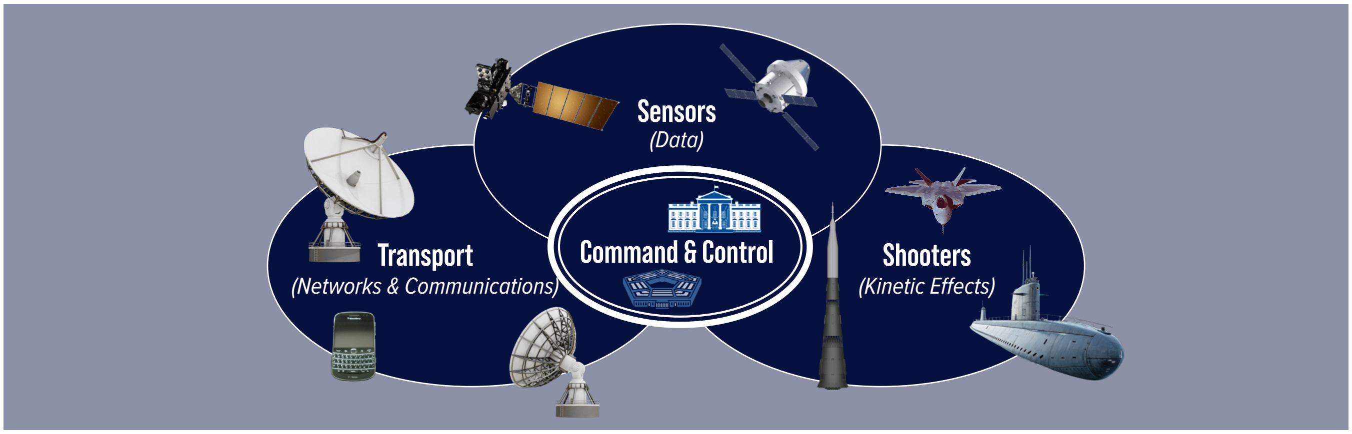
3 Peter Hayes, Binoy Kampmark, Philip Reiner, and Deborah Gordon, "Synthesis Report–NC3 Systems and Strategic Stability: A Global Overview," Institute for Security and Technology and Nautilus Institute, May 05, 2019, https://securityandtechnology.org/virtual-library/reports/nc3-systems-and-strategic-stability-a-global-overview/.

4 Hayes, Kampmark, Reiner, and Gordon, "Synthesis Report."

5 Fink, "Defense Primer: Nuclear Command, Control, and Communications."

6 "Nuclear Command, Control, and Communications: Update on DOD's Modernization," U.S. Government Accountability Office, June 15, 2015, https://apps.dtic.mil/sti/pdfs/ADA619949.pdf.

U.S. NC3 Architecture[7]



NC3 assures the integrity of transmitted information and must be survivable to reliably overcome the effects of a nuclear attack. NC3 performs five critical functions:

1. Situation monitoring;
2. Planning;
3. Decision-making;
4. Force direction; and
5. Force management.[8]

In the U.S. context, five elements–Personnel; Procedures and Processes; Facilities; Equipements; and Communications—-comprise the NC3 infrastructure that supports the President, through their military commanders, in exercising presidential authority over U.S. nuclear weapons operations, all of which need to function before and during a nuclear attack or nuclear war.[9]

Prospects for AI Integration

Given that NC3 is composed of an intricate network of interconnected systems and subsystems, rather than an assortment of isolated components, the integration of AI in NC3 is not as straightforward as one might think. On top of this, a lot of these systems support both nuclear and conventional missions, a phenomenon referred to as the "entanglement problem."

7 The Office of the Deputy Assistant Secretary of Defense for Nuclear Matters (ODASD (NM)), "Chapter 2: Nuclear Weapons Employment Policy, Planning And NC3," in *Nuclear Matters Handbook 2020* (ODASD(NM)), 2020), https://www.acq.osd.mil/ncbdp/nm/NMHB2020rev/chapters/chapter2.html.

8 "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.

9 The Office of the Deputy Assistant Secretary of Defense for Nuclear Matters (ODASD (NM)), "Chapter 2: Nuclear Weapons Employment Policy, Planning And NC3," in *Nuclear Matters Handbook 2020* (ODASD(NM)), 2020), https://www.acq.osd.mil/ncbdp/nm/NMHB2020rev/chapters/chapter2.html.

In other words, conventional and nuclear forces are "entangled" in the form of operational overlaps, such as through dual-capable platforms, shared command and control nodes, and integrated decision-support systems. This entanglement raises concerns over the likelihood of inadvertent escalation and misperception in crises. In other words, entangled forces blur the line between conventional and nuclear operations, making it hard for an adversary to distinguish whether an action is nuclear or conventional in nature.[10]

Moreover, the three specific dimensions examined and discussed during the workshop—strategic warning, decision support, and adaptive targeting—are deeply interrelated, forming a continuous cycle of data gathering, analysis, and action.

