Chapter 2

Review of the New-generation Weapon Development of the PLA Navy

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I. Introduction

The PLA Navy's development of platforms underwater, on the water surface, and over the air, such as anti-ship ballistic missiles (ASBMs), submarine-launched ballistic missiles (SLBM), and electromagnetic weapons, have constantly been improving in quality and quantity, thereby achieving significant results. Among these, electromagnetic weapons are known for low costs and high effects, which may change the patterns of warfare in the future once in service.

Therefore, this annual report on technological trends focuses on the PLA Navy's ship-based electromagnetic weapons. The weaponization of optoelectronics laser technology is mainly based on high-energy laser (HEL), high-power microwave (HPM), low frequency and extremely low frequency (LF & ELF), particle-beam weapons, plasma weaponry, radio frequency (RF), sonic weaponry, coilgun (Gauss rifle), electromagnetic railguns (EMRGs), electrothermal-chemicals (ETCs), electrothermal guns, high-altitude electromagnetic pulses (HEMPs), reconnection guns, Advanced Arresting Gear (AAG), and Electromagnetic Aircraft Launch System (EMALS). These are all new concept weaponry, distinctively different from traditional artillery. The first seven categories are classified as directed-

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energy weapons (DEWs),[1] and the remaining are the weapons and equipment driven by strong magnetic force through electricity. Limited by space, this paper only assesses laser, microwave, and electromagnetic railguns as more developed new concept weapons of the PLA Navy ship-base electromagnetic weapons. The characteristics and weaknesses are summarized, and the potential impact on modern warfare is analyzed. While this paper does not cover other electromagnetic weapons, equipment, and possible platforms, the ROC Armed Force, national defense research institutions, and think tanks should keep a close eye on the development trends given the equally profound impact on military warfare.

II. Development of the Ship-based Electromagnetic Weapons of PLA Navy

1. High Energy Laser Weapons

Under China's State High-Tech Development Plan (the 863 Program) that started in 1986, laser weapons were among the 20 prioritized military R&D highlights.[2] This includes carbon dioxide (CO2) laser, chemical oxygen-iodine laser (COIL), free-electron laser (FEL), and X-ray laser. The output power of CO2 laser and COIL is above 10,000 watts. The destructions caused by the thermal effects of strong lasers have been well tested by extensive theoretical analyses and experiments. In an anti-missile test in 2000, the PLA's high-energy laser weapons destroyed a laterally launched missile. Despite the success in the initial test, it was not deployed in the troops, possibly due to issues in energy storage, recycling, and oversizing/ overweight. Laser weaponry requires large power supplies. Although a solid-state laser (SSL) boasts longevity, its heavy 10-ton weight limits its applicability—a daunting challenge to carry it with airplanes or vehicles. Thus, it

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1 Edited by the Editorial Committee of Common Terms in Mainland China, *Compilation of Common Terms in Mainland China* (Taipei: Showwe Information, 2009), p. 172.

2 Dallas Boyd (principle), Jeffrey G. Lewis and Joshua H. Pollack (contributed), *Advanced Technology Acquisition Strategies of the People's Republic of China* (Contract Number: DTRA01-03-D-0017, T.I. 18-09-03) (Virginia, USA: Defense Threat Reduction Agency Advanced Systems and Concepts Office, 2010), p. 81.

can only be installed at fixed land positions or on large warships. If the electricity supply issue can be resolved, its advantage and efficiency of continuous firing will be easily deployed. After twenty years of testing and improvement, China seems to have overcome the difficulty in storage, size, and weight. It is even said that laser weaponry has been installed on the anti-aircraft deck of the 055 destroyers (above the bridge).[3]

