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High altitude ElectroMagnetic Pulse (HEMP): Background leading to the signing of the Executive Order by the President of the United States United States in 2019, and future outlook

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NIDSコメンタリー
No. 101, December 24, 2019

What is HEMP?

High altitude electromagnetic pulse (HEMP), also known as nuclear electromagnetic pulse (nuclear EMP), which causes high altitude nuclear explosions at a height of about 40km to 400km from the ground, has long been a point of contention in security. Even today, there are arguments for and against the evaluation of its threat. Previous research conducted in the United States is a famous example of the worst hypothesis, which posits that a HEMP attack would cause irreversible destruction to the electric grid and communications network across the whole of the United States, resulting in an extended lack of power supply from several months to even several years. This would bring about hunger, diseases, and social chaos, which would in turn lead to a loss of population of between 67% to 90% in a year (*The main figure used as the basis for this calculation was the population of the United States in 1880, which was about 50 million people. This was prior to the invention of the first power network, when society had been supported by horse carriages and coal-fired thermal power). [1] However, instead of a HEMP attack, which even countries that possess the nuclear attack capability were uncertain about with regard to its effectiveness to begin with, a direct nuclear attack on densely populated areas and key military bases of the enemy country would be far more reliable as a nuclear threat. Moreover, due to the uncertainty of hypothetical damage, there were also firmly-rooted criticisms on the excessively high cost of enhancing HEMP resistance (EMP hardening) across all manners of social infrastructure, making it not worth its while to do so.[2] With regard to the source region EMP that occurs several kilometers around the center of a nuclear blast, there have been reports about communications disruption and breakdowns in observation equipment even in atmospheric nuclear tests conducted in the past.[3] Furthermore, although the occurrence mechanism and characteristics are different, EMP can also be a natural phenomenon, such as the geomagnetic disturbances (GMD) that accompany solar flares. A well-known example would be the Carrington Event of 1859, in which a large-scale coronal mass ejection (CME) caused damage to telegraph communication systems in North America and Europe.[4] For this reason, the main contentions surrounding the HEMP threat are high power comprising of the three phases of early-time EMP (EI) that occurs when the abovementioned high altitude nuclear explosion causes a Compton effect, intermediate-time pulse (E2), and late-time pulse (E3 or Magnetohydrodynamic EMP (MHDEMP)), as well as the wide-area impact that arises when that strikes electronic equipment that is connected to power transmission lines.[5] The field intensity that HEMP has on the earth's surface and its geographical distribution is another important point to take note of. Under the United States Military (MIL) Standard, the field intensity of HEMP on the earth's surface is 50kv/m. However, this has mainly been studied from the perspective of the possibility that its scope of impact and field intensity may be stronger or weaker, depending on

factors such as the height of burst (*Diffraction in the ionosphere and other elements that have a secondary impact on the field intensity of the earth's surface have been pointed out in previous research).[6]

Historical background of the United States and Soviet Union surrounding HEMP research

At the beginning of the Cold War period, HEMP that had been proven through atmospheric nuclear tests became a subject for investigative research, with a number of high altitude nuclear tests conducted by the United States and Soviet Union from the 1950s to early 1960s, based on various height of burst and nuclear yields. According to publicly disclosed information, the United States conducted a total of nine high altitude nuclear tests at sea, at altitudes of more than 40km, while the former Soviet Union conducted about six tests on land. However, in view of the nuclear non-proliferation and strong criticism from the international community over radioactive fallout, after the Partial Test Ban Treaty (PTBT) entered into force in 1963, both countries had no choice but to make the shift to EMP-related research under restricted conditions, such as underground nuclear tests and theoretical research.[7]