Because these systems are interdependent and tightly coupled, the potential role of AI is not limited to a single application; instead, it can simultaneously enhance multiple aspects of the NC3 architecture. For instance, predictive analytics powered by AI can simulate a range of threat scenarios. This capability not only improves early threat identification by strengthening strategic warning, but also supports decision-makers by providing real-time situational awareness, aiding and providing decision support, and facilitating adaptive targeting.

To understand how these systems are interrelated, consider the following, very simplified example:

Strategic warning is the first line of defense, responsible for the early detection of potential threats. This function relies on a network of sensors—such as satellites, radars, and other intelligence-gathering systems—to monitor the operational environment. For instance, early warning systems might detect a missile launch or unusual activity in an adversary's military posture.

Once a potential threat is identified through strategic warning, decision-support systems are tasked with synthesizing and analyzing the data collected from various sources to develop a coherent picture of the evolving situation. These systems integrate inputs from multiple sensors, intelligence reports, and real-time communications, enabling commanders to rapidly evaluate the risks and benefits of various courses of action.

Targeting uses outputs from both strategic warning and decision support to refine targeting databases. In this scenario, AI would enable further "adaptability" to this process by dynamically updating and prioritizing target information based on the latest intelligence, enabling a more responsive and flexible targeting strategy. For example, if the early warning system detects a new missile launch and decision support systems analyze the threat's

10 Don Snyder and Alexis Blanc, "Unraveling Entanglement: Policy Implications of Using Non-Dedicated Systems for Nuclear Command and Control," RAND, March 9, 2023, https://www.rand.org/pubs/research_reports/RRA976-3.html.

trajectory and potential impact, adaptive targeting functions can quickly re-prioritize targets, force management requirements, and other response options.

Just as importantly, in the context of NC3, particularly when it comes to the third "C," or nuclear communications, AI plays an important role in moving information through various pathways to ensure command information flows under duress in light of likely adversarial attempts to intervene and/or observe and even under attack–one that could become increasingly important going forward. Humans are incapable of undertaking these tasks at machine speeds, making existing systems ripe for cutting-edge AI enhancements.

Where, then, within the system of systems is AI most likely to be integrated out of necessity? All throughout the systems, such opportunities arise. As mentioned above, most of today's U.S. NC3 infrastructure remains largely a Cold War relic. As a result, the ongoing modernization effort presents a key opportunity to integrate AI throughout NC3, thereby improving resilience, streamlining operations, and enhancing strategic effectiveness.

STRATCOM's 2025 Posture Statement underscores this shift. For the first time, it dedicates a section to NC3 and AI (alongside cybersecurity). General Anthony J. Cotton identifies AI as "central" to the NC3 modernization process for data collection and processing, rapid information-sharing with allies, and enhanced decision support, while stressing that human judgement will remain the final authority in nuclear use decisions.[11] In other remarks, General Cotton also highlighted AI's ability to analyze vast Intelligence, Surveillance, and Reconnaissance (ISR) datastreams quickly, offering commanders a comprehensive and unified operational picture far faster than traditional methods and enabling allied contributions through shared datasets. STRATCOM, in this context, views AI as essential to strengthening deterrence, enabling tighter integration of nuclear and conventional capabilities, and preserving a strategic edge by ensuring quicker decisions.[12]

Based on current developments, it is reasonable to assume that this push is already underway. For example, OpenAI has partnered with the three US DOE national labs overseen by the National Nuclear Security Administration (NNSA)—Los Alamos, Lawrence Livermore, and Sandia National Laboratories—for researchers with security clearances to test its reasoning models on advanced research tasks, including nuclear scenarios.[13] Anthropic, too, launched in April 2024 a classified collaboration with NNSA and DOE to evaluate its Claude 3.7 Sonnet model's performance and risks in the nuclear domain. Though the specifics remain classified,

11 Gen. Anthony J. Cotton, "2025 USSTRATCOM Congressional Posture Statement," written testimony before the U.S. Senate Armed Services Committee on Strategic Forces, March 26, 2025, https://www.stratcom.mil/2025-Posture-Statement/.

12 Army Maj. Wes Shinego, "Stratcom Commander Discusses Nuclear System Modernization," DOD News, November 20, 2024, https://www.defense.gov/News/News-Stories/Article/Article/3973074/stratcom-commander-discusses-nuclear-system-modernization/.

13 OpenAI, "Strengthening America's AI leadership with the U.S. National Laboratories," press release, January 30, 2025, https://openai.com/index/strengthening-americas-ai-leadership-with-the-us-national-laboratories/.