2. High Power Microwave System

In general, microwave weapons seek to render electronic systems overloaded and functionless by aiming at the target with high-power-directed energy pulses. The higher the energy, the greater the microwave system's interference to the target electronic systems (e.g., generators and communications systems). High-power microwave weapons can even cause physical damage to targets.[4]As microwave weapons on naval ships boast high power and long beam propagation distances, they are less restricted in terms of weight, space, and power than high-energy laser weapons. Some equipment has been installed on large warships for real battle testing and assessment, which will likely become a standard weapon for PLA Navy ships within the next five years. Deputy Head of Northwest China Nuclear Technology Institute, Huang Wen-Huang, and his team have been studying directed-energy weapons (DEWs) for years and received the first prize of the National S&T Progress Award in January 2017. According to relevant academic papers, the system developed by the team may be used for anti-missile systems on warships. This system is primarily done with microwave interfering and damaging the missiles from the enemy or the electronic equipment on the platform. Relevant tests and simulations were carried out in 2010 at the Northwest Desert, which showed meaningful results.[5] The ROC Armed Force should never underestimate

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[3] Richard D. Fisher, Jr., "China's Progress with Directed Energy Weapons," paper presented at the Testimony before the U.S.-China Economic and Security Review Commission hearing (Washington, D.C., USA: February 23, 2017), p. 8.

[4] Jeffrey Lin and Peter W. Singer, "China's New Microwave Weapon Can Disable Missiles and Paralyze Tanks," *Popular Science*, January 27, 2017, https://www.popsci.com/china-microwave-weapon-electronic-warfare/.

[5] Louis A. Del Monte, *War at the Speed of Light: Directed-Energy Weapons and the Future of Twenty First Century Warfare* (Nebraska, U.S.: University of Nebraska Press, 2021), p. 106.

the potential threat from China's high-power microwave weapons.

3. Electromagnetic Railguns (EMRGs)

Since the 1980s, when the U.S. listed the R&D of electromagnetic railguns (EMRG) in its Strategic Defense Initiative (SDI), the development and application of electromagnetic kinetic weapons have entered the world of modern warfare like in science fiction.[6] Electromagnetic railguns are named for the two electromagnetic tracks of the warhead.[7] The gigantic electromagnetic force pushes the metal warhead and strikes at the target at the ultra-speed of 4-7 Mach. This means it can go much further than any bullets of ammunition and cause greater damages to the target. For instance, the Lorentz force of 32 megajoules (MJs) can push out a solid projectile of 10kg in weight and hit-to-kill a target 100 knots away with ultrasonic kinetic energy.[8] In April 2014, the PLA Navy Type 072-class amphibious landing ship (Haiyang Shan, Pennant number 936) conducted the first test on the sea. Later in March and December of 2018, there were multiple disclosures of successful trials of electromagnetic railguns on the sea.

The U.S. intelligence determines that the year 2025 is the earliest timeframe for the PLA Navy to deploy electromagnetic railguns in service.[9] In June 2021, the U.S. Navy formally terminated its electromagnetic railgun R&D project initiated in 2005.[10] This information has two implications. First, the problems in the materials and energy storage of electromagnetic railguns are unlikely to be easily solved. Second, China may have made significant progress on these issues. Ordinary shipboard artillery can fire approximately 600 shots. Due to the limitation

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6 Brian Weeden and Victoria Samson ed., *Global Counterspace Capabilities: An Open Source Assessment* (Washington D.C., USA: Secure World Foundation, April 2019), pp. 3-13.

7 Josh K. Elliott, "Why China's 'Miracle' Railgun Weapon Should Scare the U.S. Navy," *Global News*, January 3, 2019, https://globalnews.ca/news/4810853/china-railgun-warship-weapon/.

8 Arthur Dominic Villasanta, "Type 055 Second Generation Chinese Destroyers to be Armed with Railguns," *China Topix*, July 27, 2016, https://www.chinatopix.com/articles/96685/20160727/second-generation-chinese-destroyers-armed-railguns.htm.

9 Jared Keller, "China's Electromagnetic Railgun Is Apparently Already Roaming the High Seas," *Task and Purpose*, December 29, 2018, https://taskandpurpose.com/military-tech/chinas-electromagnetic-railgun-sea-trials/.