In this process, strangely enough, both the United States and Soviet Union separately confirmed that HEMP has a physical impact over a wide area on land, based on high altitude nuclear tests carried out in 1962, when the PTBT was about to come into effect. These were the Starfish Prime Nuclear Test (United States, skies above Johnston Island in the Pacific), and Nuclear Test No. 184 (former Soviet Union, Kapustin Yar or Novaya Zemlya missile testing range. However, the name and conditions of the test are not consistent among various materials[8]). In the case of the United States, the power outage that occurred on the Hawaiian Islands, 1,400km away from the site of the explosion, immediately after the high altitude nuclear test, was a well-known incident. However, such damages were minor and restoration work was carried out swiftly. After that, the power outage incident in Hawaii was verified from a professional perspective by researchers from Sandia National Laboratories in the United States, and it was concluded that the cause of the power outage could be attributed to the HEMP effect.[9] However, at the time, there were no signs that HEMP was captured as a major security threat, and it was not possible to say, based on the power outage in Hawaii, that it had any significant impact on the nuclear strategy of the United States or the protection of its citizens.

Thereafter, in the United States, the EMP resistance of various equipment and military infrastructure, such as aircraft, naval vessels, and missiles, was measured by simulating the HEMP effect. The testing ranges used for these tests (a famous one is Atlas-I in Albuquerque, New Mexico[10]) were in operation throughout the Cold War period.[11] In addition, HEMP measures were advanced mainly in the military sector, such as the formulation of the aforementioned MIL Standard, which set out EMP measures in the field of communications. On the other hand, there were also criticisms about the slow progress in the advancement of HEMP measures for social infrastructure such as power and communication networks.[12] Depending on one's viewpoint, this suggests that it is possible that the HEMP threat had not been perceived as a major security threat in the United States until recent years.

On the other hand, at the European Electromagnetics Symposium (EUROEM) held in France in 1994, Major-General V.M. Loborev of the All-Russian Scientific Research Institute for Technical Physics, under the Ministry of Defense of the Russian Federation, presented a report on the details of physical damage caused by HEMP over several hundreds of kilometers on land, in nuclear test No. 184 conducted by the former Soviet Union (for example, a fire occurred at a power plant nearby, underground power cables melted with the heat while the insulation devices of overland power cables were also burnt, and spark gap devices for long-distance telephones broke down). This report drew much attention from the West as information that conveys the realities of HEMP threat.[13] Previous research based on publicly

disclosed information, too, showed indications of attempts at conducting comparative tests on the impact of HEMP, by matching the explosion altitude (40-50km, 150km, around 300km) and nuclear yields (from extremely small-scale to around 300kt) of the former Soviet Union's high altitude nuclear test.[14] It is worthy of special mention that in the case of the former Soviet Union, in addition to the fact that these tests were mainly conducted on land, of the comparative tests held multiple times, wide-spread damage was reported only once, on the aforementioned occasion. Another related point that cannot be overlooked is that there is testimony surrounding the development of nuclear weapons by the former Soviet Union, which appears to have specialized in the military aspects of HEMP. This testimony is the remarks made by Vladimir Lukin, former chair of the Russian assembly's (Duma's) Foreign Affairs Committee, who had also previously served as Ambassador of the Russian Federation in the United States, to U.S. congressmen on the occasion of the meeting between members of the U.S. congress and members of Russia's Duma in Vienna, Austria, on April 30, 1999, to discuss peaceful solutions to the Kosovo conflict. In his remarks, Lukin spoke about the existence of Super EMP Weapons of the former Soviet Union that could demonstrate field intensity of 200kv/m on the earth's surface.[15] While there is no way of verifying the truth of his statement, at the very least, it points to the possibility that the former Soviet Union had held a stronger military interest than the United States in the effects of HEMP. Additionally, it should be noted that from the Cold War period till today, there have been no confirmed cases of high altitude nuclear tests being conducted by nuclear-weapon states or de-facto nuclear-weapon states other than the United States and Soviet Union (Russia). Of the five nuclear-weapon states (United States, Russia, United Kingdom, France, and China), in recent years, while the United Kingdom has published results of reviews on HEMP threat based on information provided by the United States,[16] in reality, the United States and the Soviet Union (Russia) are the only two countries that have had the opportunity to validate the effects of HEMP.

