中国简报 China Brief
a journal of analysis and information
The JAMESTOWN FOUNDATION

VOLUME 19 • ISSUE 18 • OCTOBER 08, 2019

SPECIAL ISSUE: MILITARY-CIVIL FUSION AND ITS PROSPECTS FOR THE PLA AND CHINESE INDUSTRY

IN THIS ISSUE:

Military-Civil Fusion: Beijing's "Guns AND Butter" Strategy to Become a Technological Superpower
By Greg Levesque

The Limitations of Military-Civil Mobilization: Problems with Funding and Clashing Interests in Industry-Based PLA Reserve Units
By Larry Wortzel

Military-Civil Fusion and Electromagnetic Spectrum Management in the PLA
By John Dotson

China's Military Biotech Frontier: CRISPR, Military-Civil Fusion, and the New Revolution in Military Affairs
By Elsa B. Kania and Wilson VornDick

Editor's Note:

This is a special theme issue of *China Brief*, focused on the evolving concept of "military-civil fusion" (军民融合, *junmin ronghe*), or MCF, a complex set of initiatives by the People's Republic of China (PRC) to share resources between the military and civilian industry. A core focus of MCF is the effort to leverage technological expertise from the civilian sector in order to benefit the development of advanced weapons systems and other equipment for the People's Liberation Army (PLA). However, MCF is much more than that: it also embraces a broad set of organizational changes and information-sharing mechanisms intended to break down barriers between China's military and commercial sectors—with the ultimate aim of sharing resources and expertise from both sides, while keeping these efforts firmly under state direction. Whether this ambitious program succeeds or fails will have significant implications for the course of Chinese military

modernization, as well as for the future direction of China's high-technology and other emerging industrial sectors.

Image: In this cartoon from a Chinese government website, a PLA soldier and a civilian worker (holding the book of "technology") unite hands under the "National Strategy of Military-Civil Fusion" (国家战略军民融合, guojia zhanlue junmin ronghe). *(Source: Renmin Zhengxie Wang)*

In this issue, we present four articles (fewer than our usual five, but each one longer than a typical *China Brief* article). First, author Greg Levesque provides an overview of the MCF concept, as well as examples of how MCF policies are being enacted in China's commercial sector—with both public and nominally private companies applying their resources towards the pursuit of PRC state goals. Next, retired U.S. Army Colonel and U.S.-China Commission member Larry Wortzel offers an analysis of the practical problems faced by the PLA in its efforts to create reserve and militia units housed within commercial enterprises. Then, my own contribution examines the ways in which the PLA and civilian government agencies in the PRC are attempting to coordinate resources and personnel in order to more effectively manage shared use of the electromagnetic spectrum. Finally, authors Elsa Kania and Wilson Vorndick provide an analysis of the ways by which the Chinese military could seek to leverage the results of civilian research in the field of biotechnology.

Here at the Jamestown Foundation, we modestly hope that this special issue will contribute towards a greater understanding of the PRC's concept of military-civil fusion—and the complex issues that surround it—for the benefit of policymakers, scholars, military officials, and members of the business community.

— John Dotson (editor, *China Brief*)

ChinaBrief • Volume 19 • Issue 18 • October 8, 2019

Military-Civil Fusion: Beijing's "Guns AND Butter" Strategy to Become a Technological Superpower

By Greg Levesque

Introduction

A great gamble is underway in China, as the Chinese Communist Party (CCP) attempts to introduce new concepts that challenge traditional notions of centralized economic and defense planning. A key pillar of this effort is "military-civil fusion" (军民融合, *jun-min ronghe*), or MCF—a national strategy that has quickly become a guiding force behind not only local government economic planning but also the strategies of Chinese corporations. MCF is influencing investment decisions, talent recruitment, and research and development (R&D) across multiple fields of dual-use technology sectors, to include artificial intelligence, advanced materials, and aviation.

To date, most coverage of MCF has focused on the military aspects of the strategy in enabling the People's Liberation Army (PLA) to field more high-tech weaponry and systems for future combat. This is no doubt important; however, it misses the grander strategic thrust behind the initiative, which when revealed yields deeper insight into how Chinese leaders are positioning the country to compete militarily *and economically* in an emerging technological revolution. According to Jiang Luming (姜鲁鸣) of the PLA National Defense University, the MCF concept provides a long-term "law of development" for synchronizing China's economic and national defense building efforts. It involves the "comprehensive planning of the two major systems of military and civilian resources, brings about a compatible economic and technical foundation for [resource] sharing, transforms limited social resources into bidirectional and interactive combat power and production power, and achieves multiple types of production from a single investment" (PLA Daily, June 2, 2016).

This description captures MCF's importance as a means of managing resource allocation to most effectively translate economic scale into military might. Said differently, it represents an innovative, though still unproven, effort to turn the classic macroeconomic "guns versus butter" model on its head. This is especially critical as the leaders of the People's Republic of China (PRC) seek to navigate the economy through the "middle-income trap," while also revamping the country's defense science, technology, and industrial (DSTI) system to create systematized capabilities for potential future conflicts. **[1]** While this strategy makes perfectly clear that Beijing has no intention of matching Washington dollar for dollar on defense, it will likely make it more difficult to properly assess the full scope of China's military programs and posture.

The notion of "bi-directional and interactive" combat and production power noted by Jiang is generated from investments in dual-use technology sectors including aerospace, advanced equipment manufacturing, artificial intelligence, and alternative sources of energy. It also involves greater integration of military and civilian administration at all levels of government: in national defense mobilization, airspace management and civil air defense, reserve and militia forces, and border and coastal defense. In June 2017, CCP General

Secretary Xi Jinping also called for boosting MCF across dual-use infrastructure, national defense-related science and technology, weapons and equipment procurement, and talent cultivation, as well as implementing MCF in the outer space, cyberspace, biology, new energy, and maritime domains (Xinhua, June 21, 2017).

A growing body of research regarding the historical evolution and policy orientation of MCF is creating greater awareness of the issue. **[2]** Despite this, MCF is not well-understood outside China; furthermore, it is a concept undergoing steady change and evolution. As a result, the advancement of the MCF concept in Chinese industry warrants greater attention from U.S. policymakers, military officials, and businesspeople alike.

Image: The CCP Politburo meeting of January 2017, during which the formation of the CCP Central Military-Civil Fusion Development Committee was announced. (Source: QCTester.com)

The Implementation of MCF Is Progressing Rapidly

MCF appears to be entering a new phase of development, as expanded policies and doctrines clarifying roles, responsibilities, and priorities are proliferating across China's vast bureaucratic system. The formation in 2017 of the CCP Central Military-Civil Fusion Development Committee (中央军民融合发展委员会, *Zhongyang Jun-Min Ronghe Fazhan Weiyuanhui*), or CMCFDC, has greatly accelerated MCF implementation at the local-level (Xinhua, January 23, 2017). Headed by CCP General Secretary Xi Jinping, the CMCFDC acts as the highest level "decision-making and coordination mechanism" for MCF development, and it is leveraging the Party's authority to break down institutional barriers across the government, military, and industry that have hindered MCF implementation. **[3]**

Since its first plenary meeting in June 2017, the CMCFDC has promulgated at least 11 policies defining near-term MCF priorities. These include requiring the formation of local-level MCF work committees to oversee implementation and promulgation of a document detailing MCF strategic doctrine. **[4]** These

measures appear to be correlated with an uptick of MCF-related initiatives at all levels of the PRC party-state bureaucracy. Notable milestones include:

- In the last 24 months, most provincial and local governments—including examples available from Zhejiang, Guizhou, and Hunan—have announced MCF industrial development plans. **[5]**
- At least 36 national-level MCF industrial zones—many of which are home to foreign companies—have been designated across China to support interactions between companies, research institutes, civil government agencies, and military organizations. As seen in the example of the Zhongguancun Science Park in Beijing, information exchange platforms within these industrial zones link military science and technology requirements with the work of both state-owned and nominally-private technology companies (Zhongguancun Science Park, January 8).
- Central and local government agencies have unveiled tens of billions of dollars in investment funds—such as the $4.8 billion Central Military-Civil Fusion Fund (国华军民融合发展基金, *Guohua Jun-Min Ronghe Fazhan Jijin*)—dedicated to supporting MCF industrial development (Asia Corporate News Network, September 7, 2016).

Military-Civil Fusion in Action: The Commercial Activities of the Kuang-Chi Group

Understanding the growing role of PRC corporations, universities, investment vehicles, and research organizations in advancing MCF initiatives—especially when it comes to PRC defense mobilization—is critical to monitoring MCF progress, identifying potential national security risks in the commercial domain, and crafting meaningful policy responses. One case that illuminates MCF in action is the Shenzhen-based Kuang-Chi Group (光启集团, *Guangqi Jituan*). Founded in 2010 on metamaterials research (which has stealth applications) diverted from a Duke University research lab by its founder Liu Ruopeng [刘若鹏], Kuang-Chi presents itself as a multi-billion dollar "global innovation company" leading disruptive research on new materials, near space, and engine technology. **[6]**

Kuang-Chi is often referred to in Chinese media as a "military-civil fusion enterprise" (军民融合企业, *jun-min ronghe qiye*) (Sina Finance, December 29, 2017). The company is spearheading the establishment of a "military-civil fusion innovation center" in the Xiong'an New District (Baoding, Hebei Province), and its products are used in PLA warplanes, naval systems, missiles, and anti-stealth radar systems. **[7]** In fact, the company recently won a military contract to apply its metamaterials products on Chinese warships to enhance stealth capabilities (Yicai Global, January 15).) Kuang-Chi also collaborates with defense and public security stakeholders, including China Unicom, China Telecom, and the Hunan Space Bureau (068 Base)—a center for R&D and production of near space reconnaissance platforms—to develop technologies and products for government public security customers (Hong Kong Exchange News, December 27, 2017; Hong Kong Exchange News, September 20, 2017; East Money, February 28, 2015).

