LEMAY CENTER FOR DOCTRINE

ELECTROMAGNETIC DEFENSE TASK FORCE

2018 REPORT

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Edited by
Dr. Ernest Allan Rockwell

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DEVELOPMENT AND EDUCATION**

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Maj Gen Michael D. Rothstein

Director, Air University Press
Dr. Ernest Allan Rockwell

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Project Editor
Dr. Ernest Allan Rockwell

Cover Art, Book Design, and Illustrations
Daniel Armstrong
Leslie Susan Fair

Composition and Prepress Production
Nedra O. Looney

Print Preparation and Distribution
Diane Clark

Air University Press

600 Chennault Circle, Building 1405
Maxwell AFB, AL 36112-6010
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2018 REPORT

Approved for Public Release

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Contents

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Introduction to Electromagnetic Defense Task Force

The electromagnetic spectrum (EMS) is a broad area of activity characterized by physically observable activities such as visible light and lasers and unobservable phenomena such as microwaves and electromagnetic energy. EMS manifests through various frequencies and wavelengths produced by natural sources like solar storms or artificially by hardware such as radar or nuclear weapons. EMS impacts every domain of warfare.

On 20–22 August 2018, the Electromagnetic Defense Task Force (EDTF) hosted an inaugural summit in the National Capital Region (NCR). The summit was designed to aid and encourage actions to recover footing where our technological lead in EMS is being challenged. The summit was also designed to address direct EMS threats to the United States and its allies. While some issues have existed since the 1960s, the window of opportunity to mitigate some electromagnetic threats is closing. Meanwhile, many existing threats have gained prominence due to almost universal integration of silica-based technologies into all aspects of modern technology and society.

During the opening remarks of the inaugural summit, R. James Woolsey, former Director Central Intelligence, stated, "The time for research is running out; we have the data we need. IT'S TIME FOR BOLD ACTION." In the spirit of this challenge, EDTF seeks to inspire action based upon an array of research spanning more than six decades. Such actions and exploits are needed to immediately deepen the defense and resilience of the United States and its allies.

Since World War II, holding an edge in the EMS has provided the United States and its allies distinct military and economic advantages. Nevertheless, as technology has become diffused during the *Fourth Industrial Revolution* (4IR), our ability to maintain the advantage within this spectrum has diminished as peers gain capability. At present, the United States and its allies are at an EMS crossroads. In some areas, if timely actions fail to advance allied EMS capabilities, there is a likelihood adversaries can achieve parity or even dominance of the spectrum in a matter of years.

Communications and data and a myriad of essential military and economic functions—including precision navigation and timing and banking—are maintained in and through the EMS. The EMS may be described as a "Super Domain." While the only internationally recognized domains are *land*, *sea, air, space*, and *cyber*, electromagnetic activities operate in and through *all* domains regulating the most critical functions therein.

EMS is arguably the one domain that can rule them all. Failure to maintain technological dominance or freedom of operations in EMS can diminish or

> **"Failure to maintain technological dominance or freedom of operations in the EMS may diminish or stop a modern nation's broad civil and military activities."**

stop a modern nation's broad civil and defense activities. Based on the totality of available data, the task force contends the second- and third-order effects of an EMS attack may be a threat to the United States, democracy, and the world order.

The prospect of oppressive control of communications and information represents not only a capability to dictate how mankind may access information, but in an world increasingly run through the internet of things (IoT), it may disparagingly allocate or deprive individuals, groups, or societies of elements required for their survival, such as food, water, and sanitation. Therefore, the ways and means relating to EMS activities must be safeguarded.

Understanding the United States' and allied nations' EMS is being competitively challenged, the EDTF was formed to cultivate leading-edge thought on EMS issues and broadly educate military and civilian interests about the criticality of competitive EMS interactions and key strategic developments.

EDTF is a unique collaborative approach to discovering realistic, actionable steps to mitigate existing and emerging existential electromagnetic challenges. EDTF is working to forge a deeper understanding about EMS challenges and opportunities that the United States and our allies face as interlinked communities.

> **"EDTF is working to forge a deeper understanding about EMS challenges and opportunities that the United States and our allies face as interlinked communities."**

The research project aims to inform prioritized community actions (local, federal, and international) to confront challenging and complex EMS threat combinations that require holistic, sensible approaches in order to mitigate the threats. In summary, the project and resultant research is an effort to build a stronger EMS community, define key problems and issues as a community, and create a framework for community, US government, and civil actions needed for the health of the nation and our allies.

In consideration of these boundary-crossing issues, EDTF formed an initial cadre of 135 leading EMS experts, strategists, and scholars. These highly qualified military and civilian personnel represent more than 40 Department of Defense organizations, NATO, academia, and the private sector.

During the EDTF's inaugural deliberations, task force members actively participated in more than 2,000 hours of seminars, workshops, and war games to evaluate and develop actionable steps for rapid implementation at all levels of society and government. The EDTF thanks all participants and readers for their interest in this ongoing effort.

Purpose and Goals

From 20–22 August 2018, Air University brought together leading subject matter experts from government, industry, laboratories, and academia to discuss vulnerabilities and threats, raise awareness, and explore mitigation strategies on an array of national security challenges in the EMS. The inaugural summit was attended by more than 135 military and civilian personnel representing more than 40 United States Department of Defense organizations, NATO, academia, and the private sector. During the summit, working groups focused on electromagnetic pulse (EMP), geomagnetic disturbance (GMD), lasers and optics, directed energy (DE), high-power microwaves (HPM), and EMS management.

The summit was designed to challenge contemporary thinking and develop original thought about EMS and encourage actions to recover the technological initiative. Another priority was to immediately address the widening EMS threats to the United States and its allies. This report provides a summary of insights, conclusions, and recommendations developed during the inaugural summit.

Each of the above issues has the capacity to impede the free flow of information in a democratic society, challenge a nation's economy, infrastructure, population, and military; and cause long-distance non-kinetic fatalities to personnel performing essential functions (i.e., embassy staff, aircrew in flight, or sailors aboard ship).

In countering EMS challenges, some windows of opportunity needed to compete with our adversaries are closing. Meanwhile, EMS threats that have existed since the 1960s and earlier, such as nuclear-EMP and geomagnetic storms, have regained prominence. The salience of these threats has returned due to several factors, including (1) near-universal integration of electromagnetically sensitive silica-based technologies into most modern hardware, (2) adversaries' increased understanding of how to exploit critical vulnerabilities, (3) institutional knowledge atrophy due to retirement or transition of personnel who conducted nuclear and EMP testing, and (4) the emergence of novel technologies, many of them poorly understood.

"In countering EMS challenges, some windows of opportunity needed to compete with our adversaries are closing. Meanwhile, EMS threats that have existed since the 1960s and earlier, such as nuclear-EMP and geomagnetic storms, have regained prominence."

In consideration of these matters, EDTF endeavors to establish a community of leading experts, strategists, and authorities on EMS issues**.** In deliberation of the issues described, conference participants took part in more than 2,000 hours of seminars, workshops, and war games to evaluate and innovate with effective steps that can be implemented at all levels of government and society. This report provides key community observations and recommendations. **The next conference is planned for April 2019 in the NCR.**

Significant Findings

Conference participants found immediate actions are required to alleviate unmitigated strategic gray zone EMS threats. Toward the top of mitigation factors was the need to educate military forces about the existence of key vulnerabilities. Furthermore, there was consensus, from the standpoint of a state's national defense, that the ability to attribute a hostile act to an actor is an essential requisite for strategic deterrence (i.e., maintenance of the status quo). Without intentional mitigating actions, the United States and NATO are vulnerable to significant threats from both external and internal actors and natural phenomena such as solar storms. Finally, the EDTF found that a free and secure EMS is life-support to the day-to-day function and continuity of military, government, and commercial operations and commerce in democratic nations.

While EMS vulnerabilities and threats have matured, national and even international capabilities to deny or mitigate such threats and vulnerabilities remain highly dispersed or incomplete. In some areas, there is a complete absence of strategy. In other cases, traditional deterrence efforts afford little to no utility in preventing adverse enemy action in the EMS. In many respects, this is not dissimilar from deterrence activities in cyber space—which are almost completely ineffective.

> **"In a Western society governed by law and international standards, attribution is essential to viable deterrence. The party deterring must have the ability to identify an actor and justifiably hold that actor at risk."**

The EDTF found EMS threats may present as hostile, and often unattributably, gray zone activities (fig. 1.0). Gray zone activities are actions competitive in nature, but which often fall below the threshold for war. These zones of nebulous activity are situated on the spectrum in times of tension, of peace, and of war.

In a Western society governed by law and international standards, attribution is essential for viable deterrence. The party deterring must have the ability to identify an actor and justifiably hold that actor at risk. However, when an aggressor cannot be identified, the situation may embolden or persuade that actor to be aggressive (especially if the ability to remain cloaked is believed assured).