OpenAI stated that this initiative will support the laboratories' work on "reducing the risk of nuclear war and securing nuclear materials and weapons worldwide," with "careful and selective review of use cases and consultations on AI safety from OpenAI researchers with security clearances."[14] Likewise, Anthropic has indicated that this collaboration will "determine how large language models may contribute to or help to address national security risks in the nuclear domain."[15]

All of these developments make it highly likely that integration of cutting-edge AI is already underway. But what are specific examples of where AI might be applied in NC3? Based on STRATCOM's priorities, hints in official documents such as the Nuclear Posture Review, and insights from leading research centers, it is clear that AI's primary roles will be in strategic warning and decision support, with adaptive targeting as a secondary—but still vital—application. For instance, based on these documents and indicators, we can assume that strategic-warning systems will harness AI-driven fusion to reduce false positives and accelerate threat confirmation. In particular, AI enables multisensor fusion by rapidly combining disparate inputs to distinguish real warheads from decoys, assess damage, and detect changes in adversary behavior. AI-enhanced decision-support systems will, in turn, synthesize that data to recommend courses of action and contingency plans within moments, while still reserving the final call for human commanders. Finally, the 2022 Nuclear Posture Review identifies "adaptive nuclear planning" as one of the five essential functions for NC3. This "adaptive" component underscores a departure from the traditional trajectory calculations and launch-planning algorithms, where fixed flight profiles and predetermined logistics chains underpinned strike options, towards a model in which AI tools can continuously generate, evaluate, and reprioritize alternative strike options in real time, adjusting both targeting and support plans as new intelligence and threats emerge.[16]

For the purposes of this workshop, we have categorized several subsystems and inferred the primary function they support. Given the nature and significant functions of NC3 systems for national security, significant portions of it remain classified, so the authors have tried to offer insights into these systems and connected the dots where AI has been integrated and potentially could be integrated. These insights are consolidated by accessing various open-source literature and white paper documents.

14 OpenAI, "Strengthening America's AI leadership."

15 Anthropic, "Anthropic partners with U.S. National Labs for first 1,000 Scientist AI Jam," announcement, February 20, 2025, https://www.anthropic.com/news/anthropic-partners-with-u-s-national-labs-for-first-1-000-scientist-ai-jam.

16 Jill Hruby and M. Nina Miller, "Assessing and Managing the Benefits and Risks of Artificial Intelligence in Nuclear-Weapon Systems," NTI, August 2021, https://media.nti.org/documents/NTI_Paper_AI_r4.pdf.

NC3 Systems and Subsystems

Strategic Warning

Within the context of NC3 systems, strategic warning systems are the nerve center for detecting any signs of a nuclear threat, built on a robust, multi-layered sensor network designed to provide early indication of potential nuclear aggression. Strategic warning refers to the process of detecting and assessing a potential nuclear attack, providing timely information to decision-makers, and facilitating safe and secure communications to enable effective response.[17]

Strategic warning relies on a network of sensors: ground based, space-based, and intelligence. These sensor networks form the base of the system. They consist of extensive arrays of sensors, including ground-based radar installations, space-based satellites, and airborne detectors. This networked approach ensures that data detected from one system is cross-referenced with other systems.[18]

Ground-based radars

Ground-based radars cover vast distances and are calibrated to detect the specific radar signatures of ballistic missiles. For example, the AN/TPY-2 missile defense radar, delivered in May 2025 and now outfitted with Gallium Nitride (GaN) arrays to extend range and increase sensitivity and surveillance capability, allow detecting, tracking, and classifying ballistic missiles and non-threats during multiple phases of flight, as well as support hypersonic defense missions.[19] These radars scan large volumes of airspace quickly and reliably in order to allow the precise tracking of fast-moving objects. The AN/TPY-2 missile defense radar operates in two modes—one to detect missiles as they rise and another to guide interceptors toward a descending warhead. Once a missile is detected, the system acquires and tracks it, using algorithms to distinguish the warhead from other objects.[20] Moreover, the radar "also features the latest CX6 high-performance computing software that offers more precise target discrimination and electronic attack protection."[21]

17 Congressional Budget Office, "Strategic Command, Control, and Communications: Alternative Approaches for Modernization," October 1981, p. 7, https://www.cbo.gov/sites/default/files/97th-congress-1981-1982/reports/doc31-entire_1.pdf.

18 Steve Lambakis, "Space Sensors and Missile Defense," National Institute for Public Policy, August 2023, p. vi, https://nipp.org/wp-content/uploads/2023/08/Space-Sensors-2023.pdf.

19 RTX, "RTX's Raytheon delivers 13th AN/TPY-2 radar for the U.S. Missile Defense Agency," Raytheon, press release, May 19, 2025, https://www.rtx.com/news/news-center/2025/05/19/rtxs-raytheon-delivers-13th-an-tpy-2-radar-for-the-u-s-missile-defense-agency.

20 RTX, "AN/TPY-2: Army Navy/Transportable Radar Surveillance: Countering the Growing Ballistic Missile Threat," Raytheon, last accessed June 2025, https://www.rtx.com/raytheon/what-we-do/strategic-missile-defense/antpy-2.