Image: Kuang-Chi Group senior executive Liu Ruopeng (劉若鵬) speaks at the September 2017 ceremony inaugurating the company's "military-civil fusion innovation center" in Hebei Province. (Source: Hong Kong Business News)

In addition to its stated research activities, Kuang-Chi is a significant investor in foreign technology companies. Kuang-Chi operates two $250 million venture capital funds, which are collectively called the "Global Community of Innovation" (GCI) fund. The first fund (GCI Fund I) invests in emerging technology companies operating in the fields of robotics, aviation, virtual reality/augmented reality, telecommunications, internet of things, and digital health (South China Morning Post, October 31, 2016). The second fund (GCI Fund II) was announced in January 2017 and is focused on investing in Israeli tech startups (Reuters, January 12, 2017).

Kuang-Chi's $600 million investment in Singapore-based Hyalroute Communications Group hints at potential collaboration between Kuang-Chi and Chinese military planners. **[8]** Through subsidiaries, HyalRoute builds, operates, and owns a vast fiber optic communications network across Southeast Asia, including in Myanmar and Cambodia. **[9]** The company has described its network layout in the region as "in line" with Beijing's "One Belt, One Road" strategy. In April 2017, China's "Belt and Road Fund" selected HyalRoute as part of its first major round of investment projects because the company "is an important node in the 'One Belt, One Road' strategy in Southeast Asia" (Zhitong Caijing, April 9, 2017).

In March 2016, the Cambodian government granted HyalRoute a 25-year concession to build, own, and operate a landing station in Sihanoukville and underwater fiber optic cables connecting Cambodia to the AAE-1 Cable, a consortium-led high-speed submarine cable connecting Southeast Asia to Europe via Africa (Phnom Penh Post, March 3, 2016). **[10]** The landing station and HyalRoutes subterranean fiber optic networks appear to lie within or adjacent to the Ream naval base. **[11]** This is a significant fact in light of recent reports of a secret agreement between Beijing and Phnom Penh to allow PLA forces to use the Ream naval base in Sihanoukville (China Brief, August 14).

Kuang-Chi's ties to PRC military and government stakeholders, its description in Chinese media as a "military-civil fusion enterprise," and HyalRoute's claims to be advancing Chinese government strategies, all point to the Kuang-Chi Group as a prime example of MCF in action. The company's business activities in Southeast Asia appear to be aimed at both commercial and strategic state goals, and therefore warrant further consideration.

Conclusion

Beijing's focus on dual-use capabilities undermines traditional Western notions of separate spheres of commercial, academic, and military activity. The collaboration between PRC corporations, research institutes connected to military or government stakeholders, and foreign companies or universities creates technology transfer risks that "enhance the vitality of China's national defense science and technology innovation" (PLA Daily, June 2 2016). Furthermore, Chinese corporations are not solely economic actors. Clear indications exist that PRC corporations are coordinating some commercial activities in tandem with military planners—especially in relation to dual-use infrastructure connected to defense mobilization and staging. Kuang-Chi Group is but one example that helps to contextualize the role that Chinese companies can play in advancing national-level policy initiatives set by the CCP.

Though impediments remain to the full implementation of military-civil fusion, grand Chinese initiatives often start slowly, gaining momentum and adoption over time. Time is a necessary ingredient for successful cases to emerge and become models for replication. As MCF enters its next phase of development, additional financial resources will be allocated to support construction of dual-use technology zones and projects. PRC defense manufacturers are expected to expand into new markets promoting China's nuclear power technology, aerospace, and shipbuilding capabilities. Finally, as PRC companies adopt MCF into their corporate strategies, their activities may help to signal Beijing's strategic intent as it gears up for geopolitical competition with the West. The future evolution and implementation of the MCF concept are matters worthy of sustained attention and further research.

Greg Levesque is the CEO and co-founder of Strider, a technology company delivering tools that help enterprises enhance their long-term competitiveness, including the ability to combat economic espionage threats. He has advised governments and corporations on matters of economic statecraft, and is a regular contributor to publications on China's strategic initiatives.

Notes

[1] For additional information on the role of military-civil fusion within China's broader innovation policy see: Greg Levesque, "Testimony before the U.S.-China Economic and Security Review Commission Hearing on What Keeps Xi Up at Night: Beijing's Internal and External Challenges," February 7, 2019 at https://www.uscc.gov/sites/default/files/Levesque_USCC%20Testimony_Final_0.pdf.

[2] For helpful and authoritative assessments on military-civil fusion's evolution and elevation under General Secretary Xi Jinping see: Marcel Angliviel de la Beaumelle, Benjamin Spevack, Devin Thorne, "Open Arms: Evaluating Global Exposure to China's Defense-Industrial Base," C4ADS, September 25, 2019, https://static1.squarespace.com/static/566ef8b4d8af107232d5358a/t/5d8e412039dbfd5d18242d63/1569603954898/Open+Arms; and Elsa Kania, "In Military-Civil Fusion, China is Learning Lessons from the United States and Starting to Innovate," *Strategy Bridge*, August 27, 2019, https://thestrategybridge.org/the-bridge/2019/8/27/in-military-civil-fusion-china-is-learning-lessons-from-the-united-states-and-starting-to-innovate.

[3] "The Central Committee Political Bureau Holds a Meeting" [中共中央政治局召开会议], *Xinhua*, January 22, 2017 at http://www.xinhuanet.com//politics/2017-01/22/c_1120363831.htm. In December 2017, Long Hongshan, chief engineer at the State Administration of Science, Technology, and Industry for National Defense (SASTIND), outlined four main impediments to MCF implementation. Dubbed the "Four Insufficients," these include: 1) Insufficient top-level coordination; 2) Insufficient opening; 3) Insufficient sharing; and 4) Insufficient transformation. See: "SASTIND Holds Press Conference on the Situation of Military-Civil Fusion in the National Defense Science and Technology Industry" [国防科工局举行国防科技工业军民融合发展情况发布会], State Council Information Office website, December 6, 2017, http://www.scio.gov.cn/xwfbh/gbwxwfbh/xwfbh/hfkgw/Document/1612885/1612885.htm.

[4] Policies include the Strategic Doctrine of Military Civil Fusion Development [军民融合发展战略纲要] and the Law for Managing National Defense Requirements and Joining Programs in Economic Buildup and National Defense—Trial Version [经济建设与国防建设密切相关的建设项目贯彻国防要求管理办法-试行].

[5] "Zhejiang Province Military-Civil Fusion Industry 13th Five-Year Plan Plan" [浙江省军民融合产业"十三五" 规划], Zhejiang Provincial Government website (undated), at http://www.zjjxw.gov.cn/module/download/downfile.jsp?classid=0&filename=80a04fdc0dbd4ab18c32f1e623e53857.pdf; "Guizhou Province Military-Civil Fusion Industry 13th Five-Year Plan" [贵州省军民融合产业发展"十三五"规划], Guizhou Provincial Government website, May 4, 2018; www.guizhou.gov.cn/zsyz/cyfzzy/201805/t20180515_1120149.html; and "Hunan 13th Five Year Plan for Deepening National Defense Science and Technology Industry Development" [湖南国防科技工业军民融合深度发展"十三五"规划], Yongzhou City Information and Industry Technology Department, July 20, 2019, jxw.yzcity.gov.cn/jxw/0304/201707/a4eceee6ce0d4bae8e523d3b5089cc33.shtml.

[6] For additional information on Liu Ruopeng and his role in diverting metamaterials research from Duke University see: "FBI Counterintelligence Note: Chinese Talent Programs," Florida International University website, September 2015 at https://compliance.fiu.edu/documents/SPIN%20-%20Chinese%20Talent%20Program.pdf.

[7] See: "Xiong'an New Area Industrial Development Strategy Begins to Emerge, Attracts Shenzhen Kuang-Chi to Promote Military-Civil Fusion" [雄安新区产业规划战略浮现 引入深圳光启力推军民融合], China Economic Net website, September 21, 2017, http://finance.ce.cn/rolling/201709/21/t20170921_26154366.shtml; and "CASIC Aerostat Industrialization Project Settles in Yueyang Economic and Technology Development Zone" [航天科工浮空器产业化项目

落户岳阳经济技术开发区], SASAC website, March 27, 2015 at http://www.sasac.gov.cn/n2588025/n2588124/c3793585/content.html.

[8] It is likely that Kuang-Chi acquired a controlling interest in HyalRoute. References to HyalRoute as being "Shenzhen-based", a "Chinese firm", and "Kuang-Chi HyalRoute" in Chinese media, as well as the fact that Kuang-Chi executive Li Tao serves as Co-CEO and Director support this assessment. See: Jeremy Page, Gordon Lubold, and Rob Taylor, "Deal for Naval Outpost in Cambodia Furthers China's Quest for Military Network," The Wall Street Journal, July 22, 2019, https://www.wsj.com/articles/secret-deal-for-chinese-naval-outpost-in-cambodia-raises-u-s-fears-of-beijings-ambitions-11563732482; and "KuangChi Science Announces Singapore-Based Innovation HQ", *PR Newswire*, May 31, 2016 at https://www.prnewswire.com/news-releases/kuangchi-science-announces-singapore-based-innovation-hq-300276731.html.