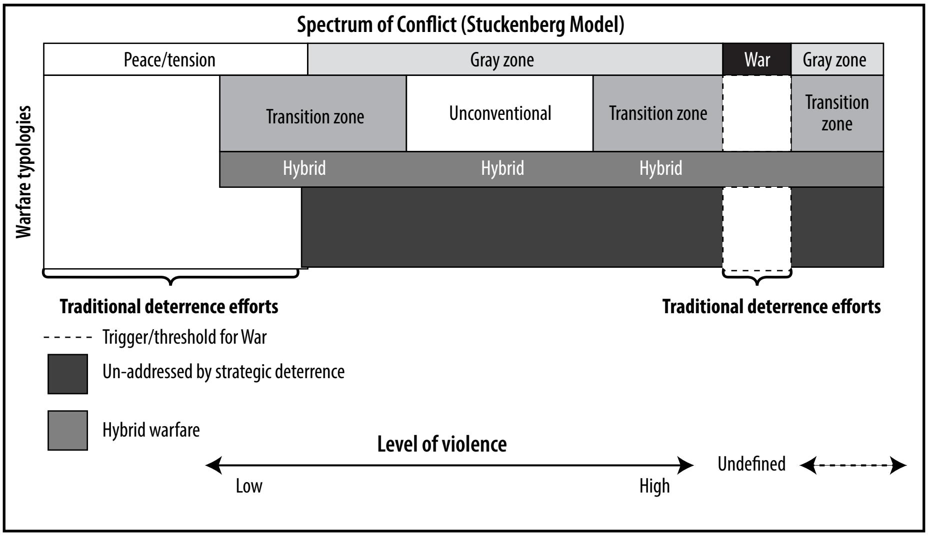


Figure 1.0. Revised spectrum of conflict (Stuckenberg model) highlighting theoretical gaps in strategic deterrence

Unlike some tactical gray zone threats, strategic EMS gray zone challenges can conceivably threaten a nation's survival. Gray zone EMS threats, such as EMP, were addressed by the commander of the United States Strategic Command, General John Hyten, USAF, during his remarks at the Air Force Association Convention on 20 September 2017, when he noted, "EMP is a realistic threat and it's a credible threat." General Hyten went on to note that civil society is not prepared to address the challenges associated with an EMP attack. EDTF supports this position. However, the issue is broader. In the majority of circumstances: the military and civil society are also unprepared to mitigate high-consequence EMS threats. The overall risks arising from reinforcing dependencies are discussed throughout this report.

ISSUE AREA 1: Electromagnetic Pulse and Geomagnetic Disturbances

PRIORITY 1: Nuclear Power Resilience

Most experts agree that if a GMD or EMP incapacitates an electrical grid, the grid will likely remain in a failed state from weeks to months. In turn, the ability to provide continued electrical cooling for nuclear power plant reactors and spent fuel pools would be at the top of electricity restoration priorities within hours.[1] Department of Energy (DOE), Department of Homeland Security (DHS), and Federal Emergency Management Agency plans to aid distressed nuclear power stations are presently very limited and wholly dependent on logistics that would likely suffer widespread regional or national interruption, thereby inhibiting response and recovery.[2] Where the military is concerned, little planning has been done to mitigate potential impact on service members, installations, or critical missions that could be affected by areas of radiation arising from reactor or spent fuel pool leakage. The national response plan for distributing medications from stockpiles needed to aid recovery efforts is also dependent on logistics for distribution.

If response organizations cannot provide timely support in terms of restoration of electrical power due to logistical interruptions or issues with control systems (caused by EMS impacts), in some cases, stations would have roughly 16 hours of battery power to continue cooling reactors and spent fuel pools. In a worst-case scenario, all reactors within an affected region could be impacted simultaneously. In the United States, this would risk meltdowns at approximately 60 sites and 99 nuclear reactors, with more than 60,000 metric tons of spent nuclear fuel in storage pools.[3]

"In a worst-case scenario, all reactors within an affected region could be impacted simultaneously. In the United States, this would risk meltdowns at approximately 60 sites and 99 nuclear reactors, with more than 60,000 metric tons of spent nuclear fuel in storage pools."

Prolonged loss of power to these critical sites poses a risk of radioactive contamination to the Continental United States (fig. 1.1) with consequentially disastrous impact to the economy and public health. Risks to military and civilian infrastructure and hardware would be similar due to jet-stream winds spreading radioactive materials. In all cases, consequence management of such impacts would be inherently complicated due to a reliance on federal and local logistics which are themselves dependent on EMS.

The Fukushima Daiichi nuclear disaster in Japan provides a compelling case study for what can go wrong and right when a nuclear power station loses off-site and on-site power for prolonged periods. On 11 March 2011, a 50 foot tsunami (caused by a 9.0 earthquake) inundated the Fukushima nuclear power station, which is situated on Japan's coast. It is important to note that the Fukushima facility employed General Electric reactors; Japan's regulatory structure was modeled after the United States', and the plant's staff were trained in accordance with US standards and procedures; everything was state-of-the-art and in line with best US practices.

> **"Operator desperation became high as creative means failed to get water circulating again. During this time, plant operators unsuccessfully attempted to use fire-truck pumps and even helicopters to supply cooling water."**

After the loss of power lines and transformers downed the coastal electric grid, Fukushima's operating nuclear reactors went offline (scrammed), as designed, which in turn inserted boron control rods next to the plutonium fuel rods.

In a disaster, reactors are designed to stop producing heat (arising from chain reaction). However, even with control rods inserted, nuclear reactors continue to produce heat. Latent residual heat from the stopped chain reaction often lasts for weeks or months. To prevent meltdown, water is normally circulated through electrically powered cooling systems. Regardless of vintage, nearly all nuclear reactor cooling systems are of a similar design.

Since the Fukushima facility had no electricity after the tsunami, it should have been able to revert to the back-up emergency core cooling system (which is usually electrically powered by emergency generators). However, the generators that would have powered the emergency cooling systems were damaged by flooding. This damage meant the latent heat from the nuclear reaction could not be removed from some of the now-offline rectors. While this situation was apparent to operators early, logistical issues hampered any efforts to restore electricity to the water pumps. No off-site help was available.

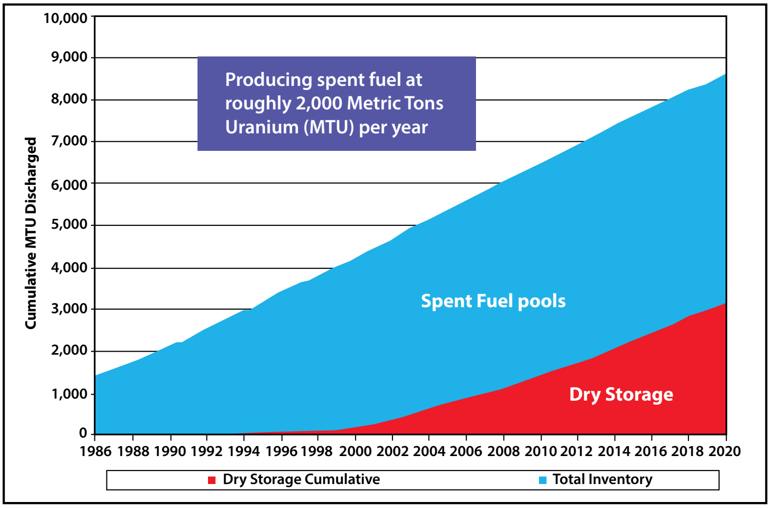


Figure 1.1. US nuclear spent fuel storage; spent fuel pools require electrically powered water pumps to circulate water so heat does not evaporate cooling water. Dry storage does not require electricity. (Source: The Union of Concerned Scientists.)

Figure 1.2. Dry cask spent fuel storage at Fukushima. Water initially flooded this chamber, but once the water receded, air cooling resumed. An example of what can go right with dry cask storage. (Source: Union of Concerned Scientists.)

Operator desperation became high as creative means failed to get water circulating again. During this time, plant operators unsuccessfully attempted to use fire-truck pumps and even helicopters to supply cooling water. After these attempts failed, operators attempted to recover vehicle batteries from piles of rubble pushed up by the wave. The plan would have used car batteries wired in series to supply DC power to water pumps, but this too was unsuccessful. Fukushima suffered from three core meltdowns, three close calls with spent fuel pools, and three hydrogen explosions.

However, some items at Fukushima functioned exactly as intended, including dry cask storage containers housing some of the site's nuclear spent fuel. Once spent fuel sufficiently cools in a spent fuel pool, it may be removed and placed into resilient dry cask storage that uses air to continue cooling (fig. 1.2). As noted (fig. 1.1), nearly 75 percent of spent nuclear fuel in the United States is stored in fuel pools (or "heat sinks") with recently used (spent) plutonium fuel rods.

Like nuclear reactors, spent fuel pools must have water circulating to remove heat. A failure to remove heat from the water (due to a loss of circulation) will cause water to boil off, in which case the radioactivity of the steam is compounded by the radioactivity of exposed rods, which emit harmful beta and gamma radiation.

Based on analysis by the National Academy of Sciences and The Union of Concerned Scientists, the ability of nations to significantly diminish secondary issues potentially arising from EMS incidents is significant if pre-emptive actions are taken. Estimates (such as those presented in figure 1.3) indicate that by placing spent fuel in dry cask storage, the United States can diminish overall loss of containment risks to North America by as much as 75 percent in terms of human impact, landmass contamination, and radiation released.

Table 1.0 provides a side-by-side comparison of risks between spent fuel pools and dry cask storage. However, even if spent nuclear fuel is placed in dry cask storage, creating resilient nuclear power stations will require additional steps: hardening emergency generators against EMP/GMD and creating accessible fuel stores in excess of seven days' needs.

As previously discussed, when suffering from a loss of grid supplied electrical power, nuclear power stations use back-up generators. Currently, there is no requirement to EMP-harden these generators. Loss of emergency power generators can lead to substantial military, human, and economic damages if these last-line units are unable to electrically power and support critical safety systems.