21 RTX, "RTX's Raytheon delivers 13th AN/TPY-2 radar."

Space-based satellites

Space-based satellites are equipped with high-resolution imagery and infrared sensors and aim to identify heat signatures that could indicate a rocket launch. For example, the Next-Generation Overhead Persistent Infrared (NG-OPIR) system is an advanced constellation that operates in highly elliptical orbits. These satellites are engineered to detect the heat from missile launches, providing persistent global surveillance and critical early-warning data across the northern hemisphere. NG-OPIR data is transmitted in near-real time to central command centers, where it provides input into the strategic warning function.[22]

Airborne detectors

Airborne detectors include aircraft equipped with specialized sensors that can complement data from ground and space, providing additional situational awareness. They provide flexible, mobile sensor platforms that can quickly cover wide areas and fill gaps in ground sensor coverage. For example, the E-3 Sentry AWACS (Airborne Warning and Control System) is equipped with rotating, phased-array radars, providing 360-degree coverage and detecting low-flying aircraft as well as missile launches during the boost, midcourse, and terminal phases.[23]

Data collection and signal processing

During data collection and signal processing, the vast streams of data from these ground, space, and airborne sensors are relayed to centralized command centers where specialized signal processing units work to identify patterns and anomalies. The system is calibrated to identify specific markers of missile launches, ballistic trajectories, or unusual movements that could signal an impending attack.[24] Today's state-of-the-art AI has the potential to apply time-series analysis and pattern recognition techniques to distinguish between normal activity and potential threats in a much quicker and higher efficient manner.[25]

Alert and escalation protocols

Once potential threats are identified, the system triggers an alert mechanism, called alert and escalation protocols. Initial alerts are automatically classified and escalated based on preset thresholds and decision protocols. Specifically, if the processed data exceeds predefined

22 Northrop Grumman, "Next Gen OPIR Polar (NGP): NGP is designed to keep pace as the threat evolves," last accessed June 2025, https://www.northropgrumman.com/space/next-gen-polar; Chairman of the Joint Chiefs of Staff, "Space Operations," Joint Publication 3.14, October 26, 2020, https://irp.fas.org/doddir/dod/jp3_14.pdf.

23 "E-3 Sentry: (AWACS)," U.S. Air Force, last updated September 2015, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104504/e-3-sentry-awacs/.

24 "Upgraded Early Warning Radars," United States Space Force, fact sheet, October 2020, https://www.spaceforce.mil/About-Us/Fact-Sheets/Fact-Sheet-Display/Article/2197738/upgraded-early-warning-radars/.

25 Zahra Zamanzadeh Darban, Geoffrey Webb, and Shirui Pan, "Deep Learning for Time Series Anomaly Detection: A Survey," arXiv, 2023, https://arxiv.org/html/2211.05244v3.

thresholds (for example, a significant thermal signature or a ballistic trajectory), the system automatically generates an alert.[26] However, in the U.S. context, it is important to note that an alert is triggered only when a potential threat is detected by at least two different and independent sensor systems. For example, a threat detected by a space-based sensor would then need to be cross verified with data from ground-based radars or airborne detectors. These alerts are then sent through secure channels to designated command centers, such as the National Military Command Center (NMCC). These command centers serve as centralized hubs where information from disparate sources is consolidated, allowing senior officials to review the data and cross-check the threat alert with additional sources (e.g., data from airborne detectors like the E-3 Sentry) before deciding on further action. The structure is designed for rapid escalation, ensuring that any credible threat is communicated quickly to the highest levels of command.[27]

Integration with command centers

Strategic warning systems are tightly integrated with command centers and the broader NC3 framework. The data they provide is continuously fed into the decision support systems, ensuring that both early warning and situational awareness are maintained in parallel. This integration facilitates a coordinated response that spans from early detection to decision-making.

Decision Support

Decision-support systems are meant to provide commanders with a real-time, comprehensive view of the strategic and operational landscape. They integrate sensors, communication networks, and command centers to help leaders quickly understand complex situations and make informed decisions. By gathering early warnings of threats, fusing data from multiple sources, and presenting actionable information, these systems ensure that orders can be delivered to forces under any conditions.

Many of the systems and subsystems that feed into decision support are currently undergoing modernization, opening up opportunities to integrate advanced AI into future systems to sustain legacy technologies.

26 U.S. Government Accountability Office, "Missile Warning Satellites: Comprehensive Cost and Schedule Information Would Enhance Congressional Oversight," GAO-21-105249, September 2021, https://www.gao.gov/assets/720/716708.pdf.

27 The Office of the Deputy Assistant Secretary of Defense for Nuclear Matters (ODASD (NM)), "Chapter 2: Nuclear Weapons Employment Policy, Planning And NC3," in *Nuclear Matters Handbook 2020* (ODASD(NM)), 2020), https://www.acq.osd.mil/ncbdp/nm/NMHB2020rev/chapters/chapter2.html.