[9] For more information, visit HyalRoute's company profile at: http://www.hyalroute.com/aboutus/company-profile/.

[10] For more information on the AAE-1 cable network, see: https://www.submarinenetworks.com/systems/asia-europe-africa/aae-1.

[11] Sketch maps of HyalRoute fiber optic networks in Cambodia are available at http://www.hyalroute.com/cambodia/. The accuracy or timeliness of the maps is unclear.

***

The Limitations of Military-Civil Mobilization: Problems with Funding and Clashing Interests in Industry-Based PLA Reserve Units

By Larry Wortzel

Introduction

One of the foundational concepts in Mao Zedong's thought is that mobilization and "People's War" (人民战争, *renmin zhanzheng*) depend on the masses and militia. **[1]** This concept is the basis for the way that the leaders of the People's Republic of China (PRC) continue to think about mobilization and the role of militia forces today. **[2]** Chinese Communist Party (CCP) General Secretary Xi Jinping (习近平) has attempted to bring "People's War" into the 21st century with his official theories on "military-civil fusion" (军民融合, *jun-min ronghe*) (MCF). **[3]** This concept embraces collective efforts by the militia, reserves, state-owned enterprises (SOEs), government organizations, and private enterprises—in other words, by virtually all economic and military institutions, as well as those engaged in the fields of science and technology. **[4]**

Xi's approach is consistent with his experience as a CCP cadre during his time serving in the municipal CCP committee of Fujian, as vice mayor of Xiamen, and as CCP Secretary in Ningde Prefecture. Xi was first secretary of the Fuzhou Military Sub-District; and when Governor of Fujian Province, he concurrently served as deputy director of the Fujian Provincial National Defense Mobilization Committee and as Political

Commissar of the PLA's Fujian Anti-Aircraft Artillery Reserve Division (Chinaculture.org, undated). However, all does not seem to be going according to Xi's plans, and some publications have indicated problems involving MCF and the defense mobilization system in multiple provinces throughout China. **[5]** As will be discussed below, the performance of militia units seems to be particularly lacking, and enterprises have shown reluctance to fully participate in the mobilization system.

This article discusses China's means for organizing and using militia and reserves in the overall national defense mobilization system, as well as the related laws and regulations that pertain to the mobilization of reserve and militia personnel. In particular, it analyzes problems in training and mobilizing reserve and militia units housed within both private and state enterprises. The first sections of this article will outline mobilization laws and policies; the article will then examine a 2019 investigation of the militia system by *China National Defense News,* and the potential consequences of the shortcomings revealed by this reporting. In its conclusion, the article argues that these problems in the enterprise militia system will be difficult to correct.

Image: Members of the militia unit housed within the Jingke Company (精科公司) *pose for a group photograph during unit training activities held in September 2012 in the city of Anqing (Anhui Province). (Source: Qianshan City Government)*

The Legal Basis for Mobilization and the Militia System

Although the PRC State Council National Defense Mobilization Commission was established in 1994, there was considerable debate for a number of years regarding the enactment of a National Defense Mobilization Law. Other laws and regulations cover such topics as civil defense, people's air defense, transportation and communications mobilization, PLA reserve forces, and the militia. **[6]** Lonnie Henley, a veteran PLA watcher, points out that between 1995 and 2000 at least 169 new laws and regulations governing the military were put into effect, many of which govern mobilization (RAND/CAN, February 2005).

The 1997 National Defense Law requires the state to "make preparations for war in peacetime and to mobilize the entire nation when China is under threat" (National People's Congress, March 14, 1997). Article 48 of the law requires local governments above the county level to compensate enterprises for economic losses related to the requisition of individuals or materiel, and does not distinguish between private enterprises and SOEs. **[7]** This provision clearly can lead to disagreements between the national government and localities or local enterprises on the value of economic losses if there are claims for compensation. Although regulations on mobilizing transportation resources were enacted in 2004, the National Defense Mobilization Law was not revised until 2010. **[8]** The revised law still provides for compensation when civil resources and personnel are requisitioned. It appears that the extended debate occurred due to resistance from provincial and local government administrations, as well as enterprise officials.

Early Complaints and Problems with the Mobilization System

In 2002, a long-term, 15-year plan for mobilization was promulgated. **[9]** However, by the end of the plan's term in 2017, it appeared that there were still problems with national and local government coordination; concerns in enterprises over revenue losses; and difficulties arising from the need for industries to operate in the civilian market while also making contributions to national defense. **[10]** Enterprises apparently objected to requirements to maintain and store supplies or equipment for mobilization. Private enterprises and SOEs also faced other problems: When personnel are mobilized, how can managers or owners keep a business running with trained staff? Who compensates enterprises if replacements are hired temporarily? And what entity pays salaries and benefits to mobilized personnel?

If it is an extended mobilization, or if entire product lines must be changed, a business may suffer financially or lose customers. Supply chains could shift, supplies could be diverted for military use, and even delivery vehicles could be taken for use in the mobilization. How does compensation work in such cases? Compensation for the "requisition of civilian resources" seems simple in principle, but contentious in practice. How long would it take to be compensated by the state or a higher body? If an enterprise suffers financial losses, how is that compensated? If an enterprise experiences a shortage of operating funds, does the state or a state-owned bank provide bridging loans?

Funding mobilization remains a thorny issue, and the problem of compensation for private parties whose goods have been requisitioned is part of the discussion. **[11]** Local governments wrestle with how to compensate owners of requisitioned vehicles, ships, personnel and supplies. Apparently, it is not uncommon for owners to avoid or refuse requisition orders. **[12]**

Problems regarding funding also exist between the national and local governments. A writer from the PLA Academy of Military Economics notes that during "sudden incidents," local governments rely on money and materials from the central government. However, before requesting funding from the central government,

local government civil affairs and financial departments must meet and agree on a proposal. This delays the arrival of aid, hampering response to incidents. Government agencies in charge of relief operations typically lack logistical support organizations, and have to scramble to find people and supplies when a crisis strikes. **[13]**

Some criticisms of the system, and recommendations for improvement, have come from military writers. For example, one group of PLA writers from the Hunan Military District has recommended modeling mobilization after the people's air defense system, which is a centrally managed system with a national-level organization exercising direct control over the subordinate organizations. **[14]** As will be seen immediately below, one of the most thorough examinations of problems in the militia mobilization system was presented earlier this year by reporters from *China National Defense News*.

The *China National Defense News* Investigation

In 2019, Meng Fanli (孟凡利), Wang Yu (王宇), and Chen Shidong (陈世东) visited militia units in military sub-districts in four provinces and a provincial level city to review how militia units assemble, train, and conduct joint operations. Some of the units were technical in nature, conducting operations with unmanned aerial vehicles (UAVs) or handling missile maintenance. Other units were training for disaster operations. In general, however, it appears that in "shaping new-quality combat power, there is still a long way to go." **[15]**

Evidently, problems noted in 2007 by earlier authors still impact the militia system today. **[16]** The three reporters found complaints from militia members that compensation was too low and that no allowances were provided for transportation to militia duties. Militia members complained that if they were injured or contracted an illness on militia duty, there was no health insurance or assistance from the locality or enterprise during recovery.

In one county in Hunan they learned that, although a specialized militia unit from a private enterprise had been tasked to provide 6 vehicles and 20 militia members, only 2 vehicles and 8 militia members showed up at the assigned place and time for training. In this instance, because enterprise owners complained they could not spare the people or equipment, the remedy was to recruit more militia members in multiple batches from other enterprises.

In a UAV-dedicated militia unit in Liaoning, the UAV team members were "indifferent and failed to perform on time, militiamen bargained over elements of assigned tasks, and there was no CCP organization in the militia unit"—and thus, no sense of national spirit or discipline. Meanwhile, in maritime support teams, militia members were untrained and did not know how to use their equipment. As a remedy, the People's Armed Forces Department (PAFD) ensured that at all levels of organization there was an appropriate level Party political officer and Party Branch. Further, militia Party Branch chiefs were told to coordinate with the Party branches chiefs embedded in private enterprises and SOEs.

In Tianjin, the three *China National Defense News* investigators found that there was no standardization for the civilian equipment carried or used by militia members to perform assigned tasks. In this case, the PAFD set up contractual agreements with private enterprises to ensure that standard, good quality equipment was issued to militia members; and that enterprise owners were compensated if equipment was lost or damaged. **[17]**

Conclusion

Militia and reserve units in today's PLA remain dedicated to providing support to active duty forces in order to "win people's war under informatized conditions" (打赢信息化条件下人民战争, *daying xinxihua tiaojian xia renmin zhanzheng*). **[18]** However, much of the support now required is far more complex than in the past, involving skills such as network services, computer defense, missile repair, and aircraft maintenance. And all is not well under heaven: it appears that enterprises have been assigned the worst equipment (or insufficient equipment) for militia use, and also have not been providing enough qualified personnel to carry out mobilization tasks.

Militia mobilization today requires more than pulling farmers out of the fields or using drivers from SOEs. The future will bring more tension between local governments, provinces, enterprises and the national government; and it is unlikely that an increasing Party presence in militia units and enterprises will resolve the issues. The Party and the PLA will face some dilemmas: to adequately train modern militia and reserve units for combat or disasters when mobilized, there must be regular, standardized training. Enterprise owners and managers, however, will worry about how to replace mobilized personnel, maintain production lines, and obtain compensation for materiel and manpower.