Evaluation of HEMP threat—Initiatives by the United States

With regard to the HEMP measures put in place by the former Soviet Union and Russia, many aspects remain unclear. Nevertheless, the United States, which has in contrast made progress in information disclosure, it is clear that the issue of HEMP threat has been taken up frequently and been reviewed by the relevant government agencies and other institutes. An example of documents related to military infrastructure that have been disclosed would be the Engineering Design Guidelines[17] for enhancing the EMP resistance of naval equipment in the United States, compiled by EMA in 1981 and submitted to the Naval Surface Weapon Center. Additionally, in 1990, a guidance on HEMP protection was prepared as a MIL Standard for a ground command, control, communications, computers, and intelligence (C4I) facility responsible for executing urgent and important missions.[18] On the other hand, in the aspect of social infrastructure, the Nuclear Regulatory Commission (NRC) of the United States had already, in 1983, compiled the results of a study on the operation of safety systems in nuclear power plants even after the occurrence of an EMP incident. When it conducted a review of the abovementioned research results in 2014, 30 years after the study, it reached a similar conclusion once again, which was published.[19]

However, to reiterate, the U.S. government and experts remain split over the evaluation of the threat of HEMP even today. It could be said that the greatest point of contention lies in the question of how to come to grips with the difference between social infrastructure of the "vacuum tube era" 60 years ago, when the high altitude nuclear tests were conducted, and the key social infrastructure of the IoT era such as power, communications, water supply and sewage, and

transportation—many of which are supported by Supervisory Control and Data Acquisition (SCADA) systems that are vulnerable to EMP.[20] Amidst this situation, the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack (hereinafter, "EMP Commission"), established pursuant to title XIV of the Floyd D. Spence National Defense Authorization Act for FY 2001, addressed the issue of HEMP threat directly. The EMP Commission continued to sound the alarm on the threat of HEMP attacks, and based on the knowledge of its influential members with technical backgrounds, drew attention from within and outside the United States by disseminating information that raised questions on the identification of social infrastructure with vulnerabilities as well as the approach to countermeasures. Furthermore, in relation to the activities by the EMP Commission, chair of the EMP Commission and former acting administrator of NASA, William Graham, staff of the EMP Commission, Peter Vincent Pry and others, with the involvement of parties such as the former Speaker of the U.S. House of Representatives, Newt Gingrich, and former head of the Central Intelligence Agency (CIA), James Woolsey, appealed frequently for the need for HEMP measures through various media. On two occasions in 2004 and 2008 respectively, reports by the EMP Commission were submitted to the congress.[21] In November 2011, approval to establish The Task Force on National and Homeland Security as an advisory committee to the U.S. congress was signed, and review commenced on the EMP threat to the United States as a man-made and natural phenomenon, as well as the response to this threat. However, as the Department of Defense and the Department of Homeland Security did not apply for a budget for the EMP Commission, its operation was concluded at the end of September 2017.[22] On the other hand, the Task Force on National and Homeland Security did not receive funds from the congress but operated solely through donations, and continued to review the HEMP threat under the leadership of former members of the EMP Commission.[23]

Signing of the Executive Order on Coordinating National Resilience to Electromagnetic Pulses