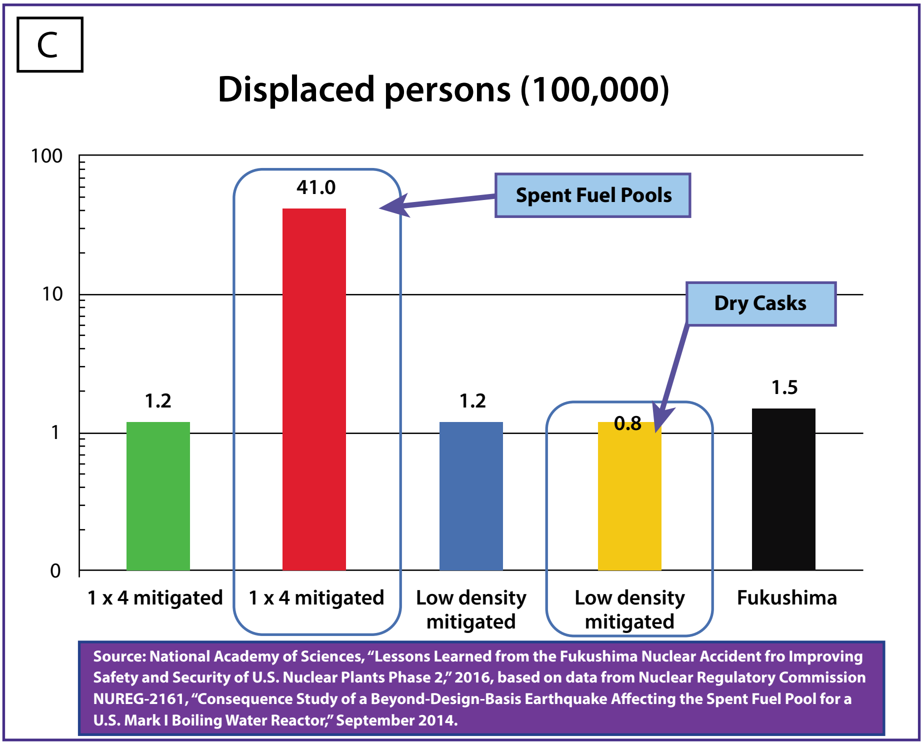


Figure 1.3. Dry cask spent fuel storage can significantly reduce risks to population, lands, and the environment.

Table 1.0. Comparison of Spent Fuel Storage Impacts (unspecified cooling loss		
Impacts	Spent Fuel Pool Storage	Dry Cask Storage
Population Displaced	**4,100,000**	**800,000**
Landmass Contamination	**94,000 sq. miles**	**170 sq. miles**
Radioactive Contaminates Released	**8.8 MCI of Ca-137**	**.8 MCI of Ca-137**
Sources: National Academy of Sciences, "Lessons Learned from the Fukushima Nuclear Accident for Improving Safety and Security of U.S. Nuclear Plants Phase 2," 2016, based on data from the Nuclear Regulatory Commission, NUREG-2161, "Consequence Study of Beyond-Design Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boling Water Reactor," September 2014.		

The Nuclear Regulatory Commission (NRC) is currently working to create new fuel storage standards based on the recommendations of the Near-Term Task Force, a 2011 NRC study group established after the Fukushima accident to evaluate lessons learned. EDTF also recognizes a limited supply (under seven days by regulation) of emergency generator fuel may cause great risk to a station and the surrounding areas. This limitation severely restricts the ability of a station to cope without outside intervention. Given the logistical complications that may arise from EMS issues, most military and civilian literature cautions that logistics will be severely impeded due to dependencies. Thus, these facilities should be able to self-support in the event of an EMS impact. A failure to prepare key nuclear facilities for beyond-design-basis events such as those encountered at Fukushima may potentially allow an adversary to achieve strategic effects that would be complicated and compounded by an inability to deliver support to more than 60 sites—a number that does not include university or national laboratories.

PRIORITY 2: Installation Command Posts (Critical Infrastructure)

At an undisclosed location, in 2017, localized flooding incapacitated operations at a major military command-and-control (C2) facility. Coordinated mission operations in a range of areas were adversely affected for several days while repairs were under way. Over the years, a number of studies have evaluated key dependencies of military installations and the minimum requirements to ensure support of defense and civilian operations will continue.

In terms of strategy, from an adversary's standpoint, military installations represent the vulnerable underbelly of the defense enterprise. In particular, if deliberate or natural EMS phenomena affect an installation's command post, the capabilities of associated forces may be degraded or stopped. Furthermore, findings suggest if a GMD or EMP event occurred, an installation's ability to maintain connectivity would depend on the nature and severity of the event, but in all likelihood, the installation would be unable to continue uninterrupted operations within a short period in the absence of a cohesive response and sustainment plan.

In the case of a GMD, duration of exposure to the coronal mass ejecta traveling through space is important. While in most cases outages would be isolated to the wider electrical power grid, longer exposures equate to increased wave strength and damage. Meanwhile, for EMP, when the deposition area is more than a certain field strength in a square meter, most equipment unprotected by high-altitude electromagnetic pulse (HEMP) filters or Faraday cages would be instantly incapacitated.

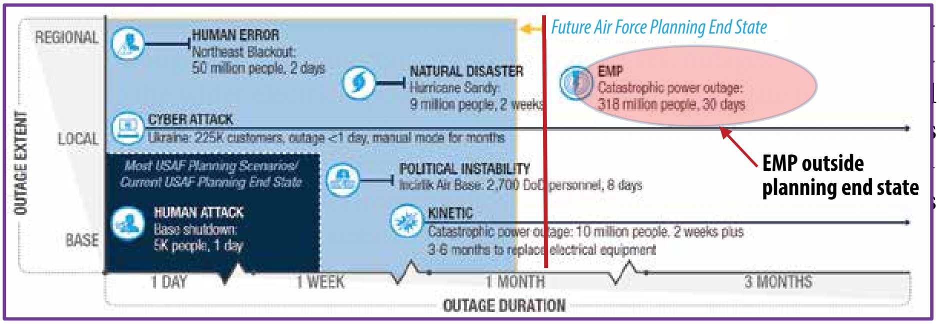


Figure 1.4. Aspirational planning horizon for USAF installations. (Source: HQ/USAF Mission Assurance Office.)

In the United States, direction from the National Military Command Authority (NMCA) is typically relayed to an installation's command post. Thus, if the command post is unable to function, in most situations, NMCA's ability to utilize a sizable portion of available forces could be impacted until contact is reestablished.

Under the right conditions, an adversary could impact the communications systems of most US military installations simultaneously. Such is why, in part, Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 6811.01 requires that the DOD ensure operations in a post-EMP/GMD environment. In the United States, each military service is obligated to meet this objective. However, the broad scope of the vulnerability has impeded the ability of installations to meet this instruction. Consequently, most installation response plans often omit EMP/GMD contingencies from sustainment or recovery planning and programs (fig. 1.4).

While USSTRATCOM assesses it has an ability to continue most operations in a GMD– or EMP–degraded environment (beyond seven days), its reliance on unhardened capabilities may rapidly restrict operations.[4] For example, if USSTRATCOM were unable to leverage refueling capabilities to support the National Airborne Operations Center (NAOC), the ability to keep this asset in service would be adversely impacted. Similar dependencies would impact take charge and move out (TACAMO) and other airborne C2 and nuclear command-and-control (NC3) assets. Thus, even organizations like USSTRATCOM that have kept up with hardening requirements since the end of the Cold War might not meet mission challenges due to structural and system dependencies which rely on unhardened sources of electricity.

A real-world event that demonstrated the prospective utility of gray zone strategic EMS employment occurred in 2012 in the Caribbean Sea. During this event, a North Korean commercial vessel was intercepted as it made passage through the Panama Canal. Previous to intercept, the vessel was loaded with a Russian SA-2 missile and launcher system. Should such weapons be equipped with a nuclear warhead and launched from a ship adjacent to the United States or its allies, the prospect of attaining altitude sufficient (low-Earth orbit) to achieve near nationwide EMS impact is realistic. It should be noted that neither range nor accuracy is important for an EMP attack to be effective. The Russian-built Club-K missile system (NATO designated "Sizzler") (fig. 1.5) is a regional ballistic-missile capability launched from within a modified standard shipping container. According to literature, this unassuming system may be equipped with a nuclear-tipped missile and smuggled through a port or across a border to present threats to a nation from inside its own boundaries.

"Complications associated with creative strategic employments may be further compounded when employed from the gray zone using proxies, unmarked weapons, stolen systems, or even weapons procured from other states. Together, these possibilities make attribution and retaliation complicated, if not impossible."

Complications associated with creative strategic employments may be further compounded when employed from the gray zone using proxies, unmarked weapons, stolen systems, or even weapons procured from other states. Together, these possibilities make attribution and retaliation complicated, if not impossible. Without early warning, there may be little time to shield critical equipment, and without attribution, there is little or no deterrence and, feasibly, a degraded ability to respond.

Post-EMP, an un-modified command post with conventional uninterruptable power systems may have only hours of electrical (battery) power to sustain over-the-horizon communications. Disruption to communications and transportation systems outside of installations may severely degrade response times where critical hours are needed to prevent collateral loss of C2 (both on and off station). In many cases, an interruption of C2 could lead to a degraded ability to bring organic mission capabilities to bear for national defense or civil recovery operations.

Figure 1.5. Russian 3M-54 ('CLUB') or NATO SS-N-27 ('Sizzler'). Reported range 1,500 miles. According to literature, this weapon can be equipped with a nuclear warhead. Source of photo: MuhdZikry, "Concern-Agat: Russian 3M-54 Club-K Missile System; Simulation and Test Fire," YouTube, 28 January 2017, https://www.youtube.com/watch?v=f_c_PelIeMw

PRIORITY 3: Exercise and Training Realism

From an installation commander's perspective, the challenges of establishing an ad hoc EMS response would be nearly difficult if not impossible to overcome. In the event of a GMD, effects would be less severe as the wave would only impact elements of the power grid such as large power transformers. However, an EMP would cause instantaneous and simultaneous loss of many technologies reliant on electrical power and computer circuit boards, such as cell phones and GPS devices.

> "Early warning is by no means guaranteed. A defense enterprise that always plans for the best case is an enterprise that can be challenged."

Additionally, most allied EMS-defense contingencies are predicated on early warning systems to signal an EMP attack or GMD so that "button-up" procedures can be implemented to protect vital assets. EDTF's evaluation of possible enemy courses of action demonstrates a shrewd enemy may prefer to employ EMS capabilities with un-attributable means that provide no warning or advanced signal. Early warning is by no means guaranteed. A defense enterprise that always plans for the best case is an enterprise that can be challenged.

Before World War II, the French went to great pains to construct the fortifications known as the Maginot Line. While this line of seemingly impregnable fortifications was state-of-the-art, well manned, durable, and well exercised, these activities failed to anticipate a creative and determined enemy. By equipping tanks with radios, the German army quickly outmaneuvered stationary French fortifications with a new strategy called the Blitzkrieg. Defeat followed in weeks. Today, there is a need for more realistic exercises, training, and crisis response plans. In light of history and the complex multidimensional possibilities in warfare, forces must train to fight a shrewd enemy rather than one who always acts predictably.