These tensions will be played out in National People's Congress meetings and CCP Central Committee meetings, where senior Party officials from provinces, counties and enterprises will complain about lost time, wages, and materiel. For the Central Military Commission, the dilemma will be whether to focus on ensuring that militia and reserve units are immediately available for service, with the right equipment, when mobilized; or, whether after mobilization poorly trained, manned and equipped forces will be put into situations that require weeks to months more training. In wartime that translates into being unprepared for the battlefield, and in disaster relief it means being unprepared to provide necessary assistance. The PRC still has a long way to go before achieving its goal of achieving effective "military-civil fusion" in the militia sector.

Larry Wortzel is a veteran Asia scholar, who served two tours of duty as a military attaché in the American Embassy in China—including during the Tiananmen Massacre of 1989. Since retirement from the U.S. Army, Dr. Wortzel has served as director of the Asian Studies Center at The Heritage Foundation, and as a longstanding member of the U.S.-China Economic and Security Review Commission. He is also a member of the Council on Foreign Relations and the International Institute of Strategic Studies.

Notes:

[1] See Li Jijun (李际均), *Military Theory and War Practice* (*Junshi Lilun Yu Zhanzheng Shijian* 军事理论与战争实践) (Beijing: Military Science Publishing House, 1994), 40–64, 100–122; Paul H.B. Godwin, "China's Defense Establishment: The Hard Lessons of Incomplete Modernization," in Laurie Burkitt, Andrew Scobell and Larry M. Wortzel, eds., *The Lessons of History: The People's Liberation Army at 75* (Carlisle, PA: Strategic Studies Institute, 2003), 15–57; also see Mao Zedong, "On Protracted War," May 1938, in *Selected Works of Mao Tse-Tung, Volume II* (Beijing: People's Publishing House, 1965), 113–194.

[2] Zhao Xueqing (赵学清) and Cui Zhanli (崔战利), eds., *Overview of National Economic Mobilization* (*Guomin Jingji Dongyuan Gailun* 国民经济动员概论) (Beijing: PLA Publishing House, 2000), 61, 77.

[3] Xi Jinping (习近平), "Focusing on implementing the military-civilian integration development strategy, promoting major military reform tasks across the military, and promoting economic development and national defense integration (*Zhuoyan yu Guanche Junmin Ronghe Fazhan Zhanlue, Tuijin Kua di Zhongda Gaige Renwu, Tuidong Jingji Jianshe he Guofang Ronghe Fazhan* 着眼于贯彻军民融合发展战略， 推进跨军地重大改革任务， 推动经济建设和国防融合发展0," in *Extract of Important Expositions on Deepening National Defense and Army Reform* (*Guanyu Shenhua Guofang he Jundui Gaige Zhongyao Lilun Zhaibian 关于深化国防和军队改革重要论述摘编*) (Beijing, PLA Publishing House, 2016), 84–97.

[4] Xi Jingping (习近平), "Speech at the Expanded Meeting of the Central Military Commission, November 16, 2012 (*Zai Zhongyang Junwei Kuoda Huiyi de Jianghua* 在中央军委扩大会议上的讲话)," *Selected Works on National Defense and Army Building* (*Guanyu Guofang he Jundui Jianshe Zhongyao Lilun Xuanbian 关于国防和军队建设重要论述选编*) (Beijing, PLA Publishing House, 2014), 8–18.

[5] See: Ling Xi (凌希), "Development in Military-Civil Integration in National Defense Mobilization (Guofang Dongyuan Junmin Ronghe Fazhan 国防动员军民融合发展)," *China Military Science* (Zhongguo Guofang Kexue 中国军事科学), Iss. 161, no 5, (October 2018): 104–111; Sun Zhaobin (孙兆斌) and Jin Lin (金琳), "Modes of Military-Civil Integration with Chinese Characteristics and Their Game Features (*Zhongguo Tese de Junmin ronghe Moshi Ji Qi Boqi Texing* 中国特色的军民融合模式及其博弈特性)," *China Military Science* (*Zhongguo Guofang Kexue* 中国军事科学), Iss. 162, no 6, (December 2018): 115–122; Meng Fanli (孟凡利), Wang Yu (王宇), and Chen Shidong (陈世东), "Break new Ground in Getting Stronger, Take Firmer Strides in Builidng Elite Forces—Surveys and Thoughts on Militia Building in the New Domains (*Kai Xin Tuqiang Lie Zou Xiang Jingrui de Bufa Kengqiang—Dui Xinxing Lingyu Junmin de Diaocha yu Sikao* 开新图强烈走向精锐的步伐铿锵—对新兴领域民兵建设的调查与思考)," *China National Defense Report* (*Zhongguo Guodang Bao 中国国防报*), June 18, 2019, 3.

[6] See: The Civil Air Defense Law of the People's Republic of China, accessible at http://www.china.org.cn/china/military/2007-07/27/content_1218752.htm; and the draft version of the National Defense Transportation and Communication Law, accessible at http://www.gfdy.gov.cn/trans/2014-10/20/content_6186688.htm. A summary of the laws and regulations is on the web site of the State Commission for National Defense Mobilization, www.gfdy.gov.cn.

[7] Xu Kui (徐奎) and Cao Yanzhong (曹延中), "The Evolutionary History of the National Defense Mobilization System in New China (*Xin Zhongguo Guofang Dongyuan Tizhi De Lishi Yanbian* 新中国国防动员体制的历史演变)," *Military History* (*Junshi Lishi* 军事历史), No. 2 (2007),19.

[8] See: Regulations on National Defense Mobilization of Civil Transport resources (Revised), State Council and Central Military Commission Order 391, http://eng.mod.gov.cn/publications/2017-03/03/content_4774225.htm: National Defense Mobilization Law of the People's Republic of China [Effective July 1, 2010], Order of the President of the People's Republic of China No. 25 http://eng.mod.gov.cn/publications/2017-03/03/content_4774223.htm.

[9] Xu Kui (徐奎) and Cao Yanzhong (曹延中), "The Evolutionary History of the National Defense Mobilization System in New China (*Xin Zhongguo Guofang Dongyuan Tizhi De Lishi Yanbian* 新中国国防动员体制的历史演变)," *Military History* (*Junshi Lishi* 军事历史), No. 2 (2007): 19; and "Cao Gangchuan (曹刚川) Stressed: The Building of National Defense Mobilization to a New Level (*Cao Gangchuan Qiangdiao: Ba Guofang Dongyuan Ge Xiang Jianshe Tigao Dao Xin Shuiping* 曹刚川强调: 把国防动员各项建设提高到新水平)," Sina.com, August 7, 2003, http://news.sina.com.cn/c/2003-08-07/0758520237s.shtml.

[10] Chen Guoquan (陈国全) "Integration of military and civilian , releasing new kinetic energy," (*Junmin Ronghe. Jiefang Qiangguo Qiangjun Xin Dongneng* 军民融合， 释放强:国强军新动能), PLA Daily (*Jiefangjun Bao* 解放军报), September 26, 2017; Yu Chuanxin (于川信), "Large-scale layout of military-civilian Integration of national strategy (*Guojia Zhanlue de Junmin Ronghe Da Bu Ju* 国家战略的军民融合 大布局)," PLA Daily (*Jiefangjun Bao* 解放军报), August 01, 2017, 24; Chen Zhuo (陈卓), "The Integration of the military and the people is also heavy and deep (*Junmin Ronghe Zhongkuan yu Zhongshen* 军民融合 重宽亦重"深)," PLA Daily (*Jiefangjun Bao* 解放军报), December 22, 2017, 10.

[11] Li Ziyao, Kong Zhaojun 李紫瑶, 孔昭君, "Building of an Emergency Supply Chain Under National Economic Mobilization Conditions (*Guomin Jingji Dongyuan Zhuangtai Xia De Weitai Gongying Lian Goujian* 国民经济动员状态下的危态供应链构建)," *Soft Science* (*Ruan Kexue* 软科学), No. 8 (2012): 27.

[12] Peng, Li and Li, "Views on Raising the Level of National Economic Mobilization at the County Level," 30.

[13] Liu Kaifeng (刘凯峰), "A Discussion of the Emergency Response Function in National Economic Mobilization (*Tan Guomin Jingji Dongyuan De Yingji Gongneng* 谈国民经济动员的应急功能)" *Military Economic Research* (*Junshi Jingji Yanjiu* 军事经济研究), No. 8 (2008): 31.

[14] Peng Qunwen (彭群文), Li Hongquan (李宏泉), and Li Lesi (李乐思), "Views on Raising the Level of National Economic Mobilization at the County Level (*Tisheng Xianji Guomin Jingji Dongyuan Shuiping Zhi Wojian* 提升县级国民经济动员水平之我见)," *Junshi Jingji Yanjiu* 军事经济研究 [Views on Raising the Level of National Economic Mobilization at the County Level, Views on Raising the Level of National Economic Mobilization at the County Level, *Military Economic Research* (*Junshi Jingji Yanjiu*军事经济研究) No. 7 (2009): 29.

[15] Meng Fanli (孟凡利), Wang Yu (王宇), and Chen Shidong (陈世东), "Break new Ground in Getting Stronger, Take Firmer Strides in Builidng Elite Forces—Surveys and Thoughts on Militia Building in the New Domains (*Kai Xin Tuqiang Lie Zou Xiang Jingrui de Bufa Kengqiang—Dui Xinxing Lingyu Junmin de Diaocha yu Sikao* 开新图强烈走向精锐的步伐铿锵—对新兴领域民兵建设的调查与思考)," *China National Defense News* (*Zhongguo Guofang Bao* 中国国防报), June 18, 2019, 3.