10 Konstantin Toropin, "The Navy Finally Pulls the Plug on the Railgun," *Military.com*, July 2, 2021, https://www.military.com/daily-news/2021/07/02/navy-finally-pulls-plug-railgun.html.

of materials resistant to high heat, an electromagnetic railgun may need to replace its gun barrel after ten to twenty shots. Further, relevant electronic components will also be burned and eroded. However, frequent replacements of gun barrels and electronic components seem uneconomical. The efficiency of energy storage is also highly relevant to the continuous firing capability of electromagnetic railguns. Hence, it is estimated that the earliest service will be in 2025 despite the "successful" test in 2018, as there should still be some outstanding problems with the PLA Navy's electromagnetic railguns. This means the pushout of the commissioning timeframe of the 055A destroyer due to the planned installation of electromagnetic railguns.

III. Advantages and Disadvantages of Ship-based Electromagnetic Weapons and their Impacts on the Battles

1. High Energy Laser Weapons

Laser weapons use powerful directed laser beams to destroy the target directly or render it functionless. It is a high-tech concept weapon that uses the strong energy of high-brightness laser beams to damage or injure the enemy's airplanes, missiles, satellites, and personnel. This type of weapon has advantages other weapons cannot compete with, including fast shooting speed, high precision, long-range interception, quick transfer of fire, freedom from electromagnetic interference, strong staying power, and no pollution to the environment. Meanwhile, the main shortcomings lie in the high energy requirement, bottlenecks in high-energy battery technology, oversizing and overweight, inability to handle all-weather operations, and vulnerability to cumulus clouds, dense fogs, heavy snows, and stormy rains. It is difficult to overcome energy attenuation caused by atmospheric disturbance and abruption of laser energy in the atmospheric environment. Despite all these, China has obtained significant achievements in the R&D of directed-energy weapons (DEWs), particularly with airborne laser (ABL), anti-satellite (ASAT) laser, and tactical high-energy laser (THEL).

There have been multiple cases evidencing China's application and achievement in weaponizing lasers. In 2005-2006, China used high-energy land-based lasers several times to illuminate the U.S. spy satellites flying over China's airspace[11] in order to dazzle or blind them.[12] In May 2018, the U.S. Armed Forces accused the PLA's base in Djibouti of using laser weapons against the U.S. reconnaissance airplanes on numerous occasions.[13] In February 2020, No. 161 Fleet of the PLA's Southern Theatre entered the West Pacific for "Long-Sea Navigation" training and used lasers to point at the U.S. Armed Forces P-8A maritime anti-submarine aircraft. The U.S. accused this as an "unsafe and unprofessional behavior."[14] According to these cases, high-energy laser weapons are non-lethal but sufficient to render the enemy and the enemy's military equipment hors de combat. During the (Abu Dhabi) International Defence Exhibition & Conference (IDEX) in February 2017, China Poly Group Corp. claimed that it was developing a navy 30+ kW Silent Hunter—a fiber-optic laser system that could destroy approaching missile boats or reconnaissance and strike integrated UAVs one kilometer away. With precise positioning, it can also neutralize the seekers of subsonic missiles or precision-guided munitions (PGM). Moreover, high-energy laser weapons are expected to dramatically reshape naval warfare.[15] The laser weapon powers required for the destruction of specific targets are summarized in Table 2-1:[16]

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[11] Ajey Lele, *Strategic Technologies for the Military: Breaking New Frontiers* (CA., USA: SAGE Publications, 2009), pp. 96-97.

[12] Yousaf Butt, "Effects of Chinese Laser Ranging on Imaging Satellites," *Science and Global Security*, No. 17, 2009, p. 30.

[13] Gordon Lubold and Jeremy Page, "Laser from Chinese Base Aimed at U.S. Military Pilots in Africa's Skies, Pentagon Charges," *The Wall Street Journal*, May 3, 2018, https://www.wsj.com/articles/laser-from-chinese-base-aimed-at-u-s-military-pilots-in-africas-skies-pentagon- charges-1525351775.

[14] Ryan Browne, "US Says Chinese Warship Fired Military Laser at US Aircraft," *CNN*, February 28, 2020, https://edition.cnn.com/2020/02/27/politics/chinese-laser-us-aircraft/index.html.

[15] Richard D. Fisher, Jr., "China's Progress with Directed Energy Weapons," p. 8.

[16] Ben Goodlad, "Star Wars: High Energy Laser Weapons Awakening," *Jane's Intelligence Briefings*, April 21, 2016, http://janes.ihs.com/Janes/display/jibr2260-jibr.