All non-EMP-hardened hardware and equipment have a high probability of disruption or failure when subjected to EMS phenomena at a range of wavelengths and power levels. Such failures may include long-term loss of electrical power (due to loss of emergency generators), sewage, fresh water, banking, landlines, cellular service, vehicles, and so forth.

It should be anticipated that widespread failures can result in civil unrest within hours. During the 1977 New York City blackout, widespread looting began within eight hours of losing power. Within 24 hours, arsonists caused more than 3,000 fires. For installations adjacent to nuclear power stations, it should be understood that there is a risk of reactor breach in under 16 hours[5] due to loss of ability to cool and resulting overpressure.[6] Such episodes represent just a handful of scenarios arising from mission codependences and EMS challenges.

In 1984, the United States Army warned: "recognize that indications and warnings of enemy use of surface and airburst nuclear weapons may not be present for HEMP threats."[7] This statement is as fundamental today as it was 34 years ago. General Norman Schwarzkopf said, "The more you sweat in peace, the less you will bleed in war." Thus, according to this wisdom, the armed forces should train like the enemy it will likely encounter rather than the enemy it hopes to encounter. As intelligent future adversaries prepare and engage the United States or it allies in nonlinear contests, such contests will be creative and asymmetrical and will employ a variety of EMS means that can achieve effects at the strategic level—the very definition of gray zone of strategic activities.

ISSUE AREA 2: Strategic Threats Arising from Adversary 5G Networks

PRIORITY 4: Competitor Control of All Digital Information

The development of 5G mobile technologies and networks represents a quantum leap in communications capabilities that is ready for robust deployment. Consequently, the development of 5G networks deserves unique consideration.

"Rapid creation of a global 5G network is also a cornerstone in China's industrial plan to compete with Western interests by creating a 'Digital Silk Road.'"

At five-year intervals, mobile technologies undergo generational updates as capabilities incrementally improve. Previous generations of mobile technology were 4G, 3G, 2G (the first digital network), and 1G (an analog network). 5G is a boundary-crossing secure communications advancement with nearly unlimited bandwidth and almost no latency; in comparison to 4G, 5G may offer 10x faster downloads, 100x higher wireless transfer rates, and 100x lower latency.

5G applications are forecast to exceed $400 billion by 2022, with the construction and maintenance of a prospective US network resulting in 3 million jobs and a $500 billion increase in GDP. Rapid creation of a global 5G network is also a cornerstone in China's industrial plan to compete with Western interests by creating a "Digital Silk Road."

"Because control of 5G is roughly equivalent to control of the Internet, open 5G is critical to freedom and free-market economics. Meanwhile, access to the 5G-millimeter wave bandwidth will be critical to operations in all war-fighting domains, in particular, space command & control."

This integrated network of digital infrastructure or "spatial information corridor" will also promote the adoption of the *Bei Dou* navigation system (a Chinese alternative to GPS), according to the US Department of Commerce's Office of Commercial Economic Analysis. Currently, China's 5G plan is underwritten by half a trillion dollars in investment with a first-to-market goal to deploy 5G commercially by 2020. In total, China will put more than $10 trillion dollars to the *One Belt One Road strategy*, of which the Digital Silk Road is one of three components.

By 2035, 5G is expected to enable $12.3 trillion in global economic output. The states or nonstates that control the 5G network will dictate or control all digital transactions including the ability to share and receive information. China's control over the majority of hardware manufacturing needed to create 5G components and antennas (41 percent of the market and rising) is part of Beijing's plan to deploy a network favorable to Chinese economic and security interests.

Because control of 5G is roughly equivalent to control of the Internet, open 5G is critical to freedom and free-market economics. Meanwhile, access to the 5G-millimeter wave bandwidth will be critical to operations in all warfighting domains, in particular, space C2. EMS experts assess that 5G market share could be "locked-up" by US competitors in under three years with no second chances to enter the race. To slow peer progression and consolidation of market share, the president of the United States recently signed a Presidential Order to stop a corporate merger that would have further conceded 5G manufacturing capability to China.

ISSUE AREA 3: Directed Energy and High-powered Microwave Systems

PRIORITY 5: Machinery, Equipment, and Critical Assets

The EDTF understands that much of the technological knowledge relating to EMS has departed the military and defense industry due to the passage of more than 60 years since robust testing. Thus, EMS realities require a renewed emphasis if states that rely on digital and EMS-operated machinery, equipment, and critical IoT assets are to build responsible and resilient societies.

Army Field Circular (FC) 50-16 notes that certain EMS vulnerabilities are not novel: "Don't regard EMP as a hard to understand newly discovered effect. EMP was one of the nuclear weapons effects predicted during the first nuclear tests, and it has been studied for over thirty years." This EMS-related circular was authored in 1986, more than 30 years before this report. However, our collective knowledge on EMS phenomena is the lowest point in recent history while the risks and threats are possibly the highest given the nature of widening knowledge and capability.

Past manuals on strategy note operators of machinery should understand their equipment and the factors that make these items more or less vulnerable to EMS effects. Yet, today, most systems operators, owners, and manufacturers (outside the nuclear triad) do not understand the potential impact of EMS phenomena.

"Today, with many fly-by-wire aircraft transiting airspace systems in the United States and allied nations, a loss of multiple aircraft in a single area impacted by an EMP could cause a significant loss of life and property."

The greater part of this institutional knowledge has diminished due to lack of training emphasis, attrition of experts, and focus on other strategic priorities such as counterinsurgencies and regional conflicts. In short, our institutional understanding has atrophied. For example, spectrum engineers noted the recent loss of a helicopter after it flew through an antenna farm comprised of several high-powered antenna arrays.

After flying through the arrays, EMS interference caused the digitally operated carburetor on the engine to fail, which caused fuel starvation to the engine. Other significant vulnerabilities include fly-by-wire systems such as those used aboard Airbus aircraft. According to regulators, the FAA has no regulatory authority to require aircraft certification for nuclear-EMP or HPM, so protection levels are not rigorously verified during civil testing.

In a recent case of GPS jamming, an Embraer 300 aircraft lost attitude control and 15,000 feet while in cruise flight. The loss of attitude and altitude was caused by the GPS-dependent stability augmentation system not being able to acquire a GPS signal. Today, with many fly-by-wire aircraft transiting airspace systems in the United States and allied nations, a loss of multiple aircraft in a single area impacted by an EMP could cause a significant loss of life and property.

At the time of this report, EMS testing (especially EMP and HEMP testing) has not been accomplished on new procurements such as the US Air Force's KC-46 Pegasus tanker or most Airbus systems which rely on fly-by-wire. Alarmingly, aircraft designed to carry large numbers of people and sizable cargo are allowed to operate without certainty about their level of resilience.

Intuitively, aircraft that rely solely on fly-by-wire systems have a unique vulnerability. If a crew is not physically attached to controls which are in turn connected to a flight control surface, a loss of onboard computers from an EMS interruption such as EMP could cause catastrophic loss of the aircraft due to an inability to revert to a manual flight control system (often known as "manual reversion"). In addition to the prospect of loss of systems or aircraft from external threats, experts noted that "onboard" EMS threats (inside an aircraft) increasingly pose a hazard.

Figure 1.7. Airbus A-380 electronic systems. (Source: FAA.)

> **"In those cases where EMS damage is severe enough, equipment may be permanently incapacitated. These kinds of vulnerabilities require planners to think creatively about mission essentials."**

In terms of installations and critical infrastructure, a number of areas have already been discussed in this report. However, it is important to reinforce the understanding that most military equipment operators are unaware of how to shield equipment from EMS, let alone how to recover if it fails. In those cases where EMS damage is severe enough, equipment may be permanently incapacitated. These kinds of vulnerabilities require planners to think creatively about mission essentials—for example, what equipment may require hardened storage or redundancy to launch, refuel, or recover the NAOC?

Mission-critical equipment should be treated as part of an equipment ecosystem. Failure to understand the complete system and its co-dependencies may ultimately cause mission failure or the failure of certain key operations required to, for example, sustain a hospital. In these areas, the EMS community is behind in identifying and addressing the totality of current and future EMS threats.

PRIORITY 6: Physical and Biological Impacts

While it is well known EMP, GMD, and other EMS phenomena do not directly cause harm to humans, some effects can be extremely dangerous and potentially deadly. As events in Cuba and China demonstrated, personnel can become ill from EMS effects. Although the nature of EMS activities that caused health issues for more than 20 diplomats is not entirely understood, what is well understood are the effects. In short, personnel at those locations are believed to have suffered traumatic brain injury (while in bed sleeping).

"DE weapons, lasers, and other EMS phenomena are often undetectable until the effects are encountered. However, once the effects are encountered, it may be too late to mitigate harmful effects."

As EMS technologies proliferate, EMS gray zone strategies that employ aggression to shape and influence the operations area will become more prolific. In fact, due to the difficulties associated with determining where a given waveform originated, EMS may one day be preferable to kinetic weapons for those actors employing from the gray zone. In the future, it may also be feasible to incapacitate or kill the crew of a ship or vessel while leaving the vessel intact. Such tactics could be equally applied to airborne assets, albeit without the prospect of equipment preservation.

DE weapons, lasers, and other EMS phenomena are often undetectable until the effects are encountered. However, once the effects are encountered, it may be too late to mitigate harmful effects. Consequently, in the future, unmanned aircraft, ships, and other vehicles may be preferable to manned defense mechanisms.

As certain military hardware becomes tougher to detect and interrupt due to hardening, humans will ultimately remain the technological Achilles' heel as adversaries increasingly attempt to target the vulnerable human physiology of operators and crew. Consequently, special consideration should be given to future hardware designs to make them automatic or proactive where the safety of human physiology could be called into question. For instance, a growing threat of laser eye injury to aircrews could be better mitigated by using electro-optically activated window treatments that automatically trigger filters if and when lasers come into contact with aircraft windows.