[16] See Note 7.

[17] Meng Fanli (孟凡利), Wang Yu (王宇), and Chen Shidong (陈世东), "Break new Ground in Getting Stronger, Take Firmer Strides in Builidng Elite Forces—Surveys and Thoughts on Militia Building in the New Domains (*Kai Xin Tuqiang Lie Zou Xiang Jingrui de Bufa Kengqiang—Dui Xinxing Lingyu Junmin de Diaocha yu Sikao* 开新图强烈走向精锐的步伐铿锵—对新兴领域民兵建设的调查与思考)," *China National Defense News* (*Zhongguo Guofang Bao* 中国国防报), June 18, 2019, 3.
[18] *Ibid.*

***

Military-Civil Fusion and Electromagnetic Spectrum Management in the PLA

By John Dotson

Introduction: EMSM as a Key Element of "Military-Civil Fusion"

Modern battlefield environments will contain a greater proliferation of electromagnetic emitters than ever before—including but not limited to radars, communications networks, and jamming systems—employed by many different platforms across multiple warfare domains. As a result, electromagnetic spectrum management (EMSM) is a discipline growing steadily in importance for modern military forces. The U.S. Department of Defense defines EMSM as "planning, coordinating, and managing joint use of the [electromagnetic spectrum] through operational, engineering, and administrative procedures… [intended] to enable EMS-dependent capabilities and systems to perform their functions in the intended environment without causing or suffering unacceptable interference." **[1]**

Amid the course of Chinese military modernization and reform, the People's Liberation Army (PLA) is well aware of the importance of electronic warfare in modern battlefield environments (China Brief, April 9, 2018; China Brief, February 1). PLA writers are also fully aware of the importance of electromagnetic spectrum management (电磁频谱管理, *dianci pinpu guanli*), and have stated that "electromagnetic space is the 'sixth domain of battle' alongside the land, sea, air, space, and internet, and is of critical function for victory or defeat in war." **[2]**

Official Chinese media sources have identified EMSM as a key component of broader efforts by the Chinese Communist Party (CCP) to implement a policy of "military-civil fusion" (军民融合, *jun-min ronghe*) throughout both the PLA and civilian industry: as stated by one source early in 2017, "EM spectrum management is an important realm for deepening the development strategy of military-civil fusion" (Zhongguo Jun Wang, February 23, 2017). Accordingly, the PLA is engaged in an ongoing effort to coordinate with civilian officials regarding shared use of the EM spectrum. It is also engaged in creating specialist EMSM reserve units intended to leverage the material resources and skilled personnel resident in civilian industry.

Who Bears Responsibility for Military EM Spectrum Management?

National-level policy direction for military EMSM is a joint effort that, as early as 2006, was coordinated by the predecessor organizations of the Ministry of Industry and Information Technology (MIIT) (工业和信息化部, *Gongye he Xinxihua Bu*) and the PLA Joint Staff Department (GSD) (联合参谋部, *Lianhe Canmou Bu*). **[3]** The two successor organizations appear to maintain this shared role. Furthermore, this parallel civilian-military responsibility is mirrored at local levels: per press coverage of a spring 2018 EMSM planning conference in Hainan, provincial-level MIIT offices [省工业和信息化厅, *sheng Gongye he Xinxihua Ting*] and provincial-level military districts [省军区, *sheng junqu*] coordinate on local implementation of higher-level policy guidance for EMSM (Hainan Provincial Government, February 9, 2018).

In many Chinese-language references regarding EMSM, the process of coordinating military and civilian resources is also referred to as "military-local radio management" (军地无线电管理, *jun-di wuxiandian guanli*), with the two terms used interchangeably *(see image below)*.**[4]** Per the *People's Republic of China Radio Management Regulations* published in 2016: "In establishing radio management coordinating mechanisms, military and local officials will share the division of radio frequencies, and consult on and resolve both military system and civilian system radio management arrangements." **[5]** Personnel and resources from the civilian "radio management system" [无线电管理机构, *wuxiandian guanli jigou*] of the area in question are key to this process. These regional radio management centers report to the National Radio Spectrum Management Center (国家无线电频谱管理中心, *Guojia Wuxiandian Pinpu Guanli Zhongxin*) in Beijing, which itself is subordinate to MIIT. **[6]**

Image: An April 2018 conference convened in Haikou (Hainan Province) to discuss the coordination of "radio management" between regional civilian and military officials. The conference was organized by the Hainan Radio Supervision and Management Agency, and reportedly included representatives from 13 agencies, including: the PLA Southern Theater Command, Hainan Military District, the South Sea Fleet, provincial People's Armed Police, fire fighters, frontier guards, and the maritime police.
(Source: Hainan Provincial Government)

The PLA Reserve Electromagnetic Spectrum Management Center

Over the past decade, the PLA has carved out a prominent role for its reserve component in working with issues related to EMSM. One of the PLA's most prominent institutions for EMSM issues is the "All-Army Reserve Electromagnetic Spectrum Management Center" (全军预备役电磁频谱管理中心, *Quanjun Houbeiyi Dianci Pinpu Guanli Zhongxin*) (hereafter "EMSM Center"), which was established in Beijing in January 2010. The EMSM Center has a mission to "advance the development of military-civil fusion, promote the important innovation and initial practice of our army's reserve troops restructuring and reform, [and] to safeguard the security of electromagnetic space, deepening preparations for military struggle" (PLA Daily, January 26, 2010). The EMSM Center is widely engaged in organizing training drills and exercises for EMSM-oriented reserve units *(see discussion further below).*

The EMSM Center also appears to play a role in fostering coordination between provincial and local-area civilian and military officials. In April 2017 the EMSM Center organized a conference in Beijing—alongside representatives of MIIT and the radio management departments of Beijing, Tianjin, Hebei, and Inner Mongolia—to discuss the delineation of roles between military and civilian agencies. An official PLA news website described this conference as an important event that "clarified the methods and way forward for inspecting regions and managing electromagnetic space in actual combat." Coverage of this conference emphasized a leading role for the civilian radio management departments: "Local radio management departments are [to be] responsible for spectrum resource distribution, and clearing the regional EM environment and other missions; working in tandem with provincial and city radio management departments to be responsible for key frequency protection, and investigation and resolution of harmful interference." Furthermore, "leadership by MIIT radio management bureaus is a clear requirement" to coordinate efforts among work units, and "to evaluate local EM space management and control abilities in combat exercises." **[7]**

Electromagnetic Spectrum Management PLA Reserve Units

Pursuant to its effort to merge military and civilian resources for EMSM, the PLA is actively engaged in creating "reserve frequency management units" (预备役频管部队, *yubeiyi pinguan budui*), which are intended to help the PLA successfully navigate the complex electromagnetic pitfalls of both major peacetime events and potential future conflicts. These units have been employed in recent field training exercises across multiple regions of China *(see discussion further below).* PLA sources have touted such units as "our army's first new model of reserve units relying on the national enterprise system" (Zhongguo Jun Wang, June 2, 2018)—thereby implying that they represent a vanguard for future units in other specialty areas, which will similarly draw upon the resources of state-controlled industry.

These units appear to be closely linked to, and to share resources with, regional civilian radio management centers. For example, in November 2014 Yin Tiehua (尹铁华), then-director of the EMSM Center, made an

inspection tour of the radio management agency in the city of Ji'An, Jiangxi Province (*see image below*). Local government coverage of this visit indicated that the center is associated with the provincial EMSM reserve group (省预备役电磁频谱管理大队, *sheng yubeiyi diance pinpu guanli dadui*), and that the agency's facilities host the "Reserve Force Ji'An Monitoring Station" (预备役吉安监测站, *Yubeiyi Ji'An Jiance Zhan*). **[8]**

Image: Yin Tiehua (military uniform, fourth from left), then-director of the PLA Reserve EMSM Center, conducts an inspection tour of the facilities at the Ji'An City (Jiangxi Province) Radio Management Agency in November 2014. (Source: Jiangxi Province MIIT Office)

It is standard practice for PLA reserve units to contain a core cadre of active-duty personnel, **[9]** and this is true as well for the reserve EMSM units. One article about such units described in positive terms a "radiation effect of 10 active duty soldiers and 100 reserve officers and soldiers" (十余名现役军人+百余名预备役官兵的辐射效应, *shi yu ming xianyi junren + bai yu ming yubeiyi guanbing de fushe xiaoying*), with the implication that reservists will benefit from exposure to the presumed greater professionalism of active-duty personnel. This same source also quoted an official from the EMSM Center as saying that "military-civil fusion is a lever [by which] ten active-duty soldiers can leverage 100 reserve soldiers; these 100 reserve soldiers are all radio industry expert personnel, and they leverage broader resources" to achieve successful results (Zhongguo Jun Wang, June 2, 2018).