After that, with growing calls of concern about HEMP threat by the EMP Commission and others, the Department of Energy launched a review on the strategy for strengthening EMP resilience, in coordination with the power industry. In 2017, the Electromagnetic Pulse Resilience Action Plan was drawn up and published.[24] Against this background, the tides changed significantly for the evaluation of HEMP threat in the United States around 2017. Specifically, firstly, the Republican platform, announced during the U.S. Presidential Elections in 2016, mentioned the nuclear issues of North Korea and Iran as well as the war plans of China and Russia, and stated clearly that the HEMP threat is real and that there was a need for the President, congress, Department of Homeland Security, Department of Defense, the government, and the private sector including power business operators, to cooperate and protect the electric grid.[25] Next, on September 3, 2017, North Korea's state-run news agency drew attention when it covered North Korea's acquisition of HEMP attack capability in a way that connected nuclear tests with the development of intercontinental ballistic missiles.[26] Strangely enough, this happened in the same month as the termination of the EMP Commission. (*Note that until then, there had also been frequent discussions linking North Korea's nuclear development with HEMP threat, including discussions by those related to the EMP Commission.)

There were more significant developments at the start of 2018. The Department of Homeland Security published a document titled "Protecting and Preparing the Homeland Against Threats of Electromagnetic Pulse and Geomagnetic Disturbances,"[27] and in the following

year, President Donald Trump signed and issued the Executive Order on Coordinating National Resilience to Electromagnetic Pulses on March 26, 2019.[28] In particular, the Executive Order issued by the President was epochal and unprecedented in that it focused on both HEMP and GMD.[29] With regard to EMP, it states that it "has the potential to disrupt, degrade, and damage technology and critical infrastructure systems," and that "Human-made or naturally occurring EMPs can affect large geographic areas, disrupting elements critical to the Nation's security and economic prosperity, and could adversely affect global commerce and stability." It sets out clearly and specifically the need for the Federal Government of the United States to strengthen resilience (Sec. 1), and defines critical infrastructure that needs to be protected as "systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters" (Sec. 2(a)). Furthermore, this Executive Order also sets out the role and responsibilities of the Secretary of State as follows: "lead the coordination of diplomatic efforts with United States allies and international partners regarding enhancing resilience to the effects of EMPs; and," "in coordination with the Secretary of Defense and the heads of other relevant agencies, strengthen nuclear nonproliferation and deterrence efforts, which would reduce the likelihood of an EMP attack on the United States or its allies and partners by limiting the availability of nuclear devices" (Sec. 5(a)(ii)). It further orders the Secretary of Defense to: "in cooperation with the heads of relevant agencies and with United States allies, international partners, and private-sector entities as appropriate, improve and develop the ability to rapidly characterize, attribute, and provide warning of EMPs, including effects on space systems of interest to the United States" (Sec. 5(b)(i)). On top of that, it sets out orders to "identify and list the national critical functions and associated priority critical infrastructure systems, networks, and assets, including space-based assets that, if disrupted, could reasonably result in catastrophic national or regional effects on public health or safety, economic security, or national security" (Sec. 6(a)(i)), and states that "Within 1 year of the identification described in subsection (a)(i) of this section, the Secretary of Homeland Security, in coordination with the heads of other agencies as appropriate, shall, using appropriate government and private-sector standards for EMPs, assess which identified critical infrastructure systems, networks, and assets are most vulnerable to the effects of EMPs" (Sec. 6(a)(ii)). It sets out deadlines such as 90 days, 180 days, one year and four years, for identifying vulnerabilities to HEMP in the relevant government agencies. For example, for the Secretary of Homeland Security, it prescribes that "Within 180 days of the identification described in subsection (a)(ii) of this section, the Secretary of Homeland Security, in coordination with the heads of SSAs and in consultation with the Director of OSTP and the heads of other appropriate agencies, shall review test data — identifying any gaps in such data — regarding the effects of EMPs on critical infrastructure systems, networks, and assets representative of those throughout the Nation" (Sec. 6(b)(i)). Concerning this Executive Order, Secretary of Energy Rick Perry has declared that "The Executive Order sends a clear message to adversaries that the United States takes this threat seriously".[30] Depending on the viewpoint, the same Executive Order could be regarded as carrying significance in terms of addressing technological vulnerabilities, while also having the implications of developing deterrence-by-denial against adversaries that are considering a HEMP attack, which also covers allies and partner countries that the United States offers extended deterrence to.