Decision-support technologies incorporated into modern NC3 systems automate certain information processing functions without removing humans from decision-making authority. Specifically:

- Automated threat assessment algorithms in early warning systems like the U.S. Integrated Tactical Warning/Attack Assessment (ITW/AA) system that rapidly converges all raw feeds and analyzes sensor data to characterize potential threats.
- Automated nuclear force status reporting systems that continuously track readiness without manual polling.
- Decision-assistance software in command centers (like those at STRATCOM and NORAD) that rapidly present decision options and consequences to leadership under compressed timelines.[28]
- Pre-programmed emergency action message composition systems that can rapidly generate authenticated command signals once a human decision is made.

These systems do not make autonomous launch decisions, but rather process information, suggest options, and implement decisions at machine speeds once authorized by human command authorities. They are designed to address the fundamental tension in NC3 between having enough time for careful human deliberation versus the compressed decision windows created by modern missile flight times.[29]

Data acquisition and fusion

Multiple sensors and information sources—including satellite imagery, radar, signals intelligence, and open-source data—feed into centralized processing hubs where diverse data sets are consolidated, correlating detections from satellites with radar tracks to filter out false alarms and pinpoint real threats to give leaders a full picture of both the threat and capabilities.[30] AI offers the prospect of performing multi-sensor fusion to combine diverse datasets more quickly and efficiently.[31]

Data acquisition and fusion consists of a number of systems. They include, for example, the Modified Miniature Receive Terminal (MMRT), which ensures robust, anti-jam communications

28 Read more about Decision Assistance Software enabling Decision Support System: "Physical Security Enterprise and Analysis Group," Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, last accessed June 2025, https://www.acq.osd.mil/ncbdp/nm/pseag/Decision%20Support.html.

29 Bruce Blair, *Strategic Command and Control: Redefining the Nuclear Threat* (Brookings Institute: 1984); Paul Bracken, *The Second Nuclear Age: Strategy, Danger, and the New Power Politics* (St. Martin's Griffin: 2013).

30 Advisory Group for Aerospace Research & Development, "Multi-Sensor Multi-Target Data Fusion, Tracking and Identification Techniques for Guidance and Control Applications," eds. Dr. David Liang, Dr. Steve Butler, Dr. Carlos Garriga, Dr. Bruno Mazzetti, Mr. Thieny Uring, and Dr. Heinz Winter, NATO, October 1996, https://apps.dtic.mil/sti/citations/ADA319213.

31 Zhihui Kang, Yanjie Zhang, and Yuhong Du, "Application of multi-sensor information fusion technology in fault early warning of smart grid equipment," *Energy Informatics* 7, no. 23 (2024), https://energyinformatics.springeropen.com/articles/10.1186/s42162-024-00433-0.

in low-frequency bands, providing a secure command-and-control link even in contested environments. Its high data-rate capability allows critical messages to be reliably transmitted to strategic forces.[32]

Another example is the Network Tactical Common Data Link (NTCDL), a high-speed, high-capacity data link in development for the U.S. Navy fleet. This specific system represents an example where AI is likely to be integrated. This system is designed to share ISR information across multiple platforms in real time and exchange command and control information across separate networks. BAE Systems, the contractor that is developing this system, notes, "[o]ur system goes a step further by allowing data sharing, exchange, transfer, or distribution in real-time across military assets such as aircraft, ships, and unmanned vehicles. By bringing together a greater volume of data, our system allows operators to effectively communicate command and control protocols among forces to maintain an advantage."[33] Although BAE Systems does not explicitly mention AI, its technical specifications and operational requirements outlined in STRATCOM's 2025 Posture Statement, as well as other statements by General Cotton and hints within the 2022 Nuclear Posture Review, suggest that the next iteration of NTCDL will likely incorporate AI systems for multisensor fusion, advanced decision-support, and strengthened communication channels.

Processing and analysis

Once the raw data is collected, decision-support systems process and analyze this raw information to derive actionable insights. Processing involves high-speed computation and filtering. These models can generate situational forecasts, simulate potential conflict scenarios, and test various response options. For example, when early warning sensors report a missile launch, these systems immediately calculate trajectories, impact prediction, and time-to-target for each inbound weapon. Simultaneously, analytical tools cross-reference these tracks with intelligence databases to assess whether an alert is likely genuine or a false alarm.[34] Human analysts and commanders are in the loop to verify automated outputs, but given the short timelines of nuclear events, a lot of the number-crunching is handled by pre-configured decision-support software that can flag the most urgent information. Decision support tools typically incorporate contingency planning modules and interactive simulation tools that allow commanders to view "what-if" scenarios in real time.[35] Modernization efforts are exploring how

32 "Minimum Essential Emergency Communications Network (MEECN)," Federation of American Scientists, December 3, 1998, https://nuke.fas.org/guide/usa/c3i/meecn.htm.

33 BAE Systems, "Network Tactical Common Data Link," last accessed June 2025, https://www.baesystems.com/en/product/network-tactical-common-data-link.