Profile of a PLA Reserve EMSM Unit

One illustrative example of a PLA reserve force EMSM unit is the Guangdong Reserve EMSM Group Mobile Monitoring Third Unit (广东预备役电磁频谱管理大队机动监测三队, *Guangdong Yubeiyi Dianci Pinpu Guanli Dadui Jidong Jiance San Dui*). This unit is composed primarily of personnel from the cities of Shantou, Meizhou, Shanwei, Jieyang, and Chaozhou. Many unit members are employees recruited from state-owned companies in the telecommunications sector—to include China Telecom (中国电信, *Zhongguo Dianxin*),

China Mobile (中国移动, *Zhongguo Yidong*), China Unicom (中国联通, *Zhongguo Liantong*), and China Tower (中国铁塔, *Zhongguo Tieta*)—as well as "radio enthusiasts from eastern Guangdong." This unit conducted training drills in December 2018 associated with a marathon race in Shantou; the unit activities focused on "simulating the emergence of major incidents, setting up and safeguarding emergency communications and power supplies, simulating searches for origins of [signals] interference, and UAV operations." **[10]**

Image: Members of the Guangdong Reserve EMSM Group Mobile Monitoring Third Unit pose for a group photograph, December 2018. (Source: Shantou City Government)

Image: The "UAV Control First Detachment," a component of the Guangdong Reserve EMSM Group Mobile Monitoring Third Unit, conducts UAV operations during training activities near the city of Shantou, December 2018. (Source: Shantou City Government)

Conferences and Exercises Seek to Develop EMSM Proficiencies

Military-Civilian EMSM Conferences

The PLA and civilian authorities are also seeking to advance coordination and share EMSM best practices via national conferences. One of the earliest such conferences was convened in October 2013, when approximately 90 representatives drawn from "information technology departments under the headquarters of various military area commands and various services and arms of the PLA" convened in Chengdu (Sichuan Province). In the course of the discussions, "the information technology departments under the headquarters of the Shenyang [military area command], the Nanjing [military area command], and the Second Artillery Force exchanged their experience of military-civilian monitoring network interconnection and [EMSM] information services… and the [EMSM] center of the PLA's reserve force introduced its achievements based on China's radio industry" (China Military Online, October 16, 2013).

In addition to the April 2017 conference organized by the EMSM Center *(see previous discussion)*, at least one other national conference was held in 2017: the "National Radio Management Work Forum" held on February 17, 2017 in Nanning (Guangxi Province), which involved representatives from 12 provinces and municipalities. During this event, representatives from Hebei, Inner Mongolia, and Hainan shared experiences on matters such as battling "black broadcasts" (黑广播, *hei guangbo*) and safeguarding frequencies for the safe operation of military and commercial aviation. MIIT officials were specifically mentioned as exercising a leadership role in the conference (Zhongguo Jun Wang, February 23, 2017).

EMSM Military Exercises

The PLA has been increasingly engaged in organizing EMSM training drills and exercises, in which the Reserve EMSM Center plays a prominent role. Many EMSM exercise activities described in official media revolve around the use of mobile monitoring teams to track down local area sources of inadvertent EM interference with military transmitters (PLA Daily, May 10, 2016). Additionally, one of the missions of the regional radio monitoring centers and their reserve units is to "uphold social harmony and stability" (维护社会和谐稳定, *weihu shehui hexie wending*).**[11]** This point suggests a potential overlap of missions for EMSM reserve units—to include not only preparations for military conflict, but also civil defense and domestic surveillance—a supposition reinforced by EMSM reserve units conducting training in conjunction with major public events.

Two recent exercises serve as illustrative examples. In early December 2018, the EMSM Center organized the "Ice Sharpens the Sword" (冰雪砺剑, *Bing Xue Li Jian*) exercise in the vicinity of Arxan (阿尔山), in eastern Inner Mongolia. The field exercise was reportedly part of an effort to train EMSM personnel for military operations, as well as to provide cold weather training for EMSM missions to be organized in support of the 2022 Winter Olympics. Personnel from 12 provinces or municipalities participated, including both

active-duty and reserve PLA personnel. Coverage of this exercise also mentioned participation by expert civilian technical personnel: this included not only civilian "local personnel" (地方人员, *difang renyuan*) drawn from Inner Mongolia's radio management bureaucracy, but also observing experts such as Zhao Yang (赵杨), a PhD faculty member from the PLA National Defense Technology University (Zhongguo Guofang Bao, December 14, 2018).

Images: Photos of PLA EMSM personnel taking part in the "Ice Sharpens the Sword" exercise held in early December 2018 in the vicinity of Arxan (阿尔山), *eastern Inner Mongolia.*
(Source: China National Defense News)

In August 2019, the EMSM Center hosted another exercise and competition in the vicinity of Korla (库尔勒) in central Xinjiang. Per the official *National Defense News*, this event involved a mix of 25 military and civilian work teams, to include participants from unidentified foreign countries. For purposes of the training exercise, the EMSM Center commandeered usage of eight local fixed ultrashort wave frequency monitoring stations and four mobile vehicles from local authorities. The EMSM Center also borrowed the use of two UAV control vehicles from the Xinjiang Radio Management Agency in order to watch for and identify unidentified aircraft (such as small UAVs) that might make unauthorized entrance into the exercise area—thereby indicating potential plans by the PLA to employ reserve EMSM units to assist with clearing physical airspace, as well as monitoring the EM airwaves (Guofang Bao, August 15).

Conclusion

The PLA's paradigm for civil-military EMSM coordination appears to be an evolving process. Media coverage of recent PLA conferences and exercises suggests that regional radio management agencies, under the overall cognizance of MIIT, will bear responsibility for frequency allocation and deconfliction between military units and civilian transmitters. However, if this is true, civilian agencies would be called upon to exercise a limited measure of command and control over PLA units—at least in the specific area of EM frequency assignment—and the specific mechanisms by which this would be accomplished remain unclear.

Questions also remain regarding the future operational deployment of EMSM reserve units. Recent exercise and training activities indicate that these units are, at a minimum, being prepared to monitor for sources of EM interference that could impact PLA and civil defense operations during wartime, natural disasters, or major public events. However, the serious attention given to these units—and the fact that technical experts from civilian industry, to include the telecom sector, are being actively recruited—suggests that they may be called upon to perform more ambitious roles in the future.

The prominence given to EMSM issues in official media, and the widespread effort on the part of the PLA and civil institutions to build mechanisms for EMSM coordination, indicate that the Chinese government is serious about EMSM—both as a practical requirement for effective military operations, and as a proof of concept for the high-priority MCF policy initiative advocated by the Party leadership. Progress in the field of EMSM could provide both a significant step forward in PLA capabilities, as well as a successful test model for the pursuit of MCF in other disciplines.

The author is grateful to Larry Wortzel (Col., U.S. Army, retired) and Dennis Blasko (LtCol., U.S. Army, retired) for their comments on an initial draft of this article. Any errors or omissions are solely my own responsibility.

John Dotson is the editor of China Brief*. Contact him at: cbeditor@jamestown.org.*

Notes

[1] U.S. Department of Defense, *Joint Publication 6-01: Joint Electromagnetic Spectrum Management Operations* (March 2012), p. viii. https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp6_01.pdf.

[2] "All-Army Reserve EMS Management Center Organizes the 'Ice Sharpening the Sword' Practical Combat Exercise" [全军预备役电磁频谱管理中心组织“冰雪砺剑-2018”实战化训练], *PLA Daily*, Dec. 14, 2018. https://baijiahao.baidu.com/s?id=1619790715663137438&wfr=spider&for=pc.

[3] The former PRC Ministry of Information Industry (信息产业部, *Xinxi Chanye Bu*) was incorporated into the current PRC Ministry of Industry and Information Technology (工业和信息化部, *Gongye he Xinxihua Bu*) in 2008. The former PLA General Staff Department (总参谋部, *Zong Canmou Bu*) was reorganized as the Central Military Commission Joint Staff Department (中央军委联合参谋部, *Zhongyang Junwei Lianhe Canmou Bu*) in 2016. For discussion of the two predecessor organizations conducting coordination on EMSM issues, see: "2006 Military-Local Radio Management Joint Conference is Convened in Beijing" [2006年军地无线电管理联席会议在北京召开], *Sina.com*, May 23, 2006, https://tech.sina.com.cn/t/2006-05-23/1639952051.shtml.

[4] The author encountered many examples of this in the research for this article. To cite but one example, see: Hainan Province Convenes a Symposium on Military-Local Radio (Electromagnetic Spectrum) Management Work in Haikou" [海南省军地无线电(电磁频谱)管理工作座谈会在海口召开], Hainan Provincial Government, Sep. 2, 2018, http://web.hainan.gov.cn/dofcom/zwdt/201809/dc0cbc39dd57487597c695ad327e59fd.shtml.