Such evolutions in technology make next-generation studies such as Pilot Training Next (PTN), the United States Air Force's study to train pilots in a primarily virtual environment, essential to maintaining a technological edge. During the PTN study, the Air Force sought to prove student training in a virtual environment is commensurate with and lower cost than traditional training methods. The study is being expanded to include Remotely Piloted Aircraft. Such knowledge and lessons learned should be shared and exchanged with US allies to help prepare our partners, side-by-side, for future challenges.

ISSUE AREA 4: EM Spectrum Policy, Management, and Organization

PRIORITY 7: Complexity, Ownership, and Investments

In simplest terms, the EMS is every bit a riddle, wrapped in a mystery inside an enigma, as Churchill said of Russia. Since the sinking of the RMS *Titanic* and the purported radio signal interference that interrupted potentially lifesaving distress calls, EMS management has continued to unfold in a dysfunctional manner. Today, the enormity of spectrum activities within EMS often inhibits sound management while cumbersome agency responsibilities are complex, duplicative, and incomplete.

For example, throughout NATO, communication with partners is often incompatible and fractured. Add to this separatist and proxy actor activities, communications—the backbone of military command-and-control—becomes a capability that cannot be taken for granted. Therefore, as the US and NATO posture to resist aggression, improved collaborative management of EMS must receive the attention and focus it deserves.

Critical questions when considering how to improve EMS management:

1. We have more guidance and directives than resources; what problems do we want to solve first?

2. Do we desire to resource existing directives?
3. Many of the areas discussed require combined military and civilian solutions; how do we get attention where needed?
4. Are we willing to use Title 32 authorities with traditional Title 10 assets?
5. How can we integrate changes into the National Response Framework?
6. If the EMS community asks for help and provides recommendations and direction, can wider DOD support be gained?

Many challenges arise from the fact that while all assets, functions, and domains rely on EMS, no one area has assumed overall responsibility for its integration and management. Thus, it was discussed, since EMS occurs in and through the medium of space, it may be sensible to consider EMS a domain in and of itself or provide overall management of EMS to a future space force or space combatant command. Consolidating EMS management into a new organization creates a viable opportunity to build a sound and deliberate architecture. Future reliability, standards, and management will all have to be coordinated in such a way as to prevent the linkages established by the IoT from continuing to give us a fragile and collapse-prone infrastructure.

"Consolidating EMS management into a new organization creates a viable opportunity to build a sound and deliberate architecture. Future reliability, standards, and management will all have to be coordinated in such a way as to prevent the linkages established by the IoT from continuing to give us a fragile and collapse-prone infrastructure."

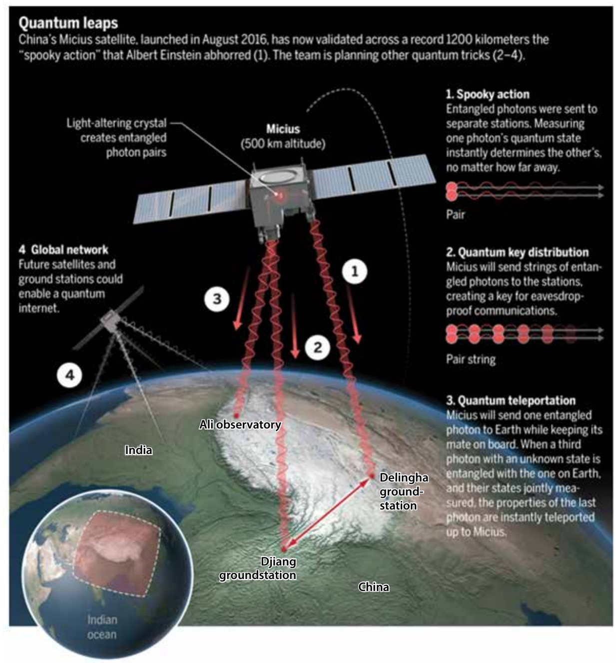
As the 5G network becomes ubiquitous, there are opportunities to not only match but also ensure competitive advantages in EMS. As 5G matures, legacy technologies will give way to reliance on this integrated, consolidated, fast, secure, and low-latency system. But 5G should not be mistaken for the acme of EMS technology. In spite of the promise 5G holds from an economic and defense perspective, the United States and its allies should continue investing in the technologies that lie beyond. It is likely our competitors are already doing so.

Moreover, it is probable that China will develop 5G as a dual use civil-military network and use the spin-off technologies to further expand its global sphere of influence. Therefore, new investment should match and surpass peer competitors working to develop technologies that could one day break society free of terrestrial networks.

In the case of quantum entanglement, China is attempting to use divided quantum particles to create a secure and impenetrable space-based communications network that will transmit secure data instantaneously without risk of adversary's penetration**.** While such capabilities sound like science fiction, in 2016 Chinese scientists demonstrated a quantum particle could be split then entangled (or invisibly joined) with a laser. After dividing the particle, it was physically separated. Half of the particle was located to space while the other half was kept on Earth's surface. Subsequent rotation of the Earth-based particle demonstrated the space-based particle could instantaneously mirror-image the rotation if its twin-particle. While the enabling mechanism for this kind of quantum behavior remains mysterious, the potential utility and capabilities afforded by this kind of science and technology are not difficult to imagine. Such concepts could not only include secure or impenetrable communications networks but also be used to activate off-network (no Wi-Fi or other signal) micro-embedded kill-switches.

Presently, the EDTF is investigating the key question of whether or not quantum phenomena take place within the range of EMS activity and therefore ought to be considered an EMS phenomena. Preliminary inquiry suggests quantum entanglement and similar activities do occur within the EMS. It was suggested by global experts that this question may have never been asked within a defense context. Thus our emerging understanding of the relationship between EMS, cyber, and quantum activity must be further explored and understood.

As this understanding unfolds, it is feasible that an evolving knowledge of these phenomena will re-shape our understanding of the domains of warfare and how EMS fits into the bigger picture. If EMS is a domain such as air, land, sea, and space—the wider implication is that cyber



CREDITS: (GRAPHIC) C. BICKEL/*SCIENCE*; (DATA) JIAN-WEI PAN was always an EMS phenomena, but one which was described improperly according to hardware rather than the medium (EMS) though which all related activities occurred. Such would be the conceptual equivalent to calling ships or aircraft domains, rather than the medium within which they operate such as water or air. In light of this possibility, the EDTF suggests evaluating the prospective value to defense community of formally defining EMS as a war-fighting domain within which EMS-enabled cyber activities take place.

Recommendations

The potential for an adversary to inflict damage on states through EMS attack has grown significantly. Today, all aspects of society, governance, and security have dependencies on EMS. However, power grids, telecommunications, and many command-and-control systems have not been designed to survive a hostile EMS environment. Once damaged by natural phenomena such as GMD or human induced phenomena such as electromagnetic pulse EMP and HEMP, it may take months to years to recover networks and other vital functions to their original state.[8]

Multiple adversaries are capable of executing a strategic attack that may black out major portions of a state's grid. An EMP attack affects all devices with solid-state electronics and could render inoperative the main grid and backup power systems, such as on-site generators. During the course of this appraisal, the EDTF evaluated a wide range of EMS activities identifying four major issue areas and seven sub-priorities. In prioritizing recommended actions, three key phases were identified: (1) prevention, (2) mitigation, and (3) recovery.

1. **The first line of effort is PREVENTION: dissuading state and state-sponsored actors from taking action due to not only a threat of credible response but the certainty that their actions will not achieve results**. Traditional nuclear deterrence strategies may not always apply to EMS—most critically EMP threats. The perceived opportunity to attack without attribution, or with delayed attribution, may allow an adversary to calculate an overwhelming advantage in initiating hostilities. Hence, the United States and NATO require stronger mutual defense agreements and distributed attribution-and-response capabilities to maintain a credible response due to the large geographic effects of a HEMP attack. The development of broad policy in this area is critical and should be implemented to dissuade an enemy from risking attack to short-circuit war and achieve a strategic "knockout" to realize their desired ends. Moreover, dissuasion strategies can allow the United States to change enemy decision calculus by influencing an adversary not to take action based on their perceived inability to achieve desired ends. While deterrence is undermined by the use of proxies, dissuasion strategies do not rely on the threat of retaliation but rather an understanding that EMS activities will not have the desired effect (or ends).

2. **Actions taken prior to an event to reduce the severity and duration of actual EMS effects make up the second line of effort: MITIGATION**. Despite technological advances, the United States and its allies have only infrequently instituted upgrades to EMS-hardening protocols since the height of the Cold War. The lack of widespread and mandatory standards has often led to trading away capability and resilience for competing priorities and even convenience and efficiency. Intentional inclusion of "firebreaks" in the national grid, or at least military installation utility systems, can help localize damage as GMD or EMP propagate across bulk power transmission systems. Policy and incentives are needed to assist in motivating state regulators and power companies to secure the grid from all hazards, including EMP. Hardened microgrids operating in "island mode" can provide enough power for life-sustaining critical infrastructure, including military installations, and ensure mission capability for both defense and civil recovery. Mitigation efforts should also include rigorous education and realistic training and exercises.
3. **Finally, post-event actions to reconstitute critical infrastructure: RECOVERY**. Such a commitment can enhance the resilience of a society at large. For EMP and GMD events in the United States, a combination of active duty and reserve component forces could augment community "black start team" (BST) (see appendix 6) first-responders. BSTs would reboot any remaining (functioning) critical infrastructure. During recovery, bottom-up, preplanned efforts will enhance local survivability. Civil-military partnerships can create solutions unique to local communities. Deliberate education, outreach, and collaborative efforts could serve as boilerplates for further community resilience. For militaries in all locales, a "home-game" operations plan should be developed. Such a plan should include providing distributed forces with commander's intent in the event that command-and-control and communications are lost.

All phases and strategies should consider civilian and military aspects and combinations of the two and the dependencies between them.