34 Lisbeth Gronlund, David Wright, Stephen Young, "An Assessment of the Intercept Test Program of the Ground-Based Midcourse National Missile Defense System," working paper, Union of Concerned Scientists, November 30, 2001, https://www.ucs.org/sites/default/files/2019-09/ift7.pdf.

35 Steven C. Gordon, "Decision Support Tools for Warfighters," Air Force Agency for Modeling and Simulation, 2000, https://apps.dtic.mil/sti/tr/pdf/ADA461228.pdf.

AI can assist in this stage, from algorithms that better discriminate real warheads from decoys to decision aids that can suggest courses of action under various scenarios.

Visualization and user interfaces

The results of data fusion and analysis are presented in national command centers or in the airborne command posts via advanced visualization platforms. These interfaces consolidate multiple streams of information for decision-makers and their staff to monitor at a glance. These include interactive maps, real-time dashboards, and multi-dimensional displays that integrate geographical, temporal, and threat-level information.[36]

Communication and coordination

These systems are integrated with secure communication networks that connect field units, intelligence centers, and command posts. They circulate decisions and critical data across the entire network of nuclear forces, connecting the National Command Authority (e.g. the President and Secretary of Defense) with deployed assets like missile silos, strategic bombers, and ballistic missile submarines. This layer uses multiple transmission methods to ensure that even if parts of the infrastructure are destroyed or impaired, the message still gets through.[37]

One example is the network for reaching submarines at sea. Submerged SSBNs (nuclear ballistic missile submarines) are normally difficult to contact because water impedes most radio waves. The Fixed Submarine Broadcast System (FSBS)—a set of powerful very-low-frequency transmitters at about 10 fixed sites worldwide—continuously broadcast one-way messages to the SSBNs. These signals can penetrate seawater to a certain depth, allowing SSBNs hiding beneath the ocean surface to receive messages without surfacing.[38]

Airborne communication assets complement fixed transmitters. One such example is the TACAMO (“Take Charge And Move Out”) strategic communication mission, which involves Navy E-6B Mercury aircraft that serve as flying communication hubs for NC3. In a scenario where ground communication centers are knocked out (for instance, if an adversary were to strike NC3 sites on land), the aircraft would act as relay stations. An E-6B in the air can receive

36 Hans-Joachim Kolb, “Approaches to the Evaluation of Intelligence: Massive Military Data Fusion and Visualisation: Users Talk with Developers,” (paper presented at RTO Information Systems Technology Panel (IST) Workshop held at the Norwegian Defence Logistics and Management College, Halden, Norway on 10-13 September 2002), MP-105, April 2004, https://apps.dtic.mil/sti/citations/ADA428034.

37 “DoD Command, Control, and Communications (C3) Modernization Strategy,” U.S. Department of Defense, September 2020, https://dodcio.defense.gov/Portals/0/Documents/DoD-C3-Strategy.pdf.

38 “Long Wave Secures $84 Million Navy Contract for Very Low Frequency (VLF) and Low Frequency (LF) Antenna Program Support,” press release, Long Wave, September 18, 2023, https://www.longwaveinc.com/long-wave-secures-84-million-navy-contract-for-very-low-frequency-vlf-and-low-frequency-lf-antenna-program-support/.

orders from the National Command Authority and then rebroadcast those orders to forces that are out of direct contact.[39]

Adaptive Targeting

Adaptive targeting refers to the dynamic updating and reprioritization of targets as new intelligence becomes available or as battlefield conditions change. Modern NC3 systems emphasize flexibility; the 2022 Nuclear Posture Review even identifies "adaptive nuclear planning" as one of the five essential functions of NC3. This "adaptive" component allows commanders to swiftly adjust targets as emergencies unfold. AI can significantly enhance this function by providing real-time data processing and advanced pattern recognition that automatically analyzes vast intelligence feeds, detects emerging threats and anomalies, and generates predictive models to update target priority lists. At their core, these AI-enhanced systems have the potential to continuously fuse sensor inputs, assess threat levels, and offer targeting recommendations. We see this already happening in combat environments in Ukraine and Israel today.[40]

Geospatial and intelligence databases

These systems rely on detailed geospatial databases that catalog potential targets along with associated intelligence. Geospatial intelligence such as satellite imagery pinpoints the precise locations of known fixed targets. Meanwhile, a wide array of ISR assets search for emerging or moving targets. Data from reconnaissance assets—such as satellites, unmanned aerial vehicles (UAVs), and on-the-ground sensors—is continuously merged with historical records to build and maintain an up-to-date target inventory.[41] For example, the Navy's Undersea Constellation concept envisions a network of undersea sensors, unmanned undersea vehicles (UUVs), and communication nodes linking underwater forces. This would provide continuous underwater surveillance and connectivity, expanding reconnaissance coverage in the undersea domain.[42] In principle, such data can be used to identify a high-value target and allow for an adaptive tasking or retasking of submarines. Taken together, all of these ISR

39 "Northrop Grumman to Deliver US Navy's E-130J Nuclear Command, Control and Communications Aircraft," Northrop Grumman, December 18, 2024, https://news.northropgrumman.com/news/releases/northrop-grumman-to-deliver-us-navys-e-130j-nuclear-command-control-and-communications-aircraft.