Table 2-1 Laser Weapon Powers Required to Destroy Specific Targets

Power in kW				
~10 kW	10~90 kW	100 kW	500~999 kW	1 MW
UAV				
	Rockets, artilleries, and mortars			
		Speed boats/trucks		
			Missiles	

Source: Jane's Intelligence Briefing, April 21, 2016.

2. High Power Microwave Weapons

The main characteristics of microwave weapons include broad beams, wide ranges, fast speeds, and great power. Attacks can be made without aiming at targets. It is not subject to the impact of weather or the atmospheric environment. As the transmission is sufficient to penetrate walls and glass, the barrier limitations are relatively low. The light size and volume imply a small space required, which allows a large number of platforms for installation. Unseeable and impalpable, microwave weapons are known as the "invisible killer". However, its major shortcoming lies in poor resistance to interference. More so, as it is impossible to differentiate proponents from opponents, friendly armies and their electronic equipment near the target zone are likely to be damaged. Further, damage assessment is difficult. Active denial systems (ADS) are one of the applications of high-power microwave weapons, whose millimeter wave (mmWave) transmitter is suitable for enforcing protection missions.[17] In continuous conflicts, HPMs can be used to intimidate enemies by achieving four strategic goals: (1) punishment; (2) risks; (3) decapitation; and (4) denial.[18] These coercive effects are particularly

[17] Edward H. Lundquist, "Transforming War at Sea Through Disruptive Technologies: New Weapons Are Energizing the Maritime Battlespace," *Defense Media Network*, May 21, 2011, https://www.defensemedianetwork.com/stories/transforming-war-at-sea-through-disruptive-technologies/.

[18] Jack McGonegal, *High Power Microwave Weapons: Disruptive Technology for the Future* (Diss., Air Command and Staff College, 2020), p. 14.

useful to counter-terrorism and for countervalue targets.[19]

Jin Canrong said in an interview in November 2020 that the PLA used microwave weapons to repel the Indian army during the Ladakh conflict. While the Indian government condemned this as fake news, the Year-End Review—2020 Ministry of Defence published in January 2021 accused China of using unorthodox weapons and causing dizziness and nausea among the Indian soldiers at the mountains near the Pangong Lake. Hence, they had to withdraw[20]—an indirect confirmation of the fact. Microwave weapons can also attack satellites, ballistic missiles, cruise missiles, airplanes, naval ships, armored vehicles, communications systems, radar, and computer equipment. In particular, it can physically damage and paralyze command nodes important to communications hubs and combat links to an irreparable degree. In February 2017, the UK Daily Star newspaper said that, even without firing a bullet, China's newest ray weapon could neutralize the enemy tanks, take down military planes, and obliterate warships. Peter Warren Singer, a U.S. expert in modern warfare, believes that microwave weapons have punished the frontier of offensive and defensive operations and changed war activities for the future.[21] Its influence cannot be ignored.

3. Electromagnetic Railguns (EMRGs)

Electromagnetic railguns (EMRGs) are known for high speeds, long ranges, severe destructivity, resistance to interception and interference, large load capacities, and low costs. They may replace land-attack cruise missiles (LACM) for tactical air support and naval gunfire support (NGFS) going forward, which

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[19] In the military theories, countervalue refers to assets valuable to opponents but not constituting military threats. Examples are cities and civilians.

[20] Press Information Bureau, "Year End Review–2020 Ministry of Defence," *Government of India*, January 1, 2021, https://pib.gov.in/PressReleseDetail.aspx?PRID=1685437; Aakriti Sharma, "Has India Finally Acknowledged That Chinese PLA Used Microwave Weapons Against Indian Soldiers in Ladakh?," *The Euro Asian Times*, January 6, 2021, https://eurasiantimes.com/has-india-finally-acknowledged-that-chinese-pla-used-microwave-weapons-against-indian-soldiers-in-ladakh/.