The report "High-Altitude Electromagnetic Pulse and the Bulk Power System"[31] published by the U.S.

Electric Power Research Institute (EPRI) soon after the Executive Order was signed, established clearly the technological means for mitigating the potential impact of HEMP, based on the review of HEMP's impact on power transmission systems in three phases. With regard to the view that HEMP could cause a continuous power outage in the United States lasting from several months to years, the EPRI report presents the clear conclusion that it does not support this from the standpoint that it is possible to put in place countermeasures to begin with. However, this EPRI report not only drew strong criticisms in the technological aspects from members of the former EMP Commission,[32] but also gave rise to discussions in various media about the views for and against its contents.[33] The results of individual research projects that formed the basis for the EPRI report were made available to the public by the research institute in 2016 [34], and these constituted a part of the aforementioned joint project with the U.S. Department of Energy. Incidentally, a general EMP measure that is deemed effective, despite the need to balance it with costs, is to use protective devices such as electromagnetic wave shields or noise filters.[35] In addition, various recommendations made by the Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T) have already defined deliberate electromagnetic attacks through HEMP as well as set out the guidelines for acquiring immunity against that.[36] Here, the focus is placed on "evaluation" of how regionally widespread HEMP is, and the extent of damage it causes, before it is deemed as a threat. Ultimately, should that not be seen as leaving it up to a "judgement" of security risks and costs?[37]

Future outlook on the HEMP threat

High altitude nuclear tests in the atmosphere are a thing of the past. Since then, the threat of HEMP has not been clearly established amidst the background of dramatic developments in critical social infrastructure. In 2019, the President of the United States signed an Executive Order that looked at both GMD and HEMP, and by doing so, drew a distinct line with the discussions to date. This has presented the possibility that the Federal Government of the United States will engage in in-depth studies going forward, as well as take a concrete step toward identifying vulnerabilities and putting in place measures in some areas, in cooperation with allies and partner countries. Incidentally, with regard to examples of past reviews on enhancing EMP resistance in relation to the U.S. military, it has been stated in congress that additional overheads for incorporation into the systems of the U.S. military and commercial computers would be 2% to 3%, and that it would also be possible to retrofit electronic hardware held by the U.S. military at a total additional cost of 3% to 10%.[38] Needless to say, as one of two nuclear-weapon states that have a history of conducting high altitude nuclear tests, the knowledge that U.S. government agencies have of HEMP can be considered superior to that of other countries. Moreover, as it also has a history of developing standards that are frequently used as a reference domestically and abroad, such as the HEMP-related MIL Standard that was also touched on in this paper, any progress made in measures in the United States are likely to have a ripple effect in some way on other countries. The trends and future developments in measures to counter the HEMP threat, put in place by the United States and its allies and partners, will continue to draw close attention.

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[7] Sukeyuki Ichimasa, "Bei-So no Taikiken-nai Kaku Jikken to Kokodo Denji Parusu (HEMP) Kenkyu" [Research on Atmospheric Nuclear Tests Conducted by the United States and Soviet Union, and high altitude electromagnetic pulse (HEMP)], *CISTEC Journal* No.173, January 2018, pp.59-63.
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[9] Charles N. Vittitoe, "Did High-Altitude EMP Cause the Hawaiian Streetlight Incident?" *System Design and Assessment Notes*, Note 31, June 1989.
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[13] In relation to this point, Gurevich indicated that there was frequently disseminated information about the former Soviet Union's high altitude nuclear tests and HEMP even prior to the EUROEM meeting. As these could also be referenced in United States in the Cold War period, it has been pointed out that rather than a lack of information, it was likely that the United States (particularly the U.S. military) had not had much interest in HEMP to begin with.
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[27] "Strategy for Protecting and Preparing the Homeland against Threats of Electromagnetic Pulse and Geomagnetic Disturbances," U.S. Department of Homeland Security, October 9, 2018.
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