SUMMARY OF NATIONAL LEVEL RECOMMENDATIONS

Only a shift in public sentiment and government policy—at multiple levels—will result in a protection effort commensurate with emerging EMS challenges and their potential consequences. Therefore, the task force recommends the consideration of an executive order similar to the order establishing the Manhattan Project in the 1940s to create comparable momentum to support and carry out the following:

- Create presidentially appointed position for an executive agent for EMS management
- Develop a national level charter for the EDTF as a supporting effort to the executive agent
    - o Immediately prioritize the protection of nuclear power stations
    - o Rapidly invest in 5G to ensure competition in a global market
    - o Develop education and outreach efforts for government and civil communities on protective measures
        - ▪ Such must understand that EMS-attack warning and attribution are far from assured
    - o Develop presidential directive: "It is the policy of the United States to vigilantly defend against and recover from EMP/GMD"
    - o Implement national dissuasion strategy to remove adversaries' incentives to use EMS
    - o Create an improved definition of resilience that includes specific language "*to sustain operations for at least 30 days*" as current definitions are nebulous
    - o Congressional engagement for public/industry policy and incentives for EMP protection
        - ▪ Direct military installations to implement base-wide EMS protection and forge partnerships with local communities to support this effort
    - o Recommend national EMS standards for aircraft, ships, and vehicles
    - o Invest in next-generation research in quantum communications and other emerging EMS phenomena
    - o Prime the US Space Force architecture to assume management of all EMS activities

SUMMARY OF REGIONAL LEVEL RECOMMENDATIONS:

- Move spent fuel in pools to dry cask storage at 60 nuclear sites to reduce hazards

- Create commander's intent to allow forces to link up in the event of a loss of C2
- Increase training realism and regional exercises, including bolt-from-blue response and recovery

SUMMARY OF LOCAL LEVEL RECOMMENDATIONS:

- Stand-up BSTs
- Create microgrids
- Implement installation EMS protection and partnerships with local communities to support this effort
- Develop community resilience in accordance with recommended definitions

ISSUE AREA 1: Electromagnetic Pulse and Geomagnetic Disturbances

PRIORITY 1: NUCLEAR POWER STATION RESILIENCE

An EMP attack affects all devices with solid-state electronics and could render inoperative the main power grid and back-up electrical power systems, such as on-site generators. Extended electrical power loss to nuclear power plants can lead to widespread radioactive contamination from the overheating of on-site spent fuel pools and breach of reactor containment at more than 60 sites and affect US military installations.

Many of these sites may be hardened at low cost by provisioning EMP-hardened generators, transferring spent fuel to dry casks, and providing additional on-site fuel for emergency generators (at least 30 days' worth). In addition, the DOD should make inputs on NRC's proposed rules on prolonged station blackouts PRM 50-96. The hazards these unique sites may pose to defense infrastructure must be considered alongside civil society.

PRIORITY 2: Installation Command Posts (Critical Infrastructure)

Installation command posts are the heart of the military enterprise. However, like with nuclear power stations, if electrical power is lost, these critical nodes could stop operating effectively within hours. Actions can be taken to survive these functions often at little to no cost.

The concept of BST provides installations with first-responder capabilities. The goal is to bring support to the command post before loss of communications connectivity. BST training and capabilities can be provided regardless of installation location and resources, offering a nearly no-cost, no-manpower interim solution. For further information, see appendix 6.

PRIORITY 3: Exercise and Training Realism

General Norman Schwarzkopf said, "The more you sweat in peace, the less you bleed in war." Defense agencies should work to understand that early warning and an inability to understand the source of an attack are strategic and tactical prospects from within the EMS. A better understanding of these potentials will allow national exercises to self-identify realistic gaps and begin meaningful mitigation.

EMS exercises should begin with the United States and broaden to NATO allies. Such should be part of an inclusive effort to educate the wider force on EMS issues.

ISSUE AREA 2: Strategic Threats Arising of Adversary 5G Networks

PRIORITY 4: Competitor Control of All Digital Information

5G is a strategic-level communications capability that will likely be governed according to either Western or competitor interests. Looking forward, the US has an opportunity to move into position, ahead of competitors, by capturing market share. Robust US government support can help ensure the democratization of information and data in the information age. However, immediate action is needed to secure US and allied advantages.

If the US supports the development of redundant terrestrial and space-based 5G networks by forming partnerships with industry, reduces FCC and FAA impediments to rapid rollout and development of key enabling technologies, and incentivizes domestic manufacturing to help underpin component security, there is a significant opportunity to partner with our allies in the creation of global networks (like GPS) that are controlled and maintained by Western interests.

ISSUE AREA 3: Directed Energy and High-powered Microwave Systems

PRIORITY 5: Machinery, Equipment, and Critical Assets

Loss of institutional knowledge regarding EMS has been ongoing over the past 30 years. However, this knowledge should be rebuilt. A failure to rebuild would be a failure to act with prudence. Within the military, all equipment operators should understand how their system integrates into the wider military ecosystem and understand how to innovate alternatives, and, where practical, know how to defend and protect the assets in their charge.

Finally, national EMS certification for aircraft that include EMP and HEMP standards should be developed and adopted. The prospective failure of critical inflight aircraft systems such as fly-by-wire on aircraft without flight control reversion options could lead to loss of life, property, and collateral damage justifies such actions. Any standards should be developed in concert with industry and the International Civil Aviation Organization to ensure coordination and integration into next-generation equipment and air traffic systems.

PRIORITY 6: Physical and Biological Impacts

Personnel need to be well apprised of emerging risks posed by DE weapons, including those that may harm or injure personnel. In those cases where assets or working locations do not shield personnel, protections should be developed. Where protections cannot be realized, the use of remote or distributed operations technologies should be considered.

In any case, assets that may be targeted by DE or HPM weapons should be equipped with instrumentation to allow crews to know when they are being targeted. Moreover, the United States should provide robust research and development alongside space-based platforms to match peer momentum.

ISSUE AREA 4: EM Spectrum Policy, Management, and Organization

PRIORITY 7: Complexity, Ownership, and Investment

Revitalization of the EMS spectrum is a defense imperative. Years of atrophy have allowed the United States' lead to be called into question.

Consolidating the management of EMS as into a new organization creates a viable opportunity to build a deliberate architecture on which to improve reliability and standards where the IoT is intrinsically linked to economy, society, and the critical infrastructure. As such, the DOD should consider the potential value of consolidating EMS management under a new space force construct. It should also evaluate current domains for restructure so EMS issues do not continue falling between the seams of current originations' views of their responsibilities.

Evaluation Methodology

At the opening of the EDTF conference, participants were informed the event would operate under Chatham House Rules. In addition, participants were made aware the conference center was an extension of the Air University campus. Academic freedom, debate, and divergent discussion were encouraged throughout.

EMS professionals formed a range of demographics, backgrounds, and points of view with varying experience levels. Non-staff participants had experience in a range of EMS areas as related to activities in government, defense, and industry. A sampling of the organizations with participants is included in appendix 1. Also present were 37 designated Air University staff, Air Force Fellows, and expert presenters, all of whom participated in workshop activities.

At the opening of the conference, a keystone thesis was presented for consideration. The hypothesis was that key strategic threats and activities may not be mitigated through classical strategic deterrence especially where the gray zone is concerned. Along with this thesis, multiple researchers presented key vulnerabilities that may feasibly present in the gray zone (from either states, nonstate actors, or proxies). Exposition of vulnerabilities was augmented by both CLASSIFIED and UNCLASSIFIED briefings (a partial list of briefings may be found in appendix 1).

At the conclusion of presentations, participants were divided into seven working groups with a diverse mix of technical experts and strategists. The focus area of each working group was EMP and GMD, lasers and optics, DE and HPM, and EMS management.

Each working group was provided a moderator (faculty from either Air University, Air Force Research Labs, or other DOD office or military officer of colonel or brigadier general rank) and a scribe (at the rank of major or lieutenant colonel). Moderators served to present scenarios to working groups and facilitate focused discussion. Moderators were instructed to remain neutral but were encouraged to provide inputs as participants.

Overseeing moderators were two adjunct professors holding the rank of retired lieutenant general. The role of the adjunct professors was to provide oversight and guidance to working group moderators and serve as a control to prevent interference with discussions or topic creep. Each moderator had access to adjunct professors on demand.

During working-group discussions, participants were allowed to have material and discussions up to SECRET. By allowing discussion up to this new level EDTF hoped to reduce inhibitions that might limit participants in thinking about the issues they would be trying to solve.

On the first day of the conference, each working group was presented with five situational or scenario-based injects (S-1 though S-5). The scenarios presented were designed to provide the most creative and damaging enemy course of action (COA) related to strategic activities within the EMS.

Scenarios were developed by experts in conjunction with the Curtis E. LeMay Center for Doctrine Development and Education. These scenarios have not been included in this paper due to sensitivities. However, they were designed to induce thinking about EMS challenges and how these could apply to our current understanding of deterrence.

By providing demanding challenges relating to current deterrence paradigms, participants were given opportunities to holistically consider the following:

1. What is available to harden current interests and setup now?
2. What concepts, policies, and procedures can we change to make us less vulnerable at little to no cost?
3. What can we build for the future to protect the United States and its allies?
4. What strategies can society and a commercial investment leverage to work congruently with US government efforts?

Injects were provided with these instructions:

For the purpose of working-group discussion scenarios, working groups will behave as Blue Team and work together to (1) prevent, (2) survive and recover/or implement (if applicable), and (3) retaliate (if applicable) from notional scenarios. Each scenario will be considered individually by each working group. For example, S-1 will first be considered from a prevention standpoint, then a survival and recovery standpoint, and finally assessed from a reaction and retaliation standpoint. After all aspects of S-1 are considered, move to the next scenario question (i.e. S-2).

For the purpose of discussions, each notional scenario should be considered the most likely enemy or friendly COA (when applicable). Also for the purpose of this discussion, each working group will function as realistically as possible. For example, we are fiscally constrained departments, agencies, and decision makers working with an understanding that certain enemy aspirations, technologies, and activities may be leveraged without escalation and/or provocation.