[21] Henry Holloway, "China's 'Killer Microwave' Drone to Blast Planes, Fry Warships and Paralyse Tanks," *Daily Star*, February 12, 2014, https://www.dailystar.co.uk/news/latest-news/china-war-weapon-microwave-drone-16983208.

is revolutionary to naval warfare, tactical operation, sea platform designs, and equipment development. In sum, it is a new concept weapon set to change the ways of war. The main weaknesses of EMRGs include the extremely high electromagnetic power requirement and the difficulty in storing electricity. The power supply systems are bulky, heavy, complex in structure, and prohibitively high in cost. The high heat and the electric arc during launch ablates the slideway and reduces the lifespan of gun barrels. In addition, shooting precision is subject to the influence of the atmospheric environment; the further the range, the greater the error. It is difficult for the EMRG anti-load capacity to reach the ideal shooting range. For example, a range of 400 km imposes a loading of 40,000 Joules on electronic components, which remains a daunting technical challenge.

The long list of shortcomings with electromagnetic railguns can be generalized into three key areas. (1) Electricity generation and storage: Electromagnetic railguns require a powerful electromagnetic force for hypervelocity projectiles (HVPs). It is also necessary to store the energy for launching at any time; (2) The ultra-heat after launch needs to be dealt with; otherwise, the electromagnetic slideway will be disintegrated by the ionized plasma caused by vaporization due to extreme heat;[22] (3) It is relatively easy to handle the friction heat born by solid bullets during flight. Guided non-solid bullets ensure precision at the possible expense of hit-and-kill effectiveness. Therefore, the key to China's success in the development of electromagnetic railguns is the materials capable of coping with high heat. Based on the strike of a target 2,000 km away by the DF-17 hypersonic missile at the 20 times of velocity of sound and the successful return and landing by the Shenzhou-12, the challenge lies in the installation of miniature seeker components for HVP and the materials resistant to ultraheat. Moreover, whether the increased bullet costs undermine the overall advantages of electromagnetic railways is worthy of assessment. China's military technology and science research institutes have been working on guided warheads and electromagnetic rockets.

[22] Tate Nurkin, *China's Advanced Weapons Systems* (Prepared for U.S.-China Economic and Security Review Commission) (USA: Jane's by IHS Markit, 2018), p. 213.

The next generation of electromagnetic railguns and electromagnetic rockets are expected to enter service in 2030.

IV. Conclusion

Both microwave and laser weapons are state-of-the-art technology with or close to the transmission speed of light. Although the functioning principles of these two types of weapons are similar, they kill and hurt in different ways. Laser weapons are out for a hard kill by focusing laser beams precisely toward targets for neutralization. On the other hand, microwave weapons aim for a soft kill by interfering or burning military electronic components, which require much lower energy than lasers and can be installed in small platforms such as UAVs. Both of these directed-energy weapons (DEWs) have already demonstrated many use cases on the battlefield. They will enter service earlier than electromagnetic railguns, which will take a few more years for maturity and readiness.

The key for electromagnetic weapons to work depends on a large amount of electricity. Traditional naval ships with mechanical propulsion and power systems separated from each other cannot continuously meet the needs of electromagnetic weapons. Other weapons and facilities can only supply electricity for different sections at the same time. In contrast, the integrated electric propulsion (IEP) system can greatly enhance the efficiency of electricity and meet the requirements for naval ship motion, weapon launches, equipment operation, and electricity for living. Meanwhile, the PLA Navy has no ships equipped with integrated electric propulsion yet—a probable limiting factor why electromagnetic weapons (particularly electromagnetic railguns) have not been installed onboard.

Judging from the installation of an electromagnetic aircraft launch system (EMALS) and advanced arresting gear (AAG) on Type 003 aircraft carriers, it can be certain that the power system of Type 003 aircraft carriers is an integrated electric propulsion to provide strong support for electromagnetic equipment on the ship. The PLA Navy's electromagnetic weapons can be used for air and missile

defense (AMD), anti-access/ area denial (A2/ AD), closed-in weapon systems (CIWS), counter-space, counter UAVs or counter drones, and electronic warfare (EW). Given the high effectiveness of electromagnetic weapons and equipment to future warfare, China will continue to splash money and efforts on R&D and deploy integrated electric propulsion on different naval ships over the next few years. This matter should be closely watched.