40 Jill Hruby and M. Nina Miller, "Assessing and Managing the Benefits and Risks of Artificial Intelligence in Nuclear-Weapon Systems," NTI, August 2021, https://media.nti.org/documents/NTI_Paper_AI_r4.pdf.

41 "Geospatial Intelligence (GEOINT) Basic Doctrine," National System for Geospatial Intelligence, April 2018, https://irp.fas.org/agency/nga/doctrine-2018.pdf ; "GEOINT Artificial Intelligence," National Geospatial-Intelligence Agency, last accessed June 2025, https://www.nga.mil/news/GEOINT_Artificial_Intelligence_.html; "Fusion-Based Target Recognition Systems," fact sheet, Air Force Research Laboratory, 2023, https://afresearchlab.com/wp-content/uploads/2023/02/AFRL_FBTRS_FS_0223.pdf.

42 "Submarine Forces release Commander's Intent 3.0," press release, Commander, Submarine Forces Public Affairs, September 25, 2020, https://www.sublant.usff.navy.mil/Press-Room/News-Stories/Article/2361234/submarine-forces-release-commanders-intent-30/.

inputs can, in principle, feed into the consolidated target database, allowing for the most up-to-date intelligence picture possible.

Dynamic analysis

At the heart of adaptive targeting is a dynamic analysis engine that reviews incoming data to determine shifts in the strategic landscape. AI can help in precisely providing this adaptive component in a quicker and more efficient way, such as by ingesting updated intelligence and recommending which targets should take priority for engagement given the current circumstances and the commander's objectives. This dynamic analysis aims to rank targets based on threat level, strategic importance, and current positioning, allowing for the rapid recalibration of target lists as new intelligence arrives. In practice, this could mean weighing options such as a new target against other pending targets or reassigning delivery platforms.[43]

Dissemination via NC3 networks

Once the targeted decision is made by human commanders, it has to be disseminated to strategic forces. Modern platforms and command centers use high-speed tactical data links and integrated networks to handle this flow of information. For instance, the Consolidated Afloat Network and Enterprise System (CANES), which is the unified IT platform aboard ships and submarines, ties together all of the ship's or sub's communications, sensors, and combat systems. If a submarine or destroyer receives updated targeting data via satellite or radio (for example, through a secure satellite link or the aforementioned NTCDL network), CANES can route that data to the relevant onboard systems. This integration means a vessel at sea can ingest updated intelligence and be ready to act on it without delay, meaning that it does not have to manually transfer data between communication systems. Thus, the network can handle it in one secure environment, reducing latency and potential human error.[44]

Real-time data integration

As changes are detected—whether due to troop movements, infrastructure alterations, or emerging threats—the system automatically adjusts the target priority list.

Operator oversight and override

Commanders interact with adaptive targeting systems through secure interfaces that display both the target lists and the underlying data supporting each prioritization. Although we

43 Mitchell S. McCallister, "The Maritime Dynamic Targeting Gap – An Analysis of Current Joint Targeting Processes in the Maritime Domain," Naval War College, May 4, 2012, https://apps.dtic.mil/sti/tr/pdf/ADA564036.pdf; Jill Hruby and M. Nina Miller, "Assessing and Managing the Benefits and Risks of Artificial Intelligence in Nuclear-Weapon Systems," NTI, August 2021, https://media.nti.org/documents/NTI_Paper_AI_r4.pdf.

44 David C. Knobel, "Consolidated Afloat Network and Enterprise Services (CANES): A Cost Effective System Enhancing Power Projection at Sea," United States Marine Corps Command and Staff College, April 2016, https://apps.dtic.mil/sti/trecms/pdf/AD1176176.pdf.

can expect AI to play a role for recommending changes and even preparing technical firing solutions, experienced commanders and targeting officers are in charge of reviewing and approving those changes before execution. Operator interaction with the system is designed to provide verification of the system's outputs and recommendations, hence allowing for manual verification and ensuring that human judgment can override or adjust automated recommendations if necessary. This supports rigorous cross-checking and validation of targets before any further action is taken.[45]

Feedback loops and data reassessment

Once a targeting decision is made, feedback loops can be established to monitor the effects of the decision. To that end, AI offers the potential to more accurately and more quickly assess changes on the ground, feeding back into the adaptive process so that targeting information remains as accurate as possible. This continuous reassessment helps maintain a dynamic balance. For example, assessment mode can be used to gauge the results and update plans again, including post-strike assessment and broader situational updates. Multiple sources contribute to this feedback, with surveillance satellites and reconnaissance aircraft capturing imagery of strike results, and with ground or other technical sensors detecting signatures of a successful detonation at the target. All this information is fed back into the targeting engine and reviewed by intelligence analysts.[46]

45 Jill Hruby and M. Nina Miller, "Assessing and Managing the Benefits and Risks of Artificial Intelligence in Nuclear-Weapon Systems," NTI, August 2021, https://media.nti.org/documents/NTI_Paper_AI_r4.pdf.