All reasonable challenges, opportunities, and creative options should be considered during scenario discussions. The goal is to achieve a conceptual breakthrough on what the US should do to deprive adversaries of options and confuse their decision calculus. Work to a logical scenario conclusion considering policy and regulatory changes that might be helpful to speed response and recovery.

"All reasonable challenges, opportunities, and creative options should be considered during scenario discussions. The goal is to achieve a conceptual breakthrough on what the US should do to deprive adversaries of options and confuse their decision calculus. "

Each group will consider the S-1 through S-5 through their own unique lens (i.e., how would the lasers and optics world be impacted, able to react, bring solutions to bear?). After individual consideration, groups will combine to discuss and exchange key observations.

On the final day of the summit, there was an executive out-brief of findings and recommendations presented to an executive member panel, which included among others the Commander of Air Education and Training Command and the Commander of Air Force Warfighting Integration Center.

Notes

1. The Nuclear Regulatory Commission (NRC) requires nuclear facilities to have the capability of continuing site operations on alternating current for at least 16 hours after the loss of off-station power. Nuclear power plants do not provide their own electricity. In some cases, under NRC waiver, time requirements may be reduced to as little as seven hours.

2. The current US nuclear-industry response plan, FLEX, relies on two warehouses located in Arizona and Tennessee. These warehouses have a combined ability to support less than 10 sites.

3. See note 1 above.

4. General John Hyten, USAF CC/USTRATCOM, Comments at Air Force Association Convention, 20 September 2017.

5. See note 1 above.

6. Congressional Commission to Assess the Threat of Electromagnetic Pulse to the United States of America, Testimony to the House Committee on Homeland Security, October 2017.

7. United States Army, Field Circular 50-16, Electromagnetic Pulse Mitigation Techniques, 1984.

8. For instance, high-voltage transformers vital to America's electrical power grid are all custom-built for specific applications. America depends upon South Korea and Germany for replacements; average replacement lead-time is 18 months.

Appendices

Appendix 1

Partial List of Participant Organizations

This appendix is a sample list of agencies represented at the 20–22 August 2018 Electromagnetic Defense Task Force summit.

- Air Education and Training Command
- The Curtis E. LeMay Center for Doctrine Development and Education
- Air University
- Air Force Warfighter Integration Center
- Air Force Research Laboratory
- Naval Research Lab
- Department of Energy
- The Union of Concerned Scientists
- Wyoming National Guard
- US Strategic Command
- AF Global Strike Command
- Booz Allen Hamilton
- Lockheed Martin
- North Atlantic Treaty Organization
- Federal Aviation Administration
- Joint Staff
- Defense Threat Reduction Agency
- Idaho National Laboratory
- Air Force Nuclear Weapons Center
- Air Force Special Operations Command
- Air Force Civil Engineering Center
- Office of Naval Intelligence
- Air Force Institute of Technology

- Air Force Materiel Command
- Department of Homeland Security
- Missile Defense Agency

During deliberations, it was recommended future events include:

- Multiple agencies from the US intelligence community (Central Intelligence Agency, Defense Intelligence Agency, National Security Agency, National Geospatial-Intelligence Agency, National Air and Space Intelligence Center, and Missile and Space Intelligence Center)
- Federal Emergency Management Agency
- New York Police Department
- National Academy of Sciences
- Defense Advanced Research Projects Agency

Appendix 2

Amplified Recommendations

Prevent—*Reinforce deterrence concepts with dissuasion elements to enhance attribution of attack vector and reduce probability that an adversary could strike without threat of retaliation*

- (Mil) Ensure EMS survivability of most-essential deterrence forces paces threat capabilities
  - o Recertification of hardened capabilities that have been compromised through neglect
  - o Revalidation of NC3 at a threat level that is paced to adversaries' capabilities
- (Mil/Civil) Deny adversaries the ability to conduct most-consequential forms of attack without rapid attribution and expectation of retribution
  - o Amend existing mutual security treaties to include commitments for mutual assistance for attributing attack origin
  - o Seek collective attribution assistance assurances among a community of states capable of space monitoring to globalize an adversary's challenge maintaining anonymity
  - o Requires information sharing derived from national and sovereign technical

Mitigate—*Take preparatory actions left-of-bang to reduce impact of adverse EMS phenomenon/attack*

- Educate and train personnel to state-of-the-doctrine, state-of-the-threat
  - o Standards and technical solutions are known within stovepiped communities of expertise, but not by the community of practice
  - o Significant lack of force development within DOD to understand threats
- Directive guidance to JROC/JCIDS process to account for hardening for military equipment
  - o Develop DOD policy that mandates levels of **EMP survivability that are not tradable**

        - Develop table of survivability that gives a warrant for program offices and contractors to set minimal standards of survivability for DOD components
        - Develop consequences, such as a "Nun-McCurdy breach," for failure to deliver required survivability in systems (consequence regime for contractor performance shortfalls currently focus on budget and schedule, not survivability)
    - DODI standards look at actual degree of hardening and pace it to the threat
        - Hardening currently pinned to kilovolt/meter standard that may be outdated. Should it be paced to threat forecast?
- Must "bake in" EMP-hardening up front and as intentional utility grid growth and refurbishments
    - Commercial infrastructure developing without robust survivability standards
    - Complete retrofit is expensive, but up-front costs with new materials (AFRL, ARL, NRL) are much more reasonable
    - Local construction firms are powerful lobbyists who will respond to incentive structures and can become participants in influencing hardening in infrastructure creation/renewal
- Secure nuclear waste (spent fuel) to reduce risk
    - Previous agreement by DOE to establish national storage capacity of spent fuel has not been realized
    - Resource and execute DOE mandate to collect and securely cask spent fuel to reduce on-site storage
- Local communities will probably be most successful in recovering from/responding to a nuclear attack
    - Develop resilient installations and communities that showcase local civil-military best-practices for survivability-by-design
    - Utilize a test city to implement a "model" action plan with a collaborative effort between DOD and local community to harden a base and surrounding community
    - Located where civ/mil/political alignment is right for a local win (Texas?)

- o Hardened communications with mil/civ critical authorities

- Installation plans integrated with community response plans
    - o Coordinated identification and hardening of critical food/water/medical/sanitation
    - o Initial (10 series) DOD action plans and targeted local education in partnership with civic/community groups
- Develop "weak links" in $4 trillion national grid infrastructure that increase ability to localize EMS damage (est. cost $400 billion)
    - o Prevent cascading electrical failure within/across electrical grid
- Government incentives/subsidies/or minimum standards for the government to contract with commercial providers
- Improve resiliency of electric grid and obtain prerequisite authority from state regulators to adjust rates to cover increased costs associated with developing this infrastructure
    - o Work across levels of government to create flexibility for state regulators to allow utility rate increases in conjunction with national hardening standards
    - o Remove "late mover advantage" for hold-out/lower-cost unhardened electrical grids
- Identify critical national industrial capabilities (development and construction of nuclear facilities, high-voltage transformers) that have been shuttered/offshored
    - o Restore education, workforce, manufacture, and industrial capability to reduce dependencies on offshore suppliers (India and China) for critical recovery components
    - o Develop new domestic electrical grid technology not reliant on foreign sales
- National standards for EMP-hardened infrastructure requirements (AFRL-construction materials)
    - o Develop layered approach with varying levels of EMP defense to provide more affordable resiliency
        - ▪ AFRL is engaging with local communities to expand these ideas; how can we spread this practice across other services?

    - How do we get facilities to buy down risk? Construction materials? Subsidies for targeted community "fallout shelters" that can thrive in EMP-attack aftermath?

- Executive authorities and direction for organize, train, equip
  - Revive national hardening standards
  - Grid, C2 nodes
  - "Go-Do" ensure funding/authority
  - Define mission command
  - Diversify power sources
  - Build isolated microgrids
  - Public affairs (US civil)
  - Training and education
  - Provide US Space Force with mandate to manage EMS
  - I/O: Flexible deterrent options (adversary)
  - Train BSTs at all installations
  - Predicate EMP/GMD TTPs on bolt-from-the-blue attacks
  - Enhance survivability (Command Posts/Continuity of Ops sites)
  - Inform Public/Public Affairs Strategic Messaging

Recover—*actions to restore critical services right-of-bang in a degraded environment*

- Dispersed (current Air Force E8 generator equipment being centralized)
  - Property-installed generators may not be hardened
  - EMP-hardened generators are managed centrally and normally assigned to a unit type code tasking
  - Connection points for portable generators and water pumps to plug in hardened capability
- National education directed toward American communities on nature of the threat and establishing expectations on role of government, defense, and civil institutions
  - Expand DOD's role in securing the United States from EMP
  - Discuss "home-game"

- Break out of mind-set that EMP is a "game over" event. Must thrive on, fight on, etc.