[5] "People's Republic of China Radio Management Regulations" [中华人民共和国无线电管理条例] (section 2, article 11), joint publication of the PRC State Council and the Central Military Commission, Dec. 1, 2016, http://www.gov.cn/zhengce/content/2016-11/25/content_5137687.htm . [Original text: "第二章, 第十一条 军地建立无线电管理协调机制，共同划分无线电频率，协商处理涉及军事系统与非军事系统间的无线电管理事宜。无线电管理重大问题报国务院、中央军事委员会决定。"]
[6] "Center Introduction" [中心介绍], PRC National Radio Spectrum Management Center, undated, http://www.srrc.org.cn/about.aspx.
[7] "Do You Understand Military-Civil Fusion in the Domain of EMSM?" [电磁频谱管理领域的军民融合你了解吗], *Zhongguo Jun Wang* [中国军网], April 26, 2017, http://www.81.cn/zgyby/2017-04/26/content_7577925.htm; and "All-Army Reserve EMSM Management Center: Training to Accomplish Great Tasks with Clever Actions" [全军预备役电磁频谱管理中心:四两拨千斤这样炼成], *Zhongguo Jun Wang*, June 2, 2018. http://www.81.cn/jwgz/2018-06/02/content_8048719_2.htm.
[8] All-Army Reserve EMSM Center Director Yin Tiehua Arrives to Inspect and Guide Work in Ji'An" [全军预备役频管中心尹铁华主任一行莅临吉安局视察并指导工作], Ji'An City (Jiangxi Province) Radio Management Bureau, Nov. 28, 2014. http://jxciit_www.jxciit.gov.cn/(S(wwhfwp55srj5dbvgt0ztax55))/Item.aspx?id=35519.
[9] Dennis J. Blasko, *The Chinese Army Today: Tradition and Transformation for the 21st Century* (Routledge, 2012), p. 26.
[10] "2018 Guangdong EMSM Group Mobile Monitoring Third Unit Training Assembly Successfully Completes Shantou Marathon Radio Security Drill Activities" [2018年广东预备役电磁频谱管理大队机动监测三队集训暨汕头马拉松无线电安全保障演练活动成功收官], Shantou City Economic and Informationization Office [汕头市经济和信息化局], Dec. 19, 2018. http://www.shantou.gov.cn/jxj/gzdt/201812/1588a4f0ce034a30b36c2bb8f1a061d0.shtml.
[11] All-Army Reserve EMSM Center Director Yin Tiehua Arrives to Inspect and Guide Work in Ji'An" [全军预备役频管中心尹铁华主任一行莅临吉安局视察并指导工作], Ji'An City (Jiangxi Province) Radio Management Bureau, Nov. 28, 2014. http://jxciit_www.jxciit.gov.cn/(S(wwhfwp55srj5dbvgt0ztax55))/Item.aspx?id=35519.

***

China's Military Biotech Frontier: CRISPR, Military-Civil Fusion, and the New Revolution in Military Affairs

By Elsa B. Kania and Wilson VornDick

Introduction

China's national strategy of military-civil fusion (军民融合, *junmin ronghe*) has highlighted biology as a priority. **[1]** It is hardly surprising that the People's Republic of China (PRC) is looking to leverage synergies

among defense, scientific, and commercial developments in biological interdisciplinary (生物交叉, *shengwu jiaocha*) technologies. Chinese military scientists and strategists have consistently emphasized that biotechnology could become a "new strategic commanding heights of the future Revolution in Military Affairs" (军事革命, *junshi geming*) (PLA Daily, October 2015). Certainly, the PRC is not alone in recognizing the potential of biotechnology on the future battlefield, but the ways in which Chinese research is seeking to integrate developments among industry, academic institutions, and military-oriented programs—including through research collaborations and the procurement of dual-purpose commercial technologies—may prove striking. In particular, China is at the forefront of today's breakthroughs in CRISPR-Cas, a new technique for gene editing that has demonstrated unique potential and precision despite its current limitations. **[2]**

The Biological Revolution in Military Affairs

Chinese military officers and scientists anticipate that current advances will contribute to an ongoing transformation in the character of conflict. Indeed, senior officers and academics in the Chinese People's Liberation Army (PLA) have not only highlighted concerns about "national biological security (and) defense" (国家生物安全防御, *guojia shengwu anquan fangyu*) in response to the threats of infectious diseases, but also emphasized the importance of exploring the military potential and even offensive applications of biotechnology (China News Network, February 15, 2012; Ministry of Science and Technology, April 18). **[3]** For instance, Senior Colonel Guo Jiwei (郭继卫) of the PLA's Third Military Medical University co-authored *War for Biological Dominance* (制生权战争, *Zhishengquan Zhanzheng*), which examined the impact of biotechnology on the Revolution in Military Affairs. **[4]** The concept *zhishengquan* (制生权), which might be translated variously as "biological dominance" or "command/superiority in biology," is starting to become more prevalent in PLA writings on future warfare of varying degrees of authoritativeness. **[5]**

Notably, Major General He Fuchu (贺福初), former president of the Academy of Military Medical Sciences (AMMS) and now vice president of the Academy of Military Sciences, has long been a prominent proponent of the militarization of biotechnology (PLA Daily, October 6, 2015). Maj. Gen. He has anticipated that "Modern biotechnology and its integration with information, nano(technology), and the cognitive, etc. domains will have revolutionary influences upon weapons and equipment, the combat spaces, the forms of warfare, and military theories" (Reference News, August 24, 2017). Consequently, pursuant to this new "Revolution in Military Affairs," success on the future battlefield will require achieving "biological dominance," and this "biological frontier" (生物疆域, *shengwu jiangyu*) of warfare will emerge as a new domain for new methods of confrontation. In the course of this transformation, the progress of such techniques as brain-machine interfaces could render human-machine integration (人机一体化, *renji yitihua*) a reality for future combat platforms. For instance, AMMS researchers have engaged with a commercial enterprise known as Cogrowth (酷成长, *ku chengzhang*) that specializes in the development of a line of products involving electroencephalograms (EEG) for brain-computer interfaces, which is exploring leveraging artificial intelligence to interpret bio-signals (Economics Daily, December 25, 2017; Sina, December 28, 2017).

Chinese military researchers have closely examined American initiatives and international advancements, which have seemed to inform and inspire the direction of developments underway in China today. For instance, DARPA's launch of the Biological Technologies Office has drawn attention, and PLA scholars have also examined exotic accounts Russia's "zombie gun" (僵尸枪, *jiangshi qiang*), based on electromagnetic radiation, and referenced supposed Israeli programs to target Arabs with genetic weapons (Sohu, 2012). **[6]** The salience of these concerns about foreign programs and the tragedy of China's own history does not appear to have resulted in restraint against considering the potential operational advantages of such offensive applications. **[7]** For instance, although writings about "genetic weapons" should not be interpreted as official doctrine or formal concepts of operations, it is noteworthy to see striking parallels in themes repeated by a number of PLA scholars and scientists from influential institutions.

基因武器如何影响未来战争

Image: A November 10, 2017 article from the PLA Daily *titled: "How Gene Weapons Could Affect Future Warfare" (*基因武器如何影响未来战争*, Jiyin Wuqi Ruhe Yingxiang Weilai Zhanzheng).*
(Source: Baijiahao)

Certain discussions about the future of "military struggle in the domain of biology" are troubling. For instance, seemingly authoritative textbooks have included references to the possibility of "specific ethnic genetic attacks" (特定种族基因攻击, *teding zhongzu jiyin gongji*), while other military experts characterize the notion of a "ethic bionation" as erroneous (China News, July 19, 2018). **[8]** According to Gen. Zhang Shibo (张仕波), former president of the PLA's National Defense University, today's biotech advances unlock the possibility to create new synthetic pathogens that are "more toxic, more contagious, and more resistant." **[9]** "Obviously, genetic weapons possess many advantages over traditional biological weapons," as one researcher from the Academy of Military Medical Sciences has argued (China Military Network, November 10, 2017). In particular, the weaponization of CRISPR is expected to prove more lethal and more precise in

ways that could cause major changes in the dynamics of future warfare, despite the risks that would be inherent in its employment and the current limitations of this nascent technology. In the long term, genetic weapons are anticipated to have more of a "strategic deterrent function," and the AMMS researcher has warned that "willful abuse of genetic weapons will bring unpredictable disasters to all mankind" (China Military Network, November 10, 2017). Such theories and speculation about future capabilities could become actual possibilities for the PLA pursuant to academic and commercial research that is currently underway.

CRISPR at the Frontier in China

At the most basic level, "CRISPR" is a tool for gene editing that possesses immense potential for precise and efficient modifications. **[10]** Chinese scientists across academic institutions and commercial enterprises have been at the forefront of experimentation with this technique from the start, including the company BGI (formerly known as "Beijing Genomics Inc."), which also manages China's National Genebank. **[11]** PRC research in CRISPR has rapidly progressed into clinical trials that involve the application of these gene editing techniques to animals and to humans, including because some of the regulatory requirements for medical research in China have been less strict and demanding. **[12]** For instance, there are currently at least fourteen trials of CRISPR underway across Chinese hospitals, which are primarily exploring its potential to treat cancer. **[13]** Strikingly, PLA medical institutions, particularly the PLA General Hospital and also the Academy of Military Medical Sciences, are involved in five of the trials known to be underway at present. **[14]**

To date, the use of CRISPR in animals has been a very prominent element of Chinese research. **[15]** For example, the use of gene-edited animals to grow human-like organs for use in transplants may prove not only lucrative but also medically promising, given continued shortages of organs (Bloomberg, August 10)**.** The creation of highly muscular dogs for use in policing illustrates the potential for gene-edited animals to contribute to state coercion (MIT Review, October 19, 2015). Meanwhile, BGI has attempted to market cloned or gene-edited animals, including 'micro-pigs' as pets, and another company, Beijing Xinuo Valley Biotechnology Co. Ltd. (北京希诺谷生物科技有限公司) has cloned a number of dogs as pets and for policing (Netease S&T, August 22). Chinese researchers have leveraged gene editing of animals to optimize their use as models for human diseases or characteristics, such as the study of intelligence. For instance, Mu-Ming Pu (蒲慕明), who has been a leader in designing the "China Brain Plan," has pursued cloning and genetic alteration of macaque monkeys at the Institute of Neuroscience (ION) in Shanghai to "customize" them for specific research requirements. **[16]** For instance, by rendering the gene BMAL1 (which is linked to the circadian sleep rhythm) inoperable with CRISPR, the ION team has sought to create and study circadian disorders, such as sleep disorders and depression. **[17]**

Although CRISPR has numerous exciting, clearly beneficial applications, particularly in medicine and agriculture, other aspects of Chinese research in CRISPR raise ethical or security concerns. **[18]** Infamously, the first humans to be subject to genetic engineering were also born in China as a result of the research of He Jianqui, who removed the gene CCR5 to give twin babies immunity to HIV. **[19]** However, some scientists

speculate that He may have removed the gene to boost the babies' cognitive power, which is believed to be an added bonus of that modification. (MIT Review, February 21). This breach of ethics has been condemned by the scientific community within China and worldwide, while also prompting the development of a new law on human gene editing. **[20]** Meanwhile, there appear to be relevant synergies among military, academic, and commercial research directions. BGI's collaboration with researchers at the PLA's National University of Defense Technology (NUDT)—as evident across co-authored publications, including the design of tools for the use of CRISPR—is hardly unexpected but nonetheless noteworthy. **[21]** For instance, one former professor who remains affiliated with NUDT also holds a position with BGI as a specially-appointed professor concentrating on research in bioinformatics (which leverages supercomputing for the processing of large-scale genetic information).