46 Kateryna Bondar, "Ukraine's Future Vision and Current Capabilities for Waging AI-Enabled Autonomous Warfare," CSIS, March 6, 2025, p. 22, https://www.csis.org/analysis/ukraines-future-vision-and-current-capabilities-waging-ai-enabled-autonomous-warfare.

Key NC3 Terms and Definitions

Positive Control: Measures ensuring nuclear weapons can be launched when authorized by legitimate authority.

Negative Control: Safeguards preventing unauthorized or accidental nuclear weapons use.[47]

	NEGATIVE CONTROLS	POSITIVE CONTROLS
Procedural Controls	» Delayed retaliation posture » No first use or launch on warning » Two-person rule » Restricted access to launch codes » Separation of warhead components » Separation of warheads & vehicles » Other	» Airborne alert status » Launch on Warning (LOW) posture » Strip alert for strategic bombers » Pre-delegation of launch authority » Final assembly of warhead » Mating warhead with delivery vehicle » Other
Technical Controls	» One-point safety warhead design » Mechanical/electrical locks » Fail safe weapon designs » Electrical exclusion regions » Weak-link designs » Environmental sensing devices » Other	» Fully automated launch system » Frequency diversity » Hardened communication systems » Sea-based delivery vehicles » Mobile command systems/posts » Jam/interference resistance » Other

False Positives: Erroneous indications of an attack when none exists, potentially triggering an unnecessary nuclear response.

False Negatives: Failure to detect an actual attack, undermining deterrence and defense capabilities.

Always-Never Dilemma: The paradoxical requirement that nuclear weapons must always work when authorized but never work when unauthorized.

47 Jerome Conley, "Nuclear Command and Control in the Twenty-first Century: Trends, Disparities, and the Impact on Stability," in *Debating 21st Century Nuclear Issues*, eds. Owen Price and Patricia Mackby, CSIS, 2007.

Dual Phenomenology: The principle requiring at least two different types of sensors or detection methods to confirm a nuclear attack before responding (e.g., satellite detection plus radar confirmation).

National Command Authority (NCA): The legal authority (typically the president/head of state and designated successors) who can authorize nuclear weapons use.

Continuity of Government (COG): Plans and procedures to maintain governmental functions during and after a nuclear attack.

Devolution: The transfer of authority to pre-designated successors if primary leadership is incapacitated.

Permissive Action Links (PALs): Electronic locks requiring specific codes to arm nuclear weapons.

Emergency Action Messages (EAMs): Encrypted communications conveying nuclear launch orders.

Launch on Warning (LOW): Policy allowing nuclear retaliation based on warning systems before enemy weapons detonate.

Fail-Deadly Systems: Unlike conventional military systems designed to fail safe, some NC3 components are designed to interpret communication loss as evidence of attack and may trigger automated responses.

Two-Person Rule: The requirement that two separate individuals must agree and take concurrent action to authorize nuclear weapons use, not typically required for conventional weapons.

Nuclear Triad: The deliberate redundancy across three delivery platforms (land-based ICBMs, submarine-launched missiles, and strategic bombers) specifically to ensure second-strike capability.

Nuclear Force Postures: Specialized alert levels and readiness conditions (like DEFCON in the U.S.) focused on nuclear forces.

Authentication Systems: Extraordinarily rigorous verification procedures exclusively for nuclear command authority that exceed those used for conventional military operations.

Survivable Command Posts: Hardened, mobile, or airborne command centers specifically designed to function during and after a nuclear attack (e.g., E-6B Mercury "Doomsday Plane").

Assured Destruction: The concept that a nuclear force must survive a first strike with enough capability to inflict unacceptable damage on an attacker.

Minimum Credible Deterrence: The strategic posture of maintaining only enough nuclear weapons to ensure deterrence through assured retaliation.

EMP Hardening: Extreme electromagnetic pulse protection measures beyond what's typically needed for conventional military systems.

Additional details on the U.S. NC3 Enterprise can be accessed in Dr. Jeffrey Larsen's paper on Nuclear Command, Control, and Communications: U.S. Country Profile[48] and in Dr. John Harvey's paper on U.S. Nuclear Command and Control for the 21st Century.[49]

48 Jeffrey Larsen, "Nuclear Command, Control, and Communications: US Country Profile," Technology for Global Security, August 22, 2019, https://securityandtechnology.org/wp-content/uploads/2020/07/us_nc3_larsen_IST_report.pdf.

49 John Harvey, "U.S. Nuclear Command and Control for the 21st Century," Technology for Global Security, May 23, 2019, https://securityandtechnology.org/wp-content/uploads/2020/07/john_harvey_u.s._nuclear_command_and_control_for_the_21st_century_IST.pdf.

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