- Ensure mutual support plan among utilities and government
- Exercise across departments and agencies during prevent phase
- Resilient supply chain
- OCONUS data/logistics sites
- Prioritized plan for resources (all classes of supply)
- Retain Title 32 assets
- Inform public/strategic messaging
- Economic stabilizing measures
- Communications/information plan
- Inform public/consistent with strategic messaging
- Ability to provide law and order

Provide Credible Response—Sustain strategic response capabilities to retaliate and regain initiative

- Establishing robust black start teams (BST)
  - Capture BST as a function of military Ability to Survive and Operate (ATSO)
    - CONUS-based units tasked to participate in BST as an ATSO activity
    - Base 10-series plans tasked to consider BST ATSO, including charge to develop key connections with local LE, EM, DR, government
    - Plan and exercise "island-mode" exercises where an installation has to plan and exercise up to 30 days completely off the grid
- Establish a means of showing attribution without revealing classified sources
  - Without attribution, response is illegitimate
- Time is of the essence; delayed response is less effective

Recommendations For Further Action

- Identify a national champion
  - o EMP is a tragedy of the commons as "no one's job jar"
- Refuse to "trade away" survivability
  - o Develop directive guidance that it is no longer acceptable to trade away survivability
  - o EMP protection is NOT a technical issue, it is an issue of will and policy
  - o Do not make survivability waiverable, it must be independently verified (no self-reporting)
- Educate all communities
  - o Start with the intel community; intelligence assessments MUST include more than enemy intent with high-consequence events; it must include capabilities
    - ▪ Justification of should not be based just on today's enemy intent but on their capabilities and military advantage projected past 10-years
  - o The intel community in key agencies must be educated so they provide the right feedback to political leadership who ask the questions
- Build in EMS resilience
  - o Need a definition of resilience that includes EMS threats (EMP, HEMP, DE, etc.)
    - ▪ The term resilient needs to be redefined to include the EMS phenomena
  - o Incentivize and "Brand It" appropriately (Energy Star example)
  - o ID all the places in government guidance (federal, state, and local) where this new definition can be applied
  - o Direct the requirement to be implemented in ALL NEW investments on identified infrastructure
  - o Need continued work on identifying critical national civil-military infrastructure
  - o Make government the de-facto standard for EMP resilience
    - ▪ Incentivize protection of long-term replacement items such as extra high-voltage (EHV) transformers

    - Invest in the $2.5 billion to protect existing EHV transformers (all hazards = neutral ground blockers, ballistic protection, SCADA systems—E-1 and 2 wave forms and cyber intrusion)
    - Incentivize the development of new EMP-protected assets by writing these EMS resilience standards into the standards for future
- Develop an operations plan for the home-game fight
  - o Start by realistically describing the post-event environment

The How

- Make it policy
- Implement the requirements
- Independently audit/inspect

Appendix 3

Recommended Development Timelines (60 Days to 5 Years)

Immediate (<60 days)

- POTUS Directive:
    - Given the threat environment outlined in the NSS and NDS, it will now be the policy of the United States that the ability to __defend__ and recover from an EMP attack or GMD event shall be national policy. The DOD shall take immediate action to develop the requirements and procedures for military installations and the DHS shall do the same for the civilian grid, consistent with PDD XXX. Any waiverable authority must be brought to the cabinet level. DOD and DHS will provide the national security staff with a status report in 180 days.

      *Sense of urgency is due to NRC ____
- ID a national champion:
    - Appointee should be bipartisan
    - Technical background in electrical engineering
    - Experience with policy and strategy
- Establish EDTF as a Federal Task Force led by DOD
    - Recruit from EDTF cadre
- Build the playbook & basket of solutions
    - Take the Show on the Road
        - Begin with "crash course" on current solutions & testing capabilities
        - ID willing/appropriate installations/states
        - Action officers and SMEs of EDTF to show "how it's done"
        - Team generates field guides
- Generate political will
    - Initiate think tank exercise:

    - Air University: Weapons of mass destruction program to pay think tanks to develop ideas to engage a conversation in think tanks
    - NDU: same

Short-term (< 2 years)

- Prioritized asset list from POTUS/departments and EXORDs
- Centralize C2 (NSC or cabinet-level)
- Delegate/Designate authorities w/PAAs
- Emphasize EMS in doctrine and high-level definitions
- Information dissemination contingency plans
- Train BSTs/MDT/CPTs in EMP response/recovery
- Develop industry standards/new regulatory framework
- Standardize/Exercise information contingency plans w/departments
- Enhance public early warning system/education

Mid-term (2-5 years)

- Appropriate funds for hardening prioritized assets
- Equip departments w/hardening technologies
- Exercise information contingency plans in public sector

Long-term (5+ years)

- Complete CONUS/OCONUS hardening for asset list
- Industry hardening standards implemented on all civil-mil tech

Appendix 4

Sample Briefings (Not all inclusive)

CLASSIFIED briefings

Curtis E. LeMay Center for Doctrine Development and Education, Office of the Secretary of Defense, United States Air Force Technical Applications Center, Air Force Testing and Evaluations Center, United States Strategic Command, Air Force Research Laboratory, and Idaho National Laboratories.

UNCLASSIFIED briefings

Congressional Commission to Assess the Threat of Electromagnetic Pulse to the United States of America, The Union of Concerned Scientists, Booz Allen Hamilton, and a briefing by multiple technology development companies. Unclassified EMS threat samples included: risks to power grids, balloon borne EMP detonations (not requiring ballistic missiles to loft to high altitude), certain threats to aircraft and human physiology, and so forth.

Appendix 5

Bullet Background Paper on the Economic and Security Implications of 5G Networks

Purpose

The development of 5G mobile technologies and networks represents a quantum leap in communications capabilities which is ready for deployment. Consequently, the development of 5G networks deserves unique consideration. This paper (1) introduces 5G mobile technologies, (2) describes key forecasts and their relationships to US economic and security interests, and (3) recommends USG support for the rapid development of a Western led strategic 5G architecture.

Introduction

- At five-year intervals, mobile technologies undergo generational updates as capabilities developed incrementally improve; preceding generations of mobile technology were 4G, 3G, 2G (the first digital network), and 1G (analog network)
- 5G is a boundary-crossing secure communications advancement with nearly unlimited bandwidth and almost no latency; in comparison to 4G, 5G may offer 10x faster downloads, 100x higher wireless transfer rates, and 100x lower latency

Economic And Security Interests

- 5G applications are forecast to exceed $400B by 2022, with the construction and maintenance of a prospective US network resulting in 3 million jobs and a $500B increase in domestic GDP
- Rapid creation of a global 5G network is a cornerstone in China's industrial plan to compete with Western interests; the plan is underwritten by half a billion dollars in investment with a first-to-market goal to deploy 5G commercially by 2020
- By 2035, 5G is expected to enable $12.3T in global economic output; states and nonstates that control the 5G network may dictate or control all digital transactions including the ability to share and receive information

- China's control over the majority of hardware manufacturing needed to create 5G components and antennas (41 percent of the market and rising) is part of Beijing's plan to deploy a network favorable to Chinese economic and security interests
  - Control of 5G is roughly equivalent to control of the internet; open 5G is critical to freedom and free market economics
- Access to 5G will be critical to operations in every war-fighting domain, in particular, space command and control
- Defense experts assess that 5G market share will be "locked-up" by US competitors in months with no second chance in 5G race; EO intervention stopped recent corporate mergers; immediate action needed to secure US first mover advantage

Recommendations

- Provide robust US government support to develop global redundant terrestrial and space-based 5G networks by forming partnerships with industry leaders owning component manufacturing capabilities, space lift capabilities, and technical expertise
- Reduce FCC and FAA impediments to rapid rollout and development of key enabling technologies in the US while incentivizing domestic manufacturing to help underpin component security
- Invite US allies to partner in the creation of global networks (like GPS) controlled and maintained by Western interests

Summary

5G is a strategic-level communications capability that will be governed according to either Western or competitor interests. In the months ahead, the US has an opportunity to move into position, ahead of China, by capturing market share. Robust US government support can help ensure the democratization of information and data in the information age for all mankind.

Appendix 6

Bullet Background Paper on Black Start Teams

Purpose

This paper introduces the concept of BLACK START TEAMS (BST) and their value to the enterprise as a method to ensure installation continuity of command in the wake of an EMP or Geomagnetic Disruption (GMD) event. A BST is a pre-equipped, geographically distributed team of personnel whose role is to "kick-start" an installation's baseline operations under extreme electromagnetic spectrum (EMS) circumstances.

Background

- The entire DOD command structure may be incapacitated without notice in the wake of an EMP/GMD event (such may occur during or outside of duty hours, holidays, and/or other inopportune times)
- While EMP is a human-caused disruption, GMDs are cyclical disruptions caused by coronal mass ejections (12 percent chance per decade that North America will be impacted by GMD)
- EMP emits E-1 through E-3 pulses while GMD generates an E-3 wave from plasma coupling with Earth's magnetic field; all can adversely impact C2 and C3 due to dependencies
- EMP may incapacitate most electronic devices and satellites in deposition regions, while GMD may cause outages in northern latitudes (circumstances over CONUS similar to Katrina—EMP Commission)

Status

- Most installations do not have contingency plans for events that include equipping key personnel to get from home or community to accomplish or establish essential preplanned mission objectives and/or capabilities
- Must be assumed widespread disruption of communications and transportation will be associated with events; such can impede recall of essential personal needed to activate baseline capabilities

Black Start Teams

- A strategic concept of operations (CONOPS) modeled after immortal jellyfish: biological organism grows to adulthood, then reverts to larva stage through transdifferentiation; next regrows to adulthood. This is an indefinite cycle.
- BST members provided training and equipment to revert an installation to baseline ops by preparing members to respond from home or community to mission objective, ensuring key post-event objectives are met
- Must first prepare family of BST members for self-sufficiency to ensure member ability to depart home for mission objective(s)—all members pre-briefed on individual roles and CC's intent/objectives

Conclusion

BSTs can provide NMCA critical continuity at all installations in lieu of certain equipment capacities. Contingency planning at wings should be a high priority and is addressed in depth in an accompanying FOUO White Paper. To request this paper, please contact Maj David Stuckenberg at david.stuckenberg.1@us.af.mil.

Abbreviations

ATSO	Ability to Survive and Operate
BST	black start team
COA	course of action
CONUS	continental United States
DE	directed energy
DHS	Department of Homeland Security
DOD	Department of Defense
DOE	Department of Energy
EDTF	Electromagnetic Defense Task Force
EHV	extra high-voltage
EMP	electromagnetic pulse
EMS	electromagnetic spectrum
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
GDP	gross domestic product
GMD	Ground-based Midcourse Defense
HEMP	high-altitude electromagnetic pulse
HPM	high-power microwaves
IoT	Internet of things
NAOC	National Airborne Operations Center
NCR	National Capital Region
NDS	National Defense Strategy
NMCA	National Military Command Authority
NRC	Nuclear Regulatory Commission
NSS	National Security Strategy
PTN	Pilot Training Next
RMS	Royal Mail Ship
TACAMO	Take Charge and Move Out
USG	United States government

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