While the potential leveraging of CRISPR to increase human capabilities on the future battlefield remains only a hypothetical possibility at the present, there are indications that Chinese military researchers are starting to explore its potential. Of course, genetic engineering has numerous military applications in materials science, such as those that can involve maritime and aerospace applications. However, at a time when the Central Military Commission (CMC) Science and Technology Commission is also supporting research in human performance enhancement and "new concept" biotechnology, the potential intersections of these interests merit concern and consideration. For instance, a doctoral dissertation titled "Evaluation and Research on Human Performance Enhancement Technology," published in 2016, envisions CRISPR as one of three primary "human performance enhancement technologies" (人效能增强技术, *ren xiaoneng zengqiang jishu*) that can be utilized to boost personnel combat effectiveness. The researcher argues that because CRISPR holds such "great potential" as a "disruptive" technology, China must "seize the initiative."

Conclusion and Implications

Ultimately, today's advances in biotechnology may prove revolutionary, and the strategic implications, whether for medicine or the military or aggregate national competitiveness, are only just starting to be appreciated. **[22]** Today, the PRC is actively exploring new frontiers of such biological cross-disciplinary technologies: from these prominent developments in CRISPR to bionic robotics, intelligentized exoskeletons, and techniques for human-machine collaboration. So too, at a time when Chinese universities and enterprises are pursuing investment and expanding global research collaborations in such fields, it is important that their foreign partners remain cognizant of the interests and involvements of their counterparts. For instance, although biomedical research involves numerous promising applications in medicine and therapeutics, there are also reasons for concern about some of the ethical and security externalities of these research engagements. **[23]** Going forward, these trends will merit continued analytic attention.

Elsa Kania is an Adjunct Senior Fellow with the Technology and National Security Program at the Center for a New American Security. Wilson VornDick consults on national security, emerging technologies, and China for Duco and Rane. Their views are their own.

Notes

[1] See the: "13th Five-Year S&T Military-Civil Fusion Development Special Plan" (Full Text)" ["十三五"科技军民融合发展专项规划》全文], http://www.aisixiang.com/data/106161.html. For further context on this initiative, see this "authoritative interpretation" of it: 《"十三五"科技军民融合发展专项规划》热点问题权威解读], Xinhua, August 23, 2017, http://www.mod.gov.cn/regulatory/2017-08/23/content_4789748.htm.

[2] "CRISPR" is named for leveraging "Clustering Regular Interval Short Palindromic Repeats," which can act as 'scissors' to enable precise editing of the genome, and the Chinese phrasing for CRISPR is: *chengcu guilu jiange duan huiwen chongfu xulie* 成簇规律间隔短回文重复序列. For general background on CRISPR, see: Ran, F. Ann, Patrick D. Hsu, Jason Wright, Vineeta Agarwala, David A. Scott, and Feng Zhang, "Genome engineering using the CRISPR-Cas9 system," *Nature Protocols* 8, no. 11 (2013), pp. 2281.

[3] Guo Jiwei(郭继卫) and Li Hongjun (李洪军), "An Analysis of the Impact of Modern Biological Technology on Future Forms of Warfare" [试析现代生物科技对未来战争形成模式的影响], *China Military Studies,* no. 3 (November 2016), pp. 31-36. See also Li Hongjun (郭继卫) and Guo Jiwei (李洪军), "Thinking on Modern Biological Science and Technology Promoting The Evolution of the Form of Warfare" [现代生物科技推动战争形态演变的思考], *Military Medical Sciences*, no. 1 2016, pp. 1-6.

[4] See: Guo Jiwei (郭继卫), *War for Biological Dominance* (制生权战争), Xinhua Press, 2010.

[5] See this recent article discussing translations and interpretations: Yi Biyi [易比一], Li Xiang [李翔], Huang Shiliang [黄世亮], and Lei Erqing [雷二庆], "Concept research of *Zhishengquan*" [制生权概念研究], *Mil Med Sci.* [军事医学], Vol 42, No 1, Jan, 2018.

[6] Zhang Shibo [张仕波], *New Highland of War* [战争新高地], National Defense University Press [国防大学出版社, January 2017, pp. 232.

[7] For historical contextualization, see: Peter Williams and David Wallace. *Unit 731: Japan's secret biological warfare in World War II*. New York: Free Press, 1989.

[8] Surprisingly number of prominent individuals have highlighted this as a possibility: Elsa Kania and Wilson VornDick, "Weaponizing Biotech: How China's Military Is Preparing for a 'New Domain of Warfare,'" Defense One, August 14, 2019, https://www.defenseone.com/ideas/2019/08/chinas-military-pursuing-biotech/159167/?oref=d-river. See, for instance: Zhang Shibo [张仕波], *New Highland of War* [战争新高地], and Xiao Tianliang [肖天亮] (ed.), *The Science of Military Strategy* [战略学], National Defense University Press, 2017.

[9] Zhang Shibo [张仕波], *New Highland of War* [战争新高地], National Defense University Press [国防大学出版社, January 2017, pp. 234.

[10] Sometimes CRISPR appears with the suffix -CAS and an alphanumeric sequence, such as CAS-12b. This phrasing designates that specific enzyme, such as the 'associated protein 12b' or 'CAS12b.' Generally, the shortened, generalized terminology CRISPR is used in both media reporting and scientific writings globally.

[11] Li Jinsong and Caixia Gao. "Preface to the special topic on genome editing research in China." *National Science Review* 6, no. 3 (2019): 389-390.

[12] See, for instance: Yangyang Cheng, "China Will Always Be Bad at Bioethics," *Foreign Policy*, April 13, 2018, https://foreignpolicy.com/2018/04/13/china-will-always-be-bad-at-bioethics/.

[13] For instance, see this study: "Study of PD-1 Gene-knocked Out Mesothelin-directed CAR-T Cells With the Conditioning of PC in Mesothelin Positive Multiple Solid Tumors," https://clinicaltrials.gov/ct2/show/NCT03747965?term=CRISPR&cntry=CN&rank=7.

[14] See: "14 Studies found for: CRISPR | China," undated, https://clinicaltrials.gov/ct2/results?cond=&term=CRISPR&cntry=CN&state=&city=&dist=.

[15] For a more detailed assessment, see: Sara Reardon, "Welcome to the CRISPR zoo," *Nature News* 531, no. 7593 (2016): pp. 160.

[16] Mu-ming Poo, Jiu-lin Du, Nancy Y. Ip, Zhi-Qi Xiong, Bo Xu, and Tieniu Tan, "China brain project: basic neuroscience, brain diseases, and brain-inspired computing," *Neuron* 92, no. 3 (2016): pp. 591-596; Liu Zhen, Yijun Cai, Zhaodi Liao, Yuting Xu, Yan Wang, Zhanyang Wang, Xiaoyu Jiang et al. "Cloning of a gene-edited macaque monkey by somatic cell nuclear transfer." *National Science Review* 6, no. 1 (2019): pp. 101-108.

[17] Qiu, Peiyuan, Jian Jiang, Zhen Liu, Yijun Cai, Tao Huang, Yan Wang, Qiming Liu et al. "BMAL1 knockout macaque monkeys display reduced sleep and psychiatric disorders." *National Science Review* 6, no. 1 (2019): pp. 87-100.

[18] Peng Yaojin, "The morality and ethics governing CRISPR–Cas9 patents in China," *Nature biotechnology* 34, no. 6 (2016): 616.

[19] He Jiankui (贺建奎) completed doctorate work at Rice and Stanford universities and was recruited back to China as part of Beijing's "Thousand Talents Plan" where he conducted research at Southern University of Science and Technology (SUSTech or 南方科技大学) in Shenzhen.

[20] Wei, Wensheng. "CRISPR twins: China academy responds." *Nature* 563 (2018): pp. 607-608.

[21] See, for instance: Cui, Yingbo, Jiaming Xu, Minxia Cheng, Xiangke Liao, and Shaoliang Peng. "Review of CRISPR/Cas9 sgRNA design tools." *Interdisciplinary Sciences: Computational Life Sciences* 10, no. 2 (2018): 455-465, accessed from https://www.pubfacts.com/detail/29644494/Review-of-CRISPRCas9-sgRNA-Design-Tools.

[22] Jennifer A. Doudna and Samuel H. Sternberg, *A Crack in Creation: Gene editing and the unthinkable power to control evolution*, Houghton Mifflin Harcourt, 2017.

[23] See, for instance: Mihir Zaveri. "Wary of Chinese Espionage, Houston Cancer Center Chose to Fire 3 Scientists," *New York Times*, April 22, 2019, https://www.nytimes.com/2019/04/22/health/md-anderson-chinese-scientists.